SoildiverAgro

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SoildiverAgro

Soil biodiversity enhancement in European agroecosystems to promote their stability and resilience by external inputs reduction and crop performance increase

D2.2- E-BOOK ABOUT OUTCOMES FROM SYSTEMATIC REVIEW, DATA MINING AND META-ANALYSIS

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D2.2. E-BOOK ABOUT OUTCOMES FROM SYSTEMATIC REVIEW, DATA MINING AND META-ANALYSIS

Summary

One of the main objectives of the WP2 is to identify the soil biodiversity problems of the European Farmers and develop strategies to help to solve them. This was made through an exhaustive process of data mining and literature review.

This deliverable presents, in the form of an appendix, an e-book with the results of this the litarature review. The aspects considered in this revision book are:

- The importance of the soil biodiversity in the design of cropping systems.
- Crop rotation and its effect over the edaphic fauna.
- The effect of tillage on the communities that inhabit in the cultivated soils.
- The ability of soil fauna to regulate the proliferation of pathogenic fungi related to certain crop diseases.
- Different types of bacteria that promote plant growth.
- The relationship between soil contamination and biodiversity.
- The effect of organic and synthetic fertilizers on the biodiversity of the edaphic fauna.
- The development of alarm systems that allow the early detection of pathogens.
- The increase in soil quality associated with the use of cover crops.
- The use of trap crops to reduce the use of pesticides while maintaining production and quality.

Deliverable Number	Work Package
D2.2.	WP2_ Identification of main challenges in European agricultural cropping systems and data mining
Lead Beneficiary	**Deliverable Author(s)**
EULS	Merrit Shanskiy [EULS] Diego Soto Gómez [UVIGO] David Fernández Calviño [UVIGO]
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Type of deliverable	R	Document, report (excluding periodic and final reports)	X
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	E	Ethycs	

Dissemination Level	PU	Public	X
	CO	Confidential, only for members of the consortium	

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Table of content

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1 Introduction

When analyzing the situation of soil biodiversity in agricultural soils throughout Europe, it is important to carry out a review work to determine which are the main problems and the possible solutions to these problems. This has been done in this work package (WP2), trying to summarize in a single book, "INTERACTIONS BETWEEN AGRICULTURAL MANAGEMENT AND SOIL BIODIVERSITY: AN OVERVIEW OF CURRENT KNOWLEDGE" (included in Annex I), the importance of soil biodiversity and the challenges that European agriculture must face to improve soil quality from a biological point of view.

Thus, this book includes aspects such as the effect of crop rotation and tillage on edaphic fauna, the ability of some microorganisms to regulate the proliferation of fungal diseases, and the ability of certain bacteria to promote plant development, among others.

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2 E-book

INTERACTIONS BETWEEN AGRICULTURAL MANAGEMENT AND SOIL BIODIVERSITY: AN OVERVIEW OF CURRENT KNOWLEDGE

EDITED BY DIEGO SOTO-GÓMEZ, MERRIT SHANSKIY AND DAVID FERNÁNDEZ-CALVIÑO

NOVEMBER 2020

INTERACTIONS BETWEEN AGRICULTURAL MANAGEMENT AND SOIL BIODIVERSITY: AN OVERVIEW OF CURRENT KNOWLEDGE

EDITED BY DIEGO SOTO-GÓMEZ,MERRIT SHANSKIY AND DAVID FERNÁNDEZ-CALVIÑO

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The book was revised by two external reviewers: Avelino Núñez Delgado (Universidade de Santiago de Compostela) and Alessandra Trinchera (Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria-CREA).

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CHAPTER 2

CROP DIVERSIFICATION AND SOIL BIODIVERSITY

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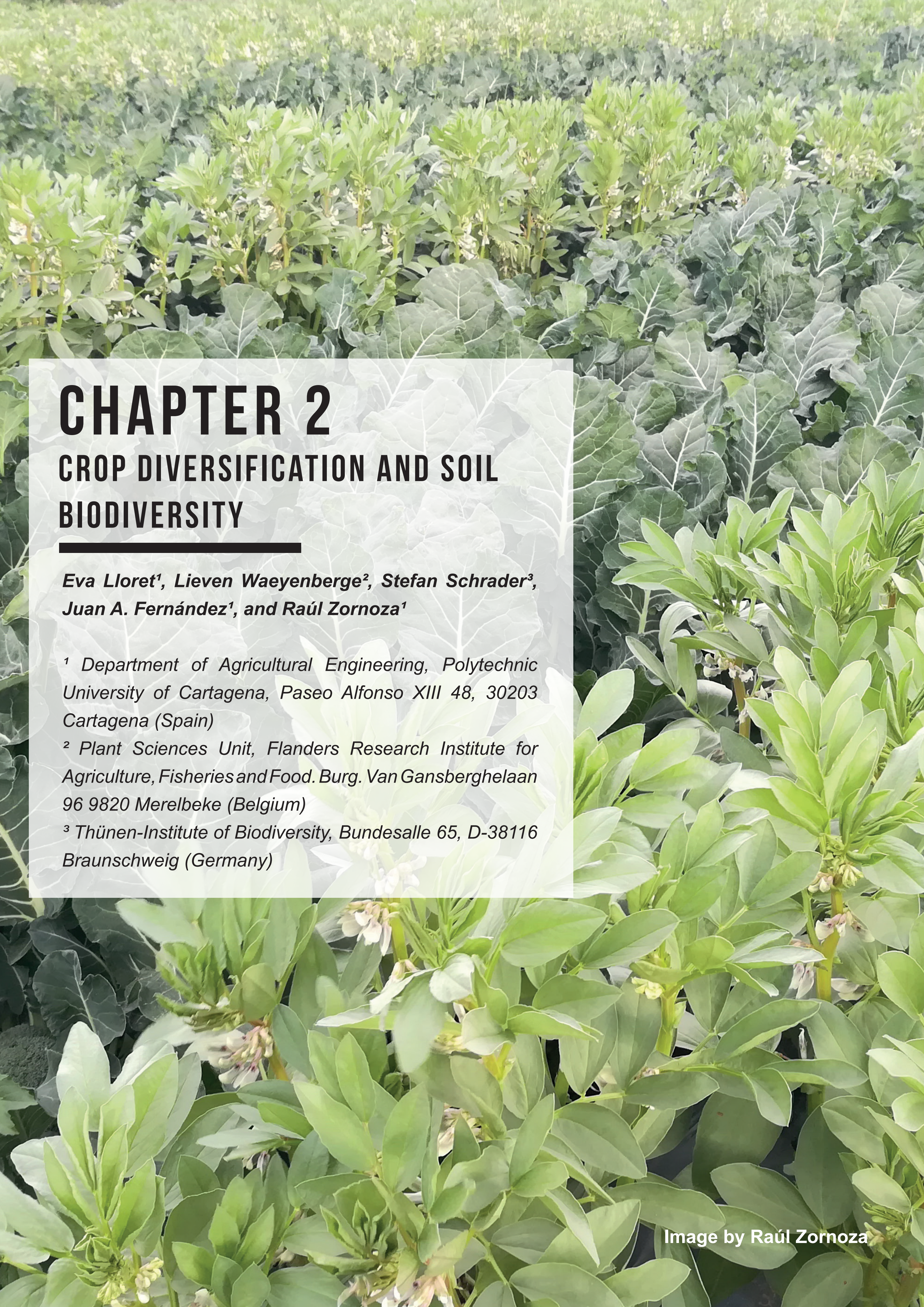

Image by Raúl Zornoza

ABSTRACT

Crop diversification is an agricultural management strategy that includes practices such as crop rotation, multiple cropping, mixed cropping and agroforestry. Crop diversification may be employed by smallholder farmers in order to reduce their vulnerability in the face of a global environmental change, as well as provide economic, social, nutritional and environmental benefits. At the same time, strong links between the above- and belowground diversity have been well established. In particular, plant diversity, can influence soil conditions and have positive impacts on belowground communities and processes, while substituting for costly agricultural inputs. Meanwhile, soil biodiversity performs ecosystem services, and provides soil functions, that are essential for plant growth and agricultural productivity. Crop diversification could become an essential tool for sustaining production and ecosystem services in croplands, and should be considered an important management strategy in the context of soil sustainability and food security. However, there is still a need to identify crops and varieties that are suited to a multitude of environments and farmer preferences. To tackle this problem, participatory approaches like the initiative Agroecosystem Living Laboratories (ALL), which aims for the assessment of new and existing agricultural practices and technologies to improve their effectiveness and early adoption, should be implemented.

Keywords: crop diversification, soil biodiversity, agricultural management; soil microbial community, soil fauna, ecosystem services.

1. WHAT IS CROP DIVERSIFICATION?

Crop diversification within agroecosystems can occur in many forms, and with many levels of complexity over different spatial and/or temporal scales. Thus, diversification at the field–crop scale may refer to changes in crop structural diversity or vegetation management strategies. These strategies will allow discontinuity of monoculture by:

1. growing different crop species on the same land in successive growing seasons, via rotations;
2. growing different crop species within a growing season, using multiple cropping;
3. growing different arable crop species in proximity, in the same field, via mixed, row and strip intercropping;
4. alley cropping planting different arable or perennial species of rows of trees, via agroforestry strategies;
5. allowing non-crop vegetation within a monoculture.

Figure 2.1. shows different crop diversification strategies at the field–crop scale.

Figure 2.1. Top: Intercropped melon (Cucumis melo) with cowpea (Vigna unguiculata) (left); Agroforestry system between mandarin trees (Citrus reticulata) and fava bean (Vicia fava) (right). Bottom: Agroforestry system between almond trees (Prunus dulcis) and thyme (Thymus hyemalis) (left); intercropped broccoli (Brassica oleracea var. italica) with fava bean (Vicia fava) (right).

At the landscape scale, diversification may be achieved by combining multiple production systems, such as complex landscapes containing woodland areas, or agroforestry management with cropping, livestock, and fallow areas, in order to create a highly diverse agricultural landscape (Altieri 1999; Gurr, Wratten, and Luna 2003).

2. BENEFITS OF CROP DIVERSIFICATION

Diversification of agricultural production, via the introduction of a greater range of species or fallow periods, can lead to benefits at different levels, including both economic and social advantages. Crop diversification can increase income for small farm holdings, providing alternative ways of generating income, as well as increasing their capacity to withstand price fluctuations. Furthermore, it can result in nutritional benefits for farmers in developing countries, and can support a country or community intending to becoming more self-reliant in terms of food production. It can also reduce dependence on off-farm inputs (Clements et al. 2011; McCord et al. 2015; Makate et al. 2016).

Crop diversification also has enviromental benefits, and can be used to mitigate the effects of climate change, strengthening the ability of agro-ecosystems to respond to environmental stresses, improving resilience to drought and heat, as well as resistance to pests and diseases, and minimising environmental pollution, contributing to the conservation of natural resources (Clements et al. 2011; Degani et al. 2019).

Finally, the introduction of new cultivated species and improved varieties of crops has advantages on food production systems, enhancing plant productivity, plant and soil quality, health and nutritional value, and/or building crop resilience to diseases, pest organisms and environmental stress. For instance, the introduction of nitrogen-fixing crops, such as legumes, within a traditional cropping system, can improve the status of the soil, making atmospheric nitrogen available to other plants, thereby reducing the need for mineral fertilisers with their associated high energy costs and use of non-renewable resources (Clements et al. 2011; Isbell et al. 2017).

3. CROP DIVERSIFICATION AND SOIL BIODIVERSITY: ABOVE- AND BELOWGROUND INTERACTIONS

Agricultural practices have a profound effect on soil quality by affecting critical biological processes essential for many ecosystem functions. The agricultural management practices that have the most significant impact on soil quality are those used in intensive agriculture such as: massive diffusion and excessive use of broad-spectrum chemical fertilisers and pesticides; slash-and-burn shifting cultivation; soil tillage and compaction; reduction in crop biodiversity; and inadequate irrigation (Giller et al. 1997). The loss of soil biodiversity in intensive farming systems threatens fundamental self-regulating mechanisms such as pest control, pollination, control of soilborne diseases, organic matter mineralisation, nitrification, denitrification, etc., leading to reductions in agroecosystem functions and services, and turning farms into highly vulnerable systems dependent on external inputs (Altieri 1999; Altieri 2018; Barrios 2007). Soil biodiversity provides services that are essential for plant growth and agricultural productivity, such as maintenance of the genetic diversity essential for successful crop and animal breeding; as well as provision of nutrients, biological control of pests and diseases, erosion control and sediment retention, and water regulation (Swift, Izac, and van Noordwijk 2004). However, not only crops are strongly influenced by soil biodiversity; there is evidence that aboveground biodiversity can affect soil conditions and have positive effects on belowground communities and processes (Tiemann et al. 2015). In fact, the sustainability of soil nutrient cycles, and thus of soil fertility, depends on crop biodiversity, which leads to greater productivity and reduced nutrient losses in more diverse ecosystems (Tilman and Downing 1994; Tilman, Wedin, and Knops 1996). Thus, the greater the aboveground biodiversity, the greater the belowground biodiversity, with positive effects on crop production, soil fertility and disease control. However, despite the evidence of strong links between above- and belowground diversity, these interactions have not yet been included in the EU's Natura 2000 and the Habitats Directive, when the need for a better understanding has been recognised in the EU biodiversity strategy (van der Putten et al. 2018). Figure 2.2. depicts the interactions between below- and aboveground diversity.

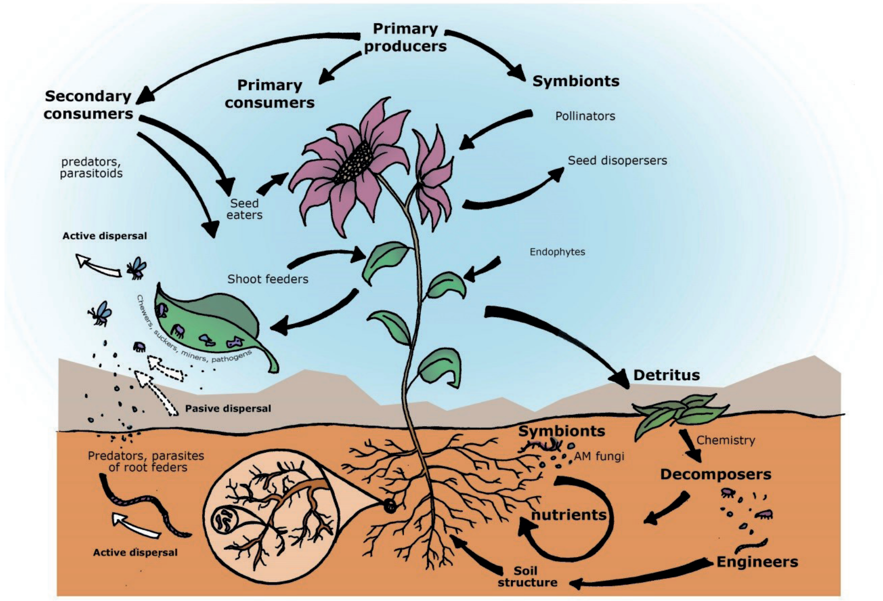

Figure 2.2. Interactions between above- and belowground biodiversity (Adapted from: De Deyn and Van der Putten 2005).

3.1. CROP DIVERSIFICATION AND SOIL MICROORGANISMS

Despite the fact that losses of biodiversity caused by intensive agriculture is a major worldwide concern, and that crop rotation and diversification can increase both crop productivity and diversity of soil macro- and microorganisms, the functional significance of changes in soil biological communities are still poorly understood. However, it has been observed that increasing temporal plant diversity can change soil microbial communities and enhance crop productivity through positive plant–soil feedback mechanisms mediated by soil biota (Zhou, Liu, and Wu 2017). An experiment with cucumber demonstrated that crop rotation increased cucumber yield and bacterial diversity, but decreased fungal diversity and abundance (Zhou, Liu, and Wu 2017). Furthermore, in diversified systems, the abundances of potential plant pathogens and antagonistic microorganisms are normally reduced, while potential plant-growth-promoting microorganisms increase (Kremen and Miles 2012; Leandro et al. 2018; Wen et al. 2016). For example, Tiemann et al. (2015) showed that crop rotational diversity enhanced belowground communities and functions in an agroecosystem. As crop diversity increased from one to five species, distinct soil microbial communities were related to increases in soil aggregation, organic carbon, total nitrogen, and microbial activity, while a decrease in carbon limitation was oberved. High diversity rotations, as well as intercropping or agroforestry systems, can sustain more diverse soil communities by increasing the quantity, quality and chemical diversity of plant residues and root exudates, with positive effects on soil organic matter and soil fertility.

3.2. CROP DIVERSIFICATION AND SOIL FAUNA

Aboveground diversity has been linked to soil fauna. For instance, Palmu et al. (2014) concluded that increased crop diversity was associated with increased ground-beetle activity and diversity in arable land, this beneficial effect particularly relevant in areas of intensive farming.

Nematodes are microscopic, but constitute a large proportion of the soil fauna. They are very abundant and diverse. One group in particular differs from other groups due to their specialisation in parasitising plants. Some species have only one plant family on which they can survive; other species can develop in a wider range of plants. The former group can easily be controlled by cultivating the host in a wide rotation with a low cropping frequency. The latter group can only be controlled by alternating hosts with tolerant or resistant crop varieties, preferably while monitoring the population dynamics of the pest. Unfortunately, often the farmer’s knowledge on this group of nematodes and its host plants is limited, resulting in less optimal crop rotation systems (Nicol et al. 2011).

Cover crops can aid in diversifying crop rotation. However, there is no precise advice concerning the choice of cover crop, as the host status of such crops in relation to plant-parasitic nematodes is mostly lacking (Thoden, Korthals, and Termorshuizen 2011). Generally, it seems that applying a cover crop species mixture may contribute to controlling soilborne diseases like nematodes (Hajjar, Jarvis, and Gemmill-Herren 2008).

Next to plant-parasitic nematodes, other nematodes thrive in the soil. They are mostly beneficial, as they participate in improving soil fertility, soil disease suppression and soil structure. A more diverse crop rotation system seems to induce a greater overall nematode diversity (Burkhardt et al. 2019). However, other factors like the agricultural management system and soil characteristics may play a larger role (Quist et al. 2016).

A land-use change towards perennial crops is a strategy to diversify cropping systems at the landscape scale, and to reduce management intensity, which preserves the soil ecosystem, including soil-associated biodiversity. This strategy is currently the focus of discussion, especially in regions where a high ratio of maize (an annual crop) is cultivated as a renewable energy resource. Compared with maize, the cultivation of the perennial crops Agropyron elongatum (cv. Szarvasi-1) and Sida hermaphrodita, for instance, enhances earthworm abundance and species richness (Emmerling 2014). In the case of the perennial cup plant (Silphium perfoliatum), (Schorpp and Schrader 2016) found a significant increase in earthworm species richness and functional diversity from the fifth year of cultivation onwards. However, a study on the interaction between alien energy crops and native potworms and springtails elucidates the need for assessing possible allelopathic effects of these crops on soil biota (Heděnec et al. 2014).

4. A FARMER'S POINT OF VIEW

In recent decades, farmers have turned to intensive monocropping, as a result of economic incentives encouraging the production of a select few crops, the push for biotechnological strategies, and the belief that monocultures are more productive than diversified systems. However, farmers are now aware of the benefits of crop diversification, mostly through rotations; and they are including rotations in their cropping schedules, with the aims to reduce the incidence of soilborne diseases, increase soil fertility and improve soil porosity and water retention. However, intercropping and agroforestry strategies in Mediterranean climate regions are not widespread, since farmers believe that these kind of agricultural systems could negatively affect water availability to the main cash crop. Furthermore, in traditional orchards, farmers prefer the inclusion of alleys without vegetation, leading to intensive tillage and removal of cover- or alley crops, since a field in which the alleys have vegetation has traditionally been considered a "dirty" field.

5. CONCLUSIONS AND FUTURE PERSPECTIVES

Consideration of risks is pivotal for farmers when making agricultural management decisions (Chavas and Holt 1990; Leathers and Quiggin 1991). The major risks confronted include production risk due to uncontrollable events produced by climate change, and market risk due to uncertainty about future input- and output prices, and volatile global markets (Pannell, Malcolm, and Kingwell 2000; Moschini and Hennessy 2001). Both of these challenges are likely to be exacerbated in the near future. Relative risk is mitigated by the ability of soil to buffer adverse weather events, as higher abundances and diversity of soil organisms increases both the generation and reliability of soil ecosystem services (Altieri 2018; Koellner and Schmitz 2006). The increased delivery of ecosystem services can substitute costly inputs such as inorganic fertilisers, pesticides and energy (Altieri 2018; Thrupp 2000; Weitzman 2000; Figge 2004). Scientific evidence has demonstrated that crop diversification can increase expected farm profit and reduce agricultural risk in the future (Cong et al. 2014), improving stress resistance, resulting in more resilient systems (Lin 2011; Degani et al. 2019). Diversification could therefore become an essential tool for sustaining production and ecosystem services in croplands, rangelands and production forest, and should be considered an important management strategy in the context of soil sustainability and food security (Isbell et al. 2017).

There is a need to identify crops and varieties that are suited to a multitude of environments and farmers' preferences. Furthermore, the interacion between crop diversity and belowground biodiversity should be further evaluated to consider potential synergic intereactions. Participatory approaches increase the validity, accuracy and efficiency of the research process and its outputs. Researchers are better informed, and can better inform others, about traits that should be incorporated into improved cultivars. Participatory processes also enhance farmers' capacity to seek information, strengthen social organisation, and experiment with different

crop species, cultivars and management practices (Clements et al. 2011). A promising approach in this context is the establishment of so-called agroecosystem living laboratories (ALLs), which aim for the assessment of new and existing agricultural pracitices and technologies to improve their effectiveness and early adoption (Anonymous 2019). An ALL implements the following components simultaneously: (i) transdisciplinary approach; (ii) co-design and co-development with participants; and (iii) monitoring, evaluation, and/or research on working landscapes.
The Global Soil Partnership and the Global Soil Biodiversity Initiative both represent outlets for further dissemination of expert-based knowledge, while a Global Soil Biodiversity Assessment is also being planned within the UN and FAO. This increased knowledge and awareness provides an opportunity for refining EU guidelines and directives, taking relationships between below- and aboveground biodiversity into account (van der Putten et al. 2018). However, economic incentives encouraging the production of a select few crops, the push for biotechnology strategies, and the belief that monocultures are more productive than diversified systems, have been hindrances in promoting this strategy (Lin 2011). Also, the majority of global agrobiodiversity is produced in smallholder food-growing systems (Zimmerer and Vanek 2016). Hence, there could be a need for governments to provide farmers with additional incentives to conserve soil capital, as a way to increase profits and reduce risks while promoting sustainable agriculture (Cong et al. 2014).

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