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Co-Design and Co-Evaluation of Traditional and Highly Biodiversity-Based Cropping Systems in the Mediterranean Area †

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Abstract: Intensive agriculture has created several problems in cropping systems that threaten the sustainability of agricultural production. In order to design new cropping systems, a new approach is emerging to support the transition toward sustainable agriculture: a co-design and co-evaluation process that involves stakeholders in the agrifood chain. The present work therefore describes the co-design and co-evaluation process that was followed to design a highly diversified cropping system in a Mediterranean environment. The different systems that were co-designed include the reference system, with wheat and barley in rotation, as well as three diversified systems that were also proposed and co-evaluated: the rotation of wheat, oil seed rape, and barley (DIV1); the rotation of wheat, pea, and barley (DIV2); and the rotation of wheat, intercrops of barley-common vetch, and barley (DIV3). The best system that was selected from the different stakeholders was the DIV3, as it had the highest evaluation of the stakeholders using agronomic, environmental, and socio-economic criteria.

Keywords: intercropping; crop rotation; reference system; diversification; co-design; co-evaluation

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1. Introduction

The Mediterranean basin is characterized by a high dependence on agricultural imports, especially cereals and legumes. Over the past 30 years, policies aimed at intensifying agricultural production have led to trajectories that have generally increased the incomes and market orientation of agricultural systems for farm households. However, the resulting economic pressure has encouraged specialization, leading to monocultures that have caused environmental degradation, such as a loss of biodiversity, which threatens the provision of ecosystem services (ES) [1]. Moreover, there is a strong need to develop modern and sustainable agriculture in the Southern Mediterranean countries to stabilize rural populations by providing them with real economic prospects and better social conditions. One way to achieve this is to increase the biodiversity of cropping systems.

Developing highly diversified-based agriculture often requires more than just efficiency or substitution strategies; it requires farming systems to be redesigned [2]. This is a knowledge-intensive approach that potentially empowers farmers and advisors in the quest for agricultural innovations [3,4]. Moreover, biodiversity-based agriculture is highly context-dependent, as designing highly diversified innovative systems requires combining locally relevant empirical knowledge with scientific process-based knowledge [4]. Therefore, a participatory approach is the most relevant way to hybridize scientific information and the expert knowledge of actors [5], acknowledging and taking advantage of the fact that farmers are also designers [1,6]. In such innovation processes, researchers act as partners in the overall approach [1,4], with one of their main roles being to structure and steer the design process [7].

The objective of the present work is to co-design locally promising innovations based on diversified cropping and farming systems using participatory methods and to co-evaluate the effects of the co-designed diversified cropping and farming systems compared to current ones.

2. Materials and Methods

The approach followed in the present study involved the participation of stakeholders from the agrifood chain. Two workshops were held on the university farm, the first being a co-design workshop aimed at finding innovative and highly species-diversified (HSD) options adapted to the Thessaloniki region case study. The second workshop took place one and a half years later and was aimed at evaluating the HSD systems suggested using a number of indicators belonging to different agronomic, environmental, and socio-economic dimensions (Table 1). Local stakeholders evaluated and ranked potential innovations in dedicated meetings based on data derived from a multi-criteria ex ante assessment, which led to a fine-tuning of the co-designed systems in an iterative manner.

Table 1. Indicators used to evaluate cropping system diversification, ordered within three categories: agronomic, environmental, and socio-economic.

Agronomic	Environmental	Socio-Economic
Grain yield (t ha^{-1})	N losses (volatilization, leaching)	Farming profit
Grain protein concentration	Soil CO_2 sequestered/emitted	Economic independence (from fuel and mineral N)
Yield variability	Energy use efficiency	Economic cost
Soil organic carbon content	Renewable energy input	Material additional cost
Soil erosion	Non-renewable energy input	Workload
Soil N mineralized		Employment of workers
Pest control (weeds, pests, and diseases)		

During the co-design process, four cropping systems were developed and evaluated. The first system served as the reference (RS) and involved a two-year rotation of wheat and barley. In this system, wheat is sown during the first growing season, while barley is sown during the second growing season. The second system (DIV1) consisted of a three-year rotation of wheat the first year, oilseed rape the second year, and barley the third year. The third system (DIV2) included a three-year rotation of wheat, pea, and barley. For these two diversified systems, wheat is cultivated for the first year, the following crop is oilseed rape for DIV1, and pea for DIV2, and finally, in the third year, both systems include barley. Finally, the fourth system (DIV3) involved a three-year rotation with wheat during the first growing season, intercropping of barley with common vetch for the second growing season, and lastly, barley for the third growing season.

3. Results and Discussion

The different stakeholders that were involved were as follows: 20 agricultural students that are also farmers, 1 seed producer and supplier of agricultural supplies, e.g., pesticides, fertilizers, etc., 13 farmers, and 5 researchers. All the participants were involved in cropping systems in Central Macedonia (Figure 1).

Most of the stakeholders indicated that the socio-economic aspects are more important, with 37.8%, followed by 35.4% of the agronomic and 26.8% of the environmental (Figure 2).

The systems that were better according to the stakeholders were DIV3 and DIV,2 as they had the best evaluation regarding the indicators that were used, such as agronomic, environmental, and socio-economic (Figure 3).

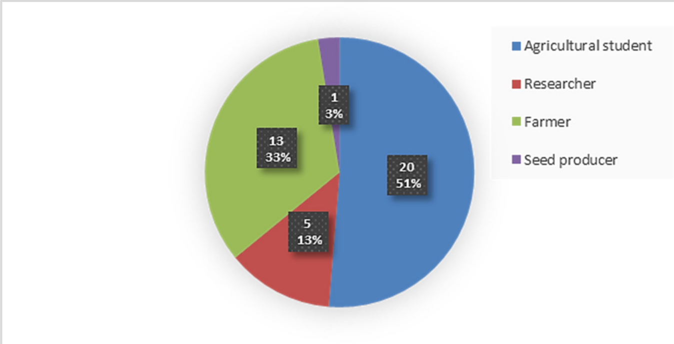

Figure 1. Stakeholders who attended the workshop.

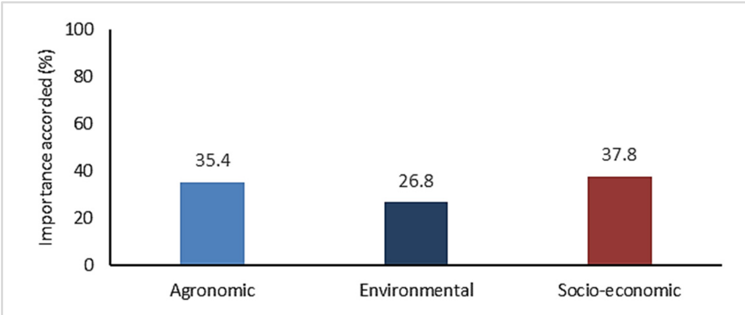

Figure 2. Importance according to each dimension by the stakeholders.

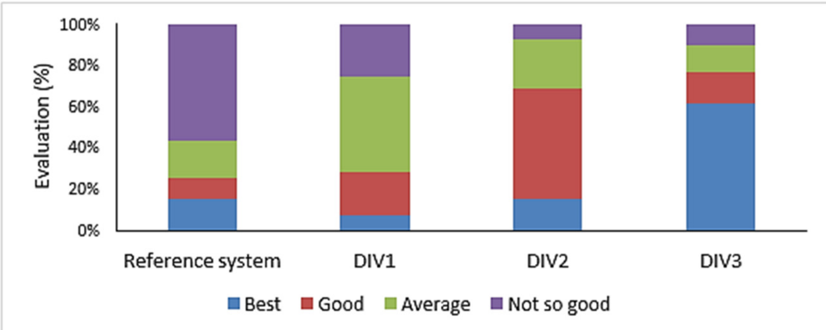

Figure 3. Evaluation of the four cropping systems designed in 2021.

4. Discussion

Based on the results, cropping systems that included legume species, either as sole crops or as intercrops with cereal, were found to be more preferable by the stakeholders [1,4]. Additionally, the farmers' main concerns were related to their final income, which is associated with socio-economic factors [5,7]. Similar responses have been reported in other studies, and it was found that it is better when legumes are included in the cropping system in a rotation or with intercropping, and more stakeholders recognized the need to develop highly diversifying cropping systems; however, the data are limited for Mediterranean cropping systems [1,3–5].

5. Conclusions

The main conclusions of the present study are that agronomic and socio-economic dimensions were the most important for the participants (over 70% combined). Furthermore, DIV2 and DIV3 were selected as the most satisfactory alternative cropping systems. Finally, throughout the discussion, it was obtained that the farmers were more concerned about the socio-economic dimension regarding the final profit.

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