Co-design and establishment of innovative fruit-based agroforestry cropping systems in Belgium

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Abstract

Multiple options exist to set up agroforestry systems that combine pome fruit trees and vegetables. Proposals for different spatial arrangements and prototypes have been developed and evaluated through participative discussions involving scientists, advisors and farmers. Key challenges will be to optimize economic/technical constraints and ecological principles that stimulate natural regulation processes against pests and diseases in a temperate climate. In 2014, an experimental agroforestry orchard was planted in Gembloux, Belgium, on a surface of one hectare. The aim was to test the following three hypotheses: (i) a mixture of selected robust fruit and vegetable cultivars creates a functional biodiversity that significantly reduces the risk of pests and diseases; (ii) annual crops and tree canopies may have an impact on soil functioning, biological interactions and regulations; and (iii) in our optimized ratio and distances between vegetables and trees in intensified and organized alley-cropping systems, the tree shading does not reduce light levels below the threshold of light saturation. Two other on-farm fruit-based agroforestry cropping prototypes in Belgium are under evaluation on two pilot farms according to the farmer's production objectives, including: (i) adaptation to mechanization, which may limit plant interactions with perennial and/or annual crops; and (ii) the need for a diversified income per surface unit that would allow the economic viability of farms in a capital-intensive economic system.

Keywords: apple, ecosystem services, intercrop, *Malus*×*domestica*, organic farming, orchard, vegetable

INTRODUCTION

The need to reduce agricultural inputs (particularly pesticides) without significant productivity loss may require a fundamental re-design of cropping systems. The optimization of various ecological processes associated with adapted biodiversity (e.g., microclimate regulation, protection against erosion, biological control, soil life processes, allelopathy and pollination) will be possible only by significantly modifying the composition, structure and organization of agroecosystems (Schut et al., 2014). The ideal approach is to implement system changes that would have a long-term effect, rather than choose simple input substitution, which would have only a short- or medium-term effect.

An example of such a system change is to combine pome fruit trees (e.g., apple, pear, quince) and vegetables in agroforestry systems. Key challenges would be to achieve the best trade-off between technical/economical constraints and the enhancement of ecosystem processes, including natural protection against pests and diseases, weed control and soil fertility factors in a temperate climate. The aim of our research is to conduct a long-term study on the sustainability of such an innovative fruit-based agroforestry cropping system in Belgium.

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MATERIALS AND METHODS

Various spatial arrangements and prototypes were proposed and evaluated through participatory discussions involving scientists, advisors and farmers. This resulted in the establishment in 2014 of an experimental agroforestry orchard at Gembloux, Belgium, covering one ha and designed to test three hypotheses: (i) a mixture of robust cultivars of fruit trees (de Goede et al., 2012) and vegetables creates a functional biodiversity that has a useful impact on pest and disease control; (ii) tree canopies might have a positive effect on soil functions and biological processes and reduce plant stress; and (iii) where distances between vegetables and trees in intensified alley-cropping systems are optimized, tree shading does not reduce light levels below the threshold of light saturation.

During the participatory design process, several meetings were organized to discuss how to:

- develop a multidimensional project via a multi-actor design process;
- increase intra- and interspecific diversification to enhance the food supply and habitat opportunities for natural enemies and pollinators in orchards;
- optimize the various ecological processes associated with adapted biodiversity (e.g., microclimate regulation, protection against erosion, biological control, soil life processes, allelopathy and pollination);
- deal with genetic innovations for rootstocks and cultivars;
- improve soil biology and fertility in orchards;
- best use mechanization to address the spatial overlap between perennial and annual crops;
- obtain a high income per unit land area to enhance the economic viability of farms in a capital-intensive economic system.

A literature review, as well as visits to current agroforestry system experiments, gave us insight into the prospects and limits of system designs and the basic ecological processes to be optimized (Malézieux, 2012).

RESULTS AND DISCUSSION

Various spatial arrangements and prototypes were proposed and evaluated over almost a year (from April 2013 to February 2014) through participatory discussions involving scientists, advisors and farmers. This resulted in a co-designed cropping plan (Figure 1) and the establishment in spring 2014 of an innovative fruit-based agroforestry cropping system at Gembloux in Belgium. An integral part of the approach was to define three priority hypotheses to test and validate (i) the impact of the system on pest and disease control, (ii) its impact on soil fertility, and (iii) its impact on overall yield and productivity.

Choosing an experimental design is a trade-off between economic/technical constraints and the enhancement of ecosystem processes, constituting a major challenge in the conception of farming systems at the field and farm levels (Sieffert et al., 2014). Designing ecologically intensive agroecosystems calls for in-depth knowledge of biological processes in ecosystems and for the integration of local traditional agricultural knowledge (Malézieux, 2012). The participatory discussions showed that temperate agroecosystems (involving alley-cropping) with highly cultivated biodiversity suffer from two main constraints compared with tropical systems: (i) difficulties in adapting mechanization, which can limit perennial and annual crop interactions and (ii) the need for a high income per unit land area in order to ensure the economic viability of farms in a capital-intensive economic system.

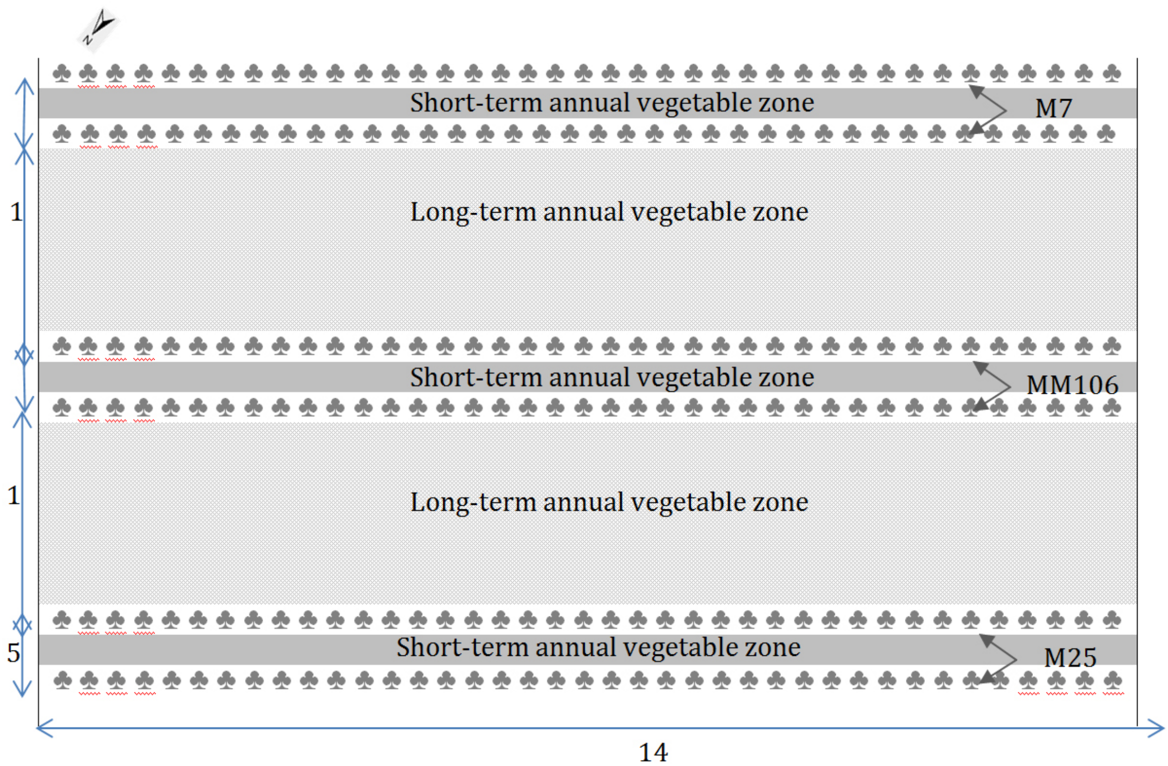

Figure 1. Basic design of the innovative fruit-based agroforestry cropping system established in 2014 at Gembloux in Belgium. A design where the width of long-term vegetable zones between the tree rows were 16 m, alternated with short-term vegetable zones from 5 to 5,5 m width, depending on the height of the trees.

Several parameters were considered in the spatial design of the cropping system (e.g., vegetable/fruit tree ratio, tree height and shape, type of rootstock, direction of rows, presence of hedges and canopy trees). The need for machinery to be able to move between fruit tree rows for fruit picking, treatment application and other activities led to a design where the width of long-term vegetable zones between the tree rows was 16 m, alternating with short-term vegetable zones from 5 to 5.5 m in width, depending on the height of the trees. Within the rows, the trees were planted 3 m apart, using semi-vigorous to vigorous rootstocks. The trees and vegetables are being grown according to organic production standards. The tree species planted were mainly *Malus* × *domestica*, and orchard maintenance includes a centrifugal spindle training system. The three rootstock types used were M7, M106 and M25, which grow to heights of 4, 6 and 8 m, respectively, after six years. The orchard included ten apple cultivars with low or moderate susceptibility to scab, selected so that fungicide treatments could be significantly reduced during the vegetable growing season. An in-row cultivator was used four times a year to remove the weeds in the tree rows. In the narrower vegetable zones, vegetable cultivation will be maintained for 5 years, after which the vegetables will be replaced by grass, mowed often enough to keep it short.

During the first year of the experiment (2014), the combination of perennial and annual cultivation was managed successfully. With regard to the annual crop, only one vegetable species was introduced in the experimental area: potatoes in 2014 and marrow in 2015. To reduce the use of copper fungicides for controlling late blight (*Phytophthora infestans*) in potatoes, two moderately susceptible cultivars, ‘Allians’ and ‘Agria’, were planted throughout the experimental area. The apple trees had not reached maturity and had no influence on the yield of the annual crops.

We still need to determine if the mixture of fruit trees and vegetables has an impact on biodiversity and on the presence of some natural enemies. We also want to find out if the combination of annual crops and trees has a measurable and useful impact on soil functions and biological processes and reduces plant stress, which could improve the resilience and health of agroecosystems (Smith et al., 2014). There is a lack of scientific studies on the impact of fruit trees on arable crops in temperate conditions. Our experiment should provide useful insight into the role of tree canopies and the optimal distances between vegetables and trees in intensified alley-cropping systems.

Two other on-farm fruit-based agroforestry cropping prototypes, designed by our team and located on two pilot farms in Belgium, are being developed to study issues related to production objectives, such as the impact of mechanization on plant interactions between perennial and annual crops and the need for a high income per unit land area to enhance the economic viability of farms in capital-intensive systems.

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