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# Crop diversification and low-input farming across Europe: from practitioners' engagement and ecosystems services to increased revenues and value chain organisation

## Farm level economic benefits, costs and improved sustainability of diversified cropping systems

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## Executive summary

Farmers are in a central position in deciding on farm management and cropping diversification. Farm level profitability is one of the pivotal elements in the development of diversified cropping systems. Showing the economic rationale for diversification requires information and knowledge on the economic farm level consequences and profitability of cropping diversification. Farmers and their close stakeholders need information about how easily they can reach economic break-even – a situation where costs of diversification are covered by the monetary benefits. Then it becomes relevant to evaluate to what extent the costs may be covered or even exceeded by the expected benefits of diversification in the short and long term. For a long-term example, soil quality may improve gradually and result in avoided costs and/or higher crop yields in later years. If crop diversification cannot be shown to be even close to economic break-even, then there is little direct economic incentive for farmers to adopt diversification. If farmers do not see diversification profitable and worth more than it costs, even in the long-term, nobody else would implement diversification and then possible social and environmental benefits will not be materialized.

This study made a large-scale attempt to evaluate farm level profitability of diversification in 14 case studies using a transparent method, gross margin tables showing key changes in revenues and costs. This was done on market basis, i.e. we did not account for non-market values such as environmental improvement, landscape, existence, or recreational value for citizens. Instead the gross margin calculation relied on observations and data gathered from experimental fields, stakeholders' consultation, statistical databases or literature sources relevant to the specific regions. This means that the gross margin calculations show the current prevailing situation when farmers are not paid, not at least directly, other than market values of agricultural outputs and usual CAP subsidies in the study areas. On this basis one may consider how much value is earned/missing from desired diversifications which show positive/negative change in gross margins. Three different gross margins (GM) were calculated: GM A – what is left from revenues after paying all immediate necessary purchased inputs during a growing season; GM B – what is left from GM A after paying compensation for family labour; and GM C – what is left from GM B after paying fixed costs which are largely independent from the production decisions of the current year. These three simple gross margins provide a transparent view how easy or difficult it is to get the money back from diversifications which often cause immediate or long-term costs.

It is important to consider avoided problems and costs which may most likely realise if no change from the current practices. For example, if almond monocrop continuous growing in current environmental conditions in Spain, some negative economic impacts are expected in the long-term, either by an increase in variable costs or a decrease in the expected revenues. Intensive monocropping may cause a decrease in the provision of a great number of ecosystem services. Maintaining this kind of cropping systems over the long-term might may have negative environmental impacts that will impact on farm profitability. Intercropping caper and thyme between almond orchards were experimented and their economic profitability was assessed. Farm level economic analysis lays bare that intercropping would not negatively affect incomes and GMs perceived by farmers in certain scenarios, such as having an adapted machinery able to reduce labour needs and selling thyme to essential oil. Intercropping with capers is another possibility for profitable diversification, if properly managed and implemented.

Another irrigated perennial crop common Spain is mandarin. Farm level economic analysis suggests that there are intercropping and low-input farming systems that would not negatively impact the GMs in comparison with monocropping. Based on the data from a two-year experiment, geotextile cover specific diversification seems to be the most profitable among alternative diversifications, although weak data about commercialization of new alley crops does not allow too strong conclusions. The main driver of the economic benefit is still the main crop, mandarins, despite diversification. To ensure economic profitability, one should be more concerned with the economic performance of mandarins than with the alley crops.

Similar kind of findings were calculated and reported also in other case studies on perennial production, e.g. wine in Hungary and Germany, or in cases of other relatively high-valued crops such as asparagus in Hungary. In perennial or high valued horticulture production the main rationale for diversification were erosion problems and their mitigation using intercrops between the rows of the main crop. One important aspect considered – but not yet much supported by the data and practical experiences – was the effect of new crop on the main crop. Crop protection costs or other costs were found to be decreased at least in the short-term but there is a reason to monitor the effects on the yield of the main crop in later years.

In cases of irrigated and rainfed field crops one important finding was that diversification is – despite the fact that the data was available only from few years – more likely to pay back in rainfed conditions. This is quite obvious because irrigation is often coupled to the intensification of the agriculture with high level of fertilisation and other inputs such as crop protection. The results suggest that diversification benefits and synergies between crops are more likely to realise in rainfed production characterised by relatively low input use compared to high input production. Such cases were studied in Spain.

Field crop monocultures were diversified in terms of crop rotation in three different case studies in Italy and in one in Finland. The results on e.g. cereals – legumes rotations suggest that potential for economic gains exist if synergies between crops can materialise and adverse weather conditions do not obscure the outcomes. Droughts at individual years, e.g. affecting growth of newly sown legume crop, may imply negative results of diversification. Price fluctuations may also affect profitability of relatively low valued field crops very significantly if gross margins are thin already. Some results suggest that consistent utilisation of break-crops with pre-crop effects may provide even significant gains if gross margins are thin initially.

Dairy farming cases in the Netherlands and Finland were analysed for profitability of legume rotations. Positive changes in GM calculations for maize-bean rotations suggest even rather robust small or moderate economic gains. Clover-grass mixtures replacing highly fertilised hay grasses in Finland were found to provide small but most likely positive economic gains.

Overall, no large economic gains can be expected at least in the short-term from various crop diversifications. Some individual diversifications turned out, based on the short-term gross margin calculations, clearly unprofitable. Nevertheless, some diversifications looked more promising, close to break even or slightly profitable in almost all case studies. These early findings lay it bare that continued monitoring of the crop yields and input use and updating the gross margin calculations is necessary. This accumulates experience and knowledge about the profitability of diversification. More exact economic information can be weighed against environmental effects and various ecosystem services linked to diversification. The results can be useful in various management and policy considerations.

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# 1. Introduction

## 1.1. Rationale and motivation for farm level economic assessment of cropping diversification

The main objectives of Diverfarming WP8 “Economic assessment and value chains” are the following:

(1) Provide an integrated estimate for the direct benefit-cost to farmers (variations in crop yield, machinery fuel, fertilisers, pesticides, water, energy, labour) associated with each diversified cropping system within each pedoclimatic area, using outputs from the previous WPs;
(2) Provide an integrated estimate for the environmental gains with regard to benefits and costs (variations in C sequestration, biodiversity, pollution, erosion and GHGs emissions) associated with cropping systems linked to value chain cases within reference pedoclimatic areas;
(3) Provide farmers and actors in the value chain with economic information on the economic benefits and risks associated with diversified cropping systems – including quality, feasibility, usability aspects;
(4) Find robust approaches to achieve long-term sustainability accounting for sensitivity to future prices;

It is crucial that farm level economic calculations on benefits and costs driven by diversification are made. Otherwise the case studies cannot show farmers the economic rationale for diversification. Farmers and their close stakeholders need information how closely they can reach economic break-even – a situation where costs of diversification are covered by the monetary benefits – already in the short-term. Then it is easier to evaluate to what extent costs may be covered or even exceeded by the expected benefits of diversification in the long run (for example, soil quality may improve gradually and result in avoided costs and/or higher crop yields in later years). If cropping diversification cannot be shown to be even close to economic break-even or economic profitability (monetary benefits should exceed the costs in the long run) then it does not provide any economic incentive for farmers to adopt diversification. This, in turn, is devastating to all other possible benefits of diversification as well.

This study is responding to the objectives (1) and (3) above. Once the benefits and costs for farmers are analysed using gross margin calculations, the economic costs and gains can be compared with improvements in key environmental indicators, most relevant to the region and case study (objective 2). This means that gains or losses from diversification to a farmer are weighed against the environmental benefits from diversification.

This as such may already have policy implications (WP9) and implications for value chains and consumers. If certain improvement in environmental indicators can be assigned an economic value (e.g. based on methods based on market prices such as emission/pollution permits and quotas, or based on non-market valuations, or other value considerations) then comparing farm level economic benefits with environmental outcomes is even more interesting and valuable for policy makers. For example, if break-even situation is sufficiently close but not obvious on market basis only, then policy makers might design and implement additional incentives, i.e. implement policy intervention based on supplying any environmental benefit to change the situation, so that many farmers could find cropping diversification an economically rational choice. This would also make other possible benefits such as environmental, social, societal, cultural benefits, reachable.

Hence farm level economic assessment is needed, even if first assessment is based on scarce data over the desirable. Scarce data, which we often find in the case study specific analyses in this study, can however be improved with new and better data and parameter estimates. From a holistic sustainability point of view, one may consider farm level economic calculations as necessary since they show the whole farm view of cropping diversification. This view can be included and utilized at value chain level or in larger societal perspective. Still farmers are key decision makers in cropping diversification: If they do not see it profitable and rational, at least in the long term, nobody else can implement diversification and then the possible benefits will not be materialized. Hence economic viability and profitability of cropping diversification is not one of the many indicators of diversification or agricultural sustainability in general, but one of the crucial ones.

We next introduce the concept of economic gross margins calculated at the farm level, as well as the structure of the report suggested for the case studies for results reporting. Then we present economic assessment of diversification per case study. We present executive summary of the main findings on the economic profitability of diversification – though mostly from short-term perspective due to limited data available - across case studies. The results show interesting and pivotal findings how close is the economic profitability of diversification in the case studies, and what kind of environmental and other sustainability challenges the diversifications could solve – if profitable, already now, or in the near or more distant future. The results of this study will be used at least in Diverfarming WP7 (overall impact and sustainability assessment of diversification) and WP9 (policy implications).

## 1.2. Economic assessment based on gross margins

Farm level economic analysis in this study is much based on gross margin (GM) calculations utilising crop specific input use, crop output and price data gathered, specific per crop and (conventional/typical and diversified) cropping system. This approach is rather data intensive but it may provide clear, convincing and transparent results. This approach in fact creates a basis for detailed follow-up of the economic farm level effects of crop diversification.

Availability of farm level input use and revenue data can be a problem with this approach. In fact, data availability has been a problem and it has caused significant extra efforts and delays since some of the case studies were not initially planned from the point of view of farm level economic calculations. If experiments in each case study do not provide sufficient data for the gross margin analysis, some input use and input cost data may be also derived from various data sources relevant for each case study region, such as stakeholder's consultations. For example, farming extension services may publish production cost and revenue data at the farm level per crop. EU wide FADN (Farm Accountancy Data Network; https://ec.europa.eu/agriculture/rica/) provides data per farm type and region.

Relatively scarce data was available in the context of some case studies. A field data collection sheet, where farmers and researchers may contribute to data needs through filling in key information, was made available on Diverfarming internal cloud OneDrive WP8 folder. After collecting data, before using it in the gross margin calculations, it may be necessary to arrange information according to a useful format for its management. Hence a separate data sheet was made and it organizes data by input categories. The whole data sheet can be consulted at Diverfarming OneDrive WP8 folder. The data sheet is specific on: plot archive, seeds, pesticides, fertilizers, labour costs, machineries, diary, subsides, revenue, and resume. The GM calculation sheets, available at Diverfarming OneDrive WP8 folder, were made available early on as well, to be modified according to the crops and related inputs and outputs in each case study. In fact, the GM sheets were heavily adjusted and modified when used in the GM calculations in the context of each case study.

It is important to understand how much input use, crop yields, market revenues and farm subsidies are different in diversified cropping system and why. The GM calculations should make this transparent. In fact, the GM calculations, or the main elements of the GM calculations showing the different costs and revenues of alternative diversification, serve as attachment on the report of each case study. It looks as follow:

Crop diversification affects changes in crop rotations, crop allocations, use of inputs and crop yields:

(1) Describe what is the starting point / baseline / common practice – what is to be diversified. One may call this "farming system 0". This may be a typical, somewhat monocultural farm management scheme of the case study region, possibly documented in some existing literature. For example, in case study 12 "farming system 0" is clearly barley monoculture.

(2) Describe alternative, diversified farming systems – "diversified farming systems 1,2,3,.." etc. These may be linked to case study experiments, or typical diversified farming systems of the case study region, possibly documented in some existing literature. If somewhat "new" in the case study region, explain why this kind of farming system is chosen and what is expected from it.

Anyway, this set up must be clear: What is diversified, how, what are the changed use of inputs, crop yields, and various other effects – expected, based on the case study description, or to be quantified in other WPs.

Depending on what factors of production are accounted for per crop we differentiate between gross margin A (only variable factors except labour considered as costs), gross margin B (variable factors and labour considered as costs) and gross margin C (all factors except land are considered as costs per crop). This kind of categorization improves comparability between the results of different case studies.

All this described above was made available already in deliverable D8.1 "Development of a common integrated research methodology and protocol", in December 2018.

## 1.3. Suggested structure and procedure for farm level economic assessment

This study is based on the guidelines given to WP8 partners and case study leaders in December 2019 and in Deliverable D8.1: Common integrate framework. A recommended structure is given below. However, it has been made clear that this structure and procedure may not be feasible in all case studies and applicable alternative solutions can be used e.g. in situations where monocultural production is not any relevant reference.

Suggested structure of case study specific farm level economic analysis reports:

- "Introduction", with background description of the case study, on the main crops cultivated (business); "Diversification description", e.g. how the current typical production practice could be changed by diversification. This is already explained in the design of each case study.
- "Hypothesis / expected benefits of the specific diversification";
- "Methods": Setting up gross margin calculation with the main data sources;
- "Results": The gross margin tables with some text on the main findings; "Comparing the gross margin"; with main results per diversification option, and reporting drivers of the results, "Uncertainty analysis" if relevant.
- "Discussion" of the results with critical remarks, remaining gaps;
- "Conclusions"; What are the most important results? To what extent diversifications are profitable, can they be recommended for farmers?

- References + possible annex tables etc.

When conducting the study per case study, it is important to think about the hypothesis on:

i. problems of monoculture, likely in the long-term if not yet, may be causing some yield decline, increasing need for fertilization and other inputs, or additional other costs (e.g. due to erosion etc);
ii. possible quantified benefits of diversification (e.g. over a 5-year period, or other time period, or averaged per annum); avoidance of the problems of the monocropping, may be even increased yields of some crops, or reduced need for some inputs (e.g. fertilization, crop protection, labour). Sure there may be some increased costs (start-up costs and then operational costs) of diversification, e.g. labour, seeds, weeding, harvesting, additional labour. Such costs may not be fully covered by benefits of diversification in the short run.

Simple static calculations showing no negative developments in monocropping may not be realistic in the long run. One might have 1 extra excel sheet gross margin (GM) calculation with monocropping over 5 years with yield decline or increasing fertilization to maintain the yield; This can be done by simulating the expected crop behaviour. E.g. by using monocrop calculation over 5 years and then decrease the yield / increase fertilization in some step over 5 years, and sum up the total 5-year gross margin. Calculate expected *average* gross margin over 5 years.

Anyway, gross margin between monoculture and diversification should be compared and what contributes to the differences most should be reported. Data produced (e.g. in WP3) on crop yields and input use should be utilised as much as considered relevant when formulating the hypothesis. Since there is limited data available – e.g. data from crop cultivation experiments over 2-3 years one may use also literature or other data, possibly supporting the hypothesis on crop yield or input use change in the diversifications. If the data tells some significant evidence on some difference / no difference between crop yields and input use then this information is used. Statistical testing of the hypothesis has been done in some case studies (e.g. Spanish case studies 1-2), but that may not be feasible / relevant in most other cases, due to limited data, or unusual weather conditions.

Case study results should include the explicit gross margin tables showing the main results in a transparent way. Conclusions should wrap up the main results: to what extent gross margins are different / are not different between monocropping and diversification? Why? What are the needed conditions for better gross margins at the farm level? Can the diversifications studied be recommended for farmers? Later, if not done already: Discuss the results with farmers, experts, those interested.

## 2. CS1. Rainfed perennial crops (almonds) in Spain

### 2.1. Case study description

Case study 1 (CS1) is located in the Mediterranean South pedoclimatic region within the Region of Murcia (SE Spain), an area characterized by semiarid climate conditions with increasing water scarcity (mean annual precipitation of 231 mm). Temperature is usually mild in winter and high in summer (mean annual temperature of 17.5 ºC). Due to these conditions, evapotranspiration is very high (annual potential evapotranspiration of 1300 mm).

CS1 is focused on rainfed perennial crops, specifically in almond orchards. The experimental field is part of a commercial farm which covers a total of 2.63 ha, where Diverfarming experimentation area has an extension of 0.19 ha, with 54 almond trees. The current crop species is *Prunus dulcis*, whose final use is food. The current farming system consists of a conventional rainfed monoculture in a 7m x 7m pattern where management practices are scarce, with just one pesticide treatment, pruning and one tillage per year.

There are many environmental problems that compromise the potential of ecosystem services related to soil and vegetation functioning, so Diverfarming project have implemented two intercropping systems. Diversification 1 (D1) consists of almond intercropped with capers (*Capparis spinosa*, permanent) for food during 2018, 2019 and 2020. Diversification 2 (D2) consists of almond intercropped with thyme (*Thymus hyemalis*, permanent) for essential oils and food during 2018, 2019 and 2020. These intercrops are cultivated between the almond tree rows. Both proposed diversifications D1 and D2 are compared with the conventional monocropping system (MC), which serves as a control experiment. There are 3 replicates from each system, grouped into 3 different blocks. Figure 2.1 shows the experimental field design.

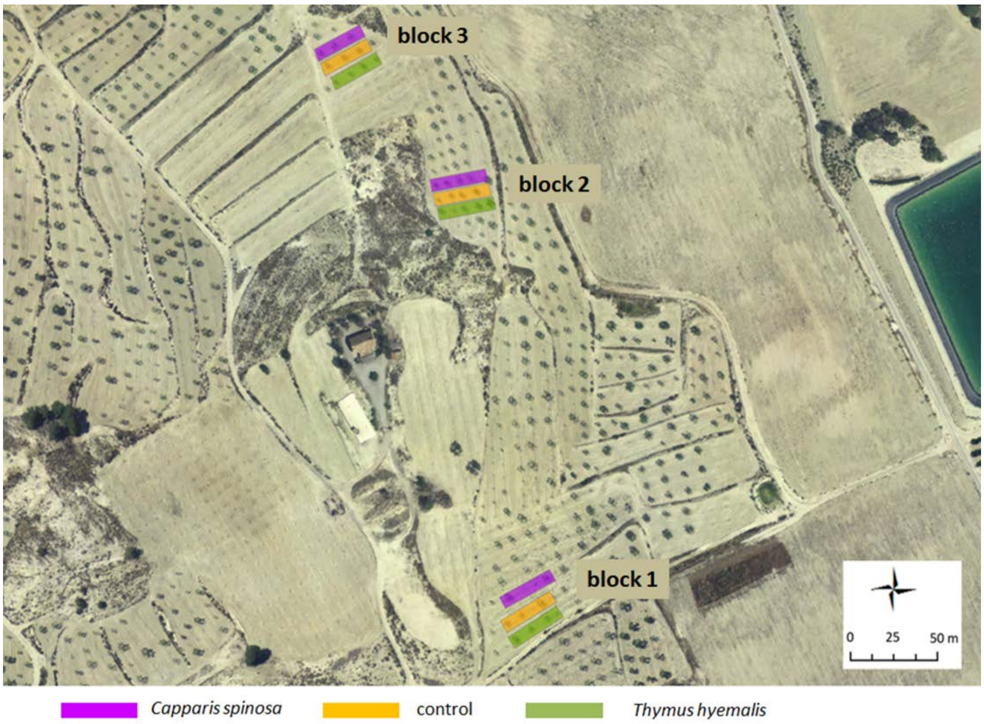


***Figure 2.1.*** *Field design of CS1*

Two case studies, rainfed almond crop (CS1) and irrigated mandarin crop (CS2), will be considered to develop non-market valuation within Mediterranean South pedoclimatic area.

## 2.2. Materials and methods

Farm level economic analysis is much based on gross margin (GM) calculations. Depending on which factors of production are accounted for per crop, three levels of GM can be differentiated: GM-A (only variable factors except labour considered as costs), GM-B (variable factors and labour considered as costs) and GM-C (all factors except land are considered as costs per crop). Details of GM methods can be found in Deliverable D8.1.

Input, yields and agricultural management practices related data have been collected every year at crop and plot levels, and aggregated by intercropping system to the farm level. The total observation number is of 34 almond trees in 2018 and 32 in 2019, which involve 3 repetitions per farming system which contain between 3 and 5 trees. Most of the technical information has been gathered directly from case study plots, while market prices and subsidy values has been derived from farmer's suppliers and official farm statistics for the Region of Murcia (CARM, 2020), respectively. Fixed costs has been derived from previous works in the same area (Alcon et al., 2013).

Farm level economic analysis at CS1 seeks to address the changes in GM of almond orchards due to (1) the maintenance of monoculture in the long-term and (2) the introduction of intercropping practices, namely, how intercropping impacts on farm yields and on the use of inputs and management practices, and consequently on the economic value of the practices. Maintaining the prevalence of monocropping systems may be translated into a depletion of biodiversity, resilience and, in summary, a decrease in environmental attributes that would imply a decrease in the ecosystem services provided, including food provision. However, intercropping systems, which imply the coexistence of different crops in the same field plot and at the same time, may increase or decrease both the use of inputs and the expected crop yield. Since inputs and crop yields have economic values at farm level, it is relevant from farmers' point of view to assess how intercropping could influence GM estimations.

Empirical evidence suggests that intercropping positively impacts on yields (Morugán-Coronado et al., 2020). However, more efforts are needed in order to better clarify the impact magnitude, as well as the expected effects of intercropping practice on input use. At this stage, the establishment of hypothesis about the changes of inputs and crop yields may be a key tool to investigate how intercropping works. Comparisons between monocropping and intercropping practices in terms of income, variable costs, fixed costs and GM allows to determine whether intercropping has a real effect on the farm economic profitability. Start-up costs of diversification have been taken into account too. These include land preparation, seeds and plants, intercrop plantation and irrigation (needed in our study area to ensure the survival of intercrops). Most of these start-up practices could be highly labour-demanding. Hence the costs could be significantly higher in some diversifications than in the monocropping case. Furthermore, both secondary crops are perennial, with an expected useful life of 25 years for capers and 10 for thyme, which imply annual depreciations.

Following the framework of GM assessment, four levels of hypothesis have been considered: (0) hypothesis on monoculture economic performance on the long-term, and (1) hypothesis on revenues, (2) hypothesis on costs and (3) hypothesis on GM due to the implementation of intercropping systems. Since our purpose is to analyse how the farm economic performance changes due to both the maintenance of monoculture and the development of intercropping practices, the first hypothesis, or hypothesis zero, assesses what impacts are expected in the long-term, in case no changes are implemented with regard to the current monocropping systems, while comparisons among different intercropping practices and monocropping in economics terms have been carried out in the three last hypothesis. The proposed hypothesis are:

***Hypothesis 0. Changes in monocrop economic performance in the long-term***

*$H0_0$: Monocrop economic performance will not be different from now in the long-term*

*$H0_A$: Monocrop economic performance will be different from now in the long-term*

In the case of monocropping practices continue being applied, some environmental harmful damages could be expected in the long term. Climate change effects on Mediterranean semiarid areas (IPCC, 2014), together with the decrease in the provision of ecosystem services, may provide negative effects on farm level economic performance. The main environmental issues which may have an economic impact are related to soil and biodiversity loss, since IPCC (2014) models show an increase in temperature and extreme events as droughts and floods which will specially increase erosion rates in agrosystems like rainfed monocropping almond orchards (García et al., 2012). Hence, the loss of soil organic matter may have a negative impact in farm profitability. On the one hand, almond yield may be negatively affected, and thus, farm revenues, in case farmers do not act to deal with these challenges. On the other hand, and in case farmers act to avoid yield decrease, it may be translated into an increase in farm costs, since the loss of soil fertility might be replaced by using soil amendment practices, such as increasing fertilizer requirements.. High erosion rates have been actually measured in the case study, which may reach more than 4 tons/ha/year of soil loss (Verschaeren et al., 2019). All these economic values may be estimated using avoided and replacement cost methods.

***Hypothesis 1. Changes in farm revenues due to intercropping***

*$H1_0$: Mean revenues are not different between intercropping and monocropping in almond orchard*

*$H1_A$: Mean revenues are different between intercropping and monocropping in almond orchard*

The inclusion of different crops within the same plot is expected to have a positive impact in the total revenues. Although there is no found empirical evidences that intercropping has a positive (or negative) impact on almond yields in rainfed orchards, previous intercropping experiences in other different crops tend to have positive impact on farm yields (Rosa-Schleich et al., 2019), and thus similar results are expected in CS1.

***Hypothesis 2a. Changes in variable costs at farm level due to intercropping***

*$H2a_0$: Mean variable costs are not different between intercropping and monocropping in almond orchard*

*$H2a_A$: Mean variable costs are different between intercropping and monocropping in almond orchard*

The implementation of intercropping practices implies different crops growing simultaneously in the same plot. The number of agricultural management practices (tillage, fertilizer and pesticide application, …) is expected to increase due to the fact that additional crops are included in the same field. However, there is no evidences of the real impact on the current practices to the main crop (almond). Thus, the net effect of intercropping on these management practices is assessed through the implied cost, i.e. the cost of energy, pesticides and fertilizers, etc.

***Hypothesis 2b. Changes in labour costs at farm level due to intercropping***

*$H2b_0$: Mean labour costs are not different between intercropping and monocropping in almond orchard*

*$H2b_A$: Mean labour costs are different between intercropping and monocropping in almond orchard*

The inclusion of additional crops in woody crop orchards may imply the increment the number of labours in detriment the use of machinery (Rosa-schleich et al., 2019). It finally may be reflected as an increment in labour cost at farm level. However, intercropping may reduce the number of labours required to the main crop, for instance, application of crop protection to almonds. Under this situation, it is required to check if intercropping has a significant effect on the labour costs at farm level.

***Hypothesis 2c. Changes in fixed costs at farm level due to intercropping***

*$H2c_0$: Mean fixed costs are not different between intercropping and monocropping in almond orchard*

*$H2c_A$: Mean fixed costs are different between intercropping and monocropping in almond orchard*

Fixed cost at farm level includes mainly the depreciation of machinery and crop plantation, for both main crop (almond) and alley crops (caper and thyme). At first glance, it is expected that intercropping may imply higher fixed costs, especially taking into account that all the start-up costs related to intercropping.

***Hypothesis 3. Changes in GM at farm level due to intercropping***

*$H3_0$: Mean GM is not different between intercropping and monocropping in almond orchard*

*$H3_A$: Mean GM is different between intercropping and monocropping in almond orchard*

Depending on the impact of intercropping practices on revenue and costs, different impact effect on GM (GM-A, GM-B and GM-C) is expected. Intercropping is expected to increase both, revenue and costs. However, the impact on the GM would depend on the individual increment magnitude.

To check the hypothesis established, analysis of variance (ANOVA), or alternatively Kruskal-Wallis tests, have been carried out. It allows to test the statistically significant differences in revenue, costs and GMs between the different intercropping and monocropping practices. If significant differences among practices are found, Dunn's post-hoc test is used to determine which practices are different, especially regarding comparison between intercropping and monocropping practices.

## 2.3. Results

In order to estimate the increase in variable costs that soil loss implies by the replacement cost method, Soil amendment composed by bare soil and organic manure (Zhong et al., 2010) is proposed as a feasible alternative to replace soil loss, and avoid as well the remarked decline in soil organic matter. It implies an increase in variable costs which may range between 60-80% of total variable costs. Besides, the depletion in ecosystem services, mainly those related to soil properties and biodiversity, could also advocate to a decrease in almond yield. Despite no experimental data are obtained to cover this gap, interviews with farmers and some other stakeholders involve in almond crops in the case study, has allowed to state that a decrease between 10-20% of almond yield might be expected. Therefore, if almond monocrop continuous growing in current environmental conditions, some negative economic impacts are expected in the long-term, either by an increase in variable costs or a decrease in the expected incomes, and so hypothesis H00 cannot be accepted.

Transition from monocropping to intercropping has implied a change in the number of management practices within the farm. As it is shown in Table 2.1, the number of practices required annually in both intercropping systems has increased. It is due to the start-up practices that intercropping involves (land preparation, intercrop plantation, minimum irrigation to ensure intercrops to survive). However, other management practices, such as tillage, are not required in intercropping systems.

DIVERFARMING

*Table 2.1. Agricultural management practices developed in CS1*

| | Farming systems | | |
|---|---|---|---|
| | MC | D1 | D2 |
| Tillage | 1 | | |
| Pruning | 1 | 1 | 1 |
| Pesticide treatment | 1 | 1 | 1 |
| Harvesting | 1 | 1 | 1 |
| Start-up intercropping practices | | 5 | 5 |
| Total | 4 | 8 | 8 |

Results of costs, revenue and GM calculation are summarized in Table 2.2. It should be noted that, at experimental level, no diversification practices were carried out in 2018, since the water-scarcity and climate conditions did not allow intercrops to grow. Hence, results from 2018 allude to almond monocrop, even though references to D1 and D2 have been included in Table 2.2 to account implicit differences that may arise among them. Another key point in the GM estimation comprises the fact that, although 2019 includes actually intercropping practices – caper in D1 and thyme in D2 –, these intercrops have not produced anything yet, and thus, any income related to them can be expected in the near future. However, they have some start-up costs, whose depreciation should be included as an annual fixed cost.

Related to revenues, almond is the only source of revenues for farm during both years. In 2018, similar yields within the different farming systems are found. In fact, no significant differences have been found among farming systems. However, in 2019, the intercropping system shows revenue differences between farming systems. Revenue values in all farming systems from 2018 to 2019 decreased but at different rates, with a -14.5% variation in MC, -29.6% in D1 and -48.5% in D2. Despite of that, no significant differences have been found between incomes in each intercropping practice and monocropping, and therefore, hypothesis $H1_0$ cannot be rejected.

Regarding farm variable costs, no significant differences has been found between agricultural farming system, including labour variable costs. Therefore, hypothesis $H2a_0$ and $H2b_0$ cannot be rejected.

The fixed costs analysis reveals that there are no differences between systems regarding fixed costs due to machinery depreciation. So start-up costs that imply perennial intercrops and their amortization have to be considered. Taken into account start-up investment in both crops, the annual depreciation is about 154€/ha for capers and 1,546€/ha for thymus. And if we also consider the decrease of almonds yield in both diversifications, caper income must be, at least, 271€/ha and thymus 1,729€/ha per year in order to equalize or improve the MC economic performance. If these thresholds are exceeded, the economic performance of both diversifications could be much higher than from the conventional monocropping system. Therefore, hypothesis $H2c_0$ cannot be accepted, and significant differences have been found between both intercropping systems and monocropping regarding fixed costs.

*Table 2.2.* GM results from CS1

| | | MC | | D1 | | D2 | | *p-value*[a] |
|---|---|---|---|---|---|---|---|---|
| | | 2018 | 2019 | 2018 | 2019 | 2018 | 2019 | 2019 |
| Revenue | Almond | 589 | 504 | 785 | 552 | 541 | 278 | |
| | Caper | | | | | | | |
| | Thymus | | | | | | | |
| | CAP subsides | 190 | 190 | 190 | 190 | 190 | 190 | |
| | Total | 779 | 694 | 975 | 742 | 731 | 468 | 0.04 |
| Variable costs | Treatments | 9 | 33 | 9 | 33 | 9 | 33 | |
| | Machinery | 86 | 92 | 86 | 92 | 86 | 92 | |
| | Other materials | | | | | | | |
| | Total | 95 | 126 | 95 | 126 | 95 | 126 | |
| | Gross Margin A | 684 | 567 | 879 | 616 | 636 | 342 | 0.04 |
| | Labour costs | 45 | 32 | 45 | 32 | 45 | 32 | |
| | Gross Margin B | 639 | 534 | 834 | 583 | 591 | 309 | 0.04 |
| Fixed Costs | Machinery | 29 | 36 | 29 | 36 | 29 | 36 | |
| | Installation | 72 | 72 | 72 | 301 | 72 | 1,694 | |
| | Total | 101 | 109 | 101 | 338* | 101 | 1,731* | 0.00 |
| | **Gross Margin C** | **537** | **425** | **732** | **245** | **489** | **-1,421*** | **0.00** |

[a]p-value refers to Kruskal-Wallis test

* Significant differences (p-value < 0.10) between the mentioned system (DX) and MCh by year

Taking into consideration income and costs, GMs are obtained. Despite diversification does not work in 2018, all GMs are positive, ranging from about 500€/ha to 730€/ha for GM-C. The variance analysis reveals that no significant differences are found. However, results from 2019 are clearly different. GM-A and GM-B are quite similar for both intercropping and monocropping systems, while GM-C remains positive for MC and D1, and turns to negative for D2. This is due to the high start-up costs of intercropped thyme. Hence, hypothesis $H3_0$ cannot be accepted for GM-C, and thus D2 may provide economic losses in case thyme does not generate any income.

## 2.4. Discussion

Intensive monocropping may cause a decrease in the provision of a great number of ecosystem services. Maintaining this kind of cropping systems over the long-term might may have negative environmental impacts that will impact on farm profitability. Although no experimental data has been found yet, the first estimations based on expert opinions indicate that some negative impacts, or an exacerbation of some problems related to climate change, might be expected whether no farm systems are readapted. To overcome this challenge, intercropping in rainfed almond orchards can be seen as a feasible alternative.

Diversified farming system in experimental case study is still at an early stage. The first year of intercropping experiment has just finished, and therefore, due to the type of intercrops, there is no data about their production. However, these early results serve to show that no significant differences are expected in main crop (almond) due to the establishment of intercropping. Furthermore, according to previous literature (Lozano, 1977), the intercropping of almonds with capers has been a typical association in the south of Spain that does not affect to almond yield. This fact, together with the relatively low start-up costs that capers require, provides positive GMs for D1, even when no intercropping incomes are obtained. At this point, the only differences found refers to the high start-up costs of the intercrops, especially in thyme, which finally have a negative effect on the economic profitability of the farm (D2). Hence, the challenge is to identify GM differences derived from intercropping yields considering both main and secondary crops.

To address the consideration of both crops yielding, a scenario assessment has been developed. Since there is no data about the production of caper and thyme in the case study, incomes have been estimated taking into account the expected intercrop production and price information from secondary sources, based on data obtained from interviews with stakeholders and experts involves in the different commercialization ways of these products. With this information, multiple hypothetical scenarios have been estimated. The proposed scenarios refer to intercropping systems and assume that almond yields and fixed costs remain stable at the same level as 2019. Any additional inputs and management practices are expected due to the intercrops, further than harvest. Different proposals have been made in terms of intercropping revenues and variable and labour costs related to harvest in order to generate the different scenarios. Two scenarios by diversification are proposed, D1-S1 and D1-S2 for Diversification 1 and D2-S1 and D2-S2 for Diversification 2 (table 2.3).

***Table 2.3.*** *Proposed scenarios for intercropping systems*

| Scenario | Income | Harvest |
|---|---|---|
| D1-S1 | Sale of capers to make pickles | Pick by hand |
| D1-S2 | Sale of caper stems to make pickles | Pick by hand |
| D2-S1 | Sale of thyme to essential oil | Reaper machine + reap by hand |
| D2-S2 | Sale of thyme to spices | Reaper machine + reap by hand |

Results from the proposed scenarios are summarised in Table 2.4. As it reveals, selling caper stems to make pickles (D1-S2) and thyme to essential oil (D2-S1) comprise the best scenarios according to their economic profitability. These are the alternatives that require less labour costs, since their collection is faster, as well as less post-harvest treatment by the farmer. To achieve these results, caper stems have been considered to be sold at 3'25€/kg and the thymus at 70€/kg, considering a 1% yield during the transformation to essential oil. In addition, the mechanized harvesting of thyme has been taken into consideration, so the development of adapted machinery that manages to reduce labour is crucial for the profitability of D2. However, alternative scenarios for caper, such as those which refer to sell capers directly to make pickles (D1-S1), are not economically recommended since income is not enough to encompass the labour costs required to harvest. Regarding alternatives for thyme, D2-S2 may not be economically advised seeing that, though income is high enough to cover harvest costs, fixed costs still be such high that cannot be neutralized by the benefits thyme provides.

Once the scenarios have been selected using economic criteria (D1-S2/D2-S1), the formulated hypothesis can be retested. The results from ANOVA and Kruskal-Wallis tests reveal that significant differences between intercropping and monocropping systems are found in either income, costs and GMs. Therefore, differences in incomes show that intercrops provide additional revenues, and thus, hypothesis H10 cannot be rejected. Related to costs, as expected, labour costs are significantly higher at intercropping than monocropping due to harvesting. Similar statements could be applied to fixed costs, and thus, hypothesis H2b0 and H2c0 cannot be rejected. These differences are translated into GMs, although at a different scale depending on the intercrop. Selling capers stems (D1-S2) provides significantly higher GMs than only almonds (MC), and therefore, H30 cannot be rejected for this intercrop. However, thyme intercrop is not expected to provide differences in terms of GM-C due to its high start-up costs again, which does not allow to accept hypothesis H30.

***Table 2.4.*** *GM results from scenario assessment in CS1*

| | | MC | D1 | | D2 | |
|---|---|---|---|---|---|---|
| | | | D1-S1 | D1-S2 | D2-S1 | D2-S2 |
| Income | Almond (15% yield decrease due to erosion) | 504 | 470 | 470 | 237 | 237 |
| | Caper | | 1,837 | 3,980 | | |
| | Thymus | | | | 1,841 | 653 |
| | CAP subsides | 190 | 190 | 190 | 190 | 190 |
| | Total | 694 | 2,496* | 4,639* | 2,268* | 1,080 |
| Variable costs | Treatments | 34 | 34 | 34 | 34 | 34 |
| | Machinery | 92 | 92 | 92 | 212 | 212 |
| | Other materials | | | | | |
| | Total | 126 | 126 | 126 | 246 | 246 |
| | Gross Margin A | 568 | 2,370* | 4,513* | 2,022* | 834 |
| | Labour costs | 33 | 3,298* | 2,482* | 193* | 238* |
| | Gross Margin B | 535 | -928* | 2,031* | 1,828* | 595 |
| Fixed Costs | Machinery | 37 | 37 | 37 | 37 | 37 |
| | Installations | 73 | 302 | 302 | 1,694 | 1,694 |
| | Total | 109 | 338* | 338* | 1,731* | 1,731* |
| | **Gross Margin C** | **350** | **-1,266*** | **1,693*** | **97** | **-1,136*** |

*Significant differences (p-value < 0.10) between the mentioned system (DX-SX) and MC

## 2.5. Conclusions

Intercropping systems represent a way to overcome main environmental issues that monoculture provides in Mediterranean South region, especially in rainfed perennial crops, such as almond orchards. Within the case study we have presented here, that intercropping caper and thyme between almond orchards, have been experienced and their economic profitability have been assessed Farm level economic analysis lays bare that intercropping systems would not negatively affect incomes and GMs perceived by farmers in certain scenarios, such as selling thyme to essential oil (D2-S1). Furthermore, D1-S2 scenario, where caper stems are sold to make pickles, would significantly improve gross margin C results. Mechanized harvesting of thyme has been taken into consideration, so the development of adapted machinery that manages to reduce labour is crucial for the profitability of D2. Selling capers directly to make pickles (D1-S1), are not economically recommended since income is not enough to encompass the labour costs required to harvest. Regarding alternatives for thyme, D2-S2 (Thymus for spices) may not be economically advised since income is high enough to cover harvest costs.

Capers sold by stems and thymus for essential oil are the cases which imply less processing and labour costs to farmers than the other alternative, possible outlets of these alley crops. So, in both diversification cases, the key issue that would make alley cropping profitable, and by consequence, the entire farming system, is the extra costs related to these alley crops. Nevertheless, profitability of both diversification scenarios depends on more factors that cannot barely be estimated, like long term changes in the crops yield when intercropped, the develop of adapted machinery, access to Thymus oil and caper markets, and risks related to market variations.

It is important to note that the change from monoculture to diversified systems requires an initial investment or start-up costs in thymus case, that may compromise profits in the forthcoming years. However, the medium to long term profitability (in conditions close to those specified above) and the better environmental performance of this type of farming system make it possible for them to have a general better economic performance than monocrop.

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# 3. CS2. Irrigated perennial crops (citrus) in Spain

## 3.1. Case study description

Case study 2 (CS2) is located in the Mediterranean South pedoclimatic region within the Region of Murcia (SE Spain), an area characterized by semiarid climate conditions with increasing water scarcity (mean annual precipitation of 231 mm). Temperature is usually mild in winter and high in summer (mean annual temperature of 17.5 ºC). Due to these conditions, evapotranspiration is very high (annual potential evapotranspiration of 1300 mm).

CS2 is focused on irrigated perennial crops, specifically in mandarin orchards. The experimental field is part of a commercial farm which covers around 206 ha, where Diverfarming experimentation area has an extension of 2.3 ha. The current species is *Citrus reticulate* var. Clemenvilla, whose final use is food. The farming system 0 consists of a conventional irrigated monoculture, in a 6m x 4m pattern, where management practices are intense tillage and mineral fertilizer, with intensive pesticides and herbicides application.

To overcome the diversity of environmental issues associated with the conventional farming system (erosion and soil loss, greenhouse gases emissions, soil and water pollution, …), Diverfarming project has implemented two diversified systems together with various farming systems with low input practices. Diversification 1 (D1) consists of mandarin intercropped with multiple cropping of vetch/barley (*Vicia sativa/Hordeum vulgare*) for feed and fava bean (*Vicia faba*) for food, during 2018, 2019 and 2020. Diversification 2 (D2) consists of mandarin intercropped with a rotation of vetch/barley (*Vicia sativa/Hordeum vulgare*) and fava bean (*Vicia faba*) during 2018; purslane (*Portulaca oleracea*) during 2019 and cowpea (*Vignia unguiculata*) and rocket (*Eruca sativa*) during 2020. Intercrops are cultivated between the mandarin tree rows, which have a wideness of 6m. Figure 3.1 shows the experimental field design.

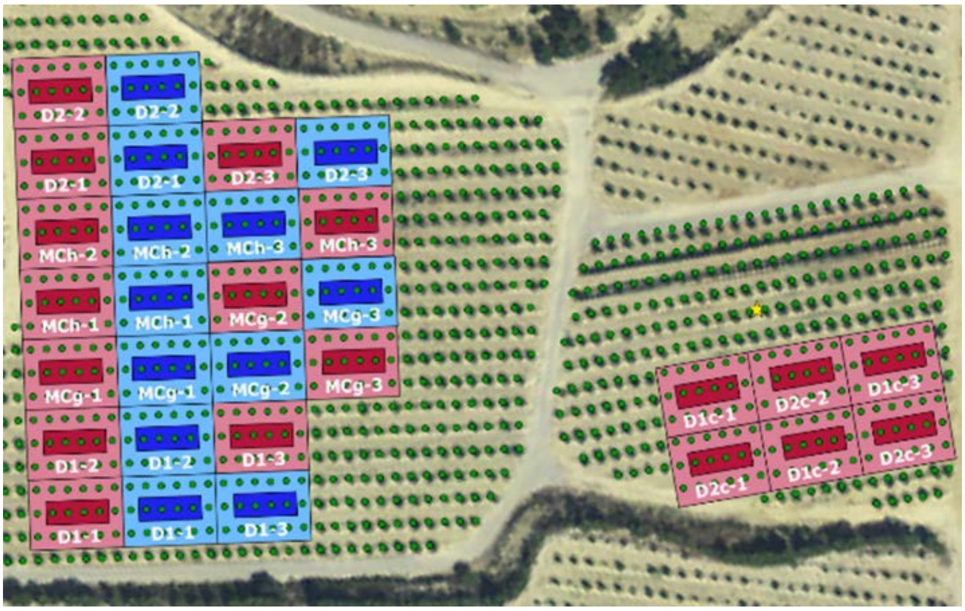


***Figure 3.1.*** *Field design of CS2*

Based on low input management practices, the monocrop (MC) farming system has 4 subsystems and both D1 and D2 have 3 subsystems which are detailed in Table 3.1. Main differences between subsystems are based on the irrigation strategy –conventional irrigation (CTL) and regulated deficit irrigation (RDI)–, as well as the method for controlling weeds, only presented in MC –conventional herbicides application (MCh) and using a geotextile cover (MCg)–. In summary, there are 3 farming systems (MC, D1 and D2) on which different practices are applied, making a total of 10 different subsystems.

***Table 3.1.*** *Description of farming systems in CS2*

<table>
<tr><th colspan="12">Monocrop (MC)</th></tr>
<tr><td colspan="3">MC with herbicides application and conventional irrigation (MCh-CTL)</td><td colspan="3">MC with herbicides application and regulated deficit irrigation (MCh-RDI)</td><td colspan="3">MC with geotextile cover and conventional irrigation (MCg-CTL)</td><td colspan="3">MC with geotextile cover and regulated deficit irrigation<br>(MCg-RDI)</td></tr>
<tr><th colspan="6">Diversification 1 (D1)</th><th colspan="6">Diversification 2 (D2)</th></tr>
<tr><td colspan="2">D1 with conventional irrigation<br>(D1-CTL)</td><td colspan="2">D1 with regulated deficit irrigation (D1-RDI)</td><td colspan="2">D1 with compost and regulated deficit irrigation (D1c-RDI)</td><td colspan="2">D2 with conventional irrigation<br>(D2-CTL)</td><td colspan="2">D2 with regulated deficit irrigation (D2-RDI)</td><td colspan="2">D2 with compost and regulated deficit irrigation (D2c-RDI)</td></tr>
</table>

## 3.2. Materials and methods

Farm level economic analysis is much based on gross margin (GM) calculations. Depending on which factors of production are accounted for per crop, three levels of GM can be differentiated: GM-A (only variable factors except labour considered as costs), GM-B (variable factors and labour considered as costs) and GM-C (all factors except land are considered as costs per crop). Detail of GM methods can be found in Deliverable 8.1.

Inputs, yields and agricultural management practices related data have been collected every year at crop and plot levels and aggregated by intercropping system to the farm level. The total observation number is of 114 mandarin trees in 2018 and 116 in 2019, which involve 3 repetitions per farming system with between 3 and 5 trees by each one. Most of the technical information has been gathered directly from case study plots, while market prices and subsidy values have been derived from farmer's suppliers and official farm statistics for the Region of Murcia (CARM, 2020), respectively. Fixed costs have been derived from previous works in the same area (Alcon et al., 2013).

Farm level economic analysis at CS2 seeks to address changes in GM of mandarin orchards due to (1) the maintenance of monoculture in the long-term and (2) the introduction of intercropping and low input practices, namely, how these different farming systems impact on farm yields and on the use of inputs and management practices. Maintaining the prevalence of monocropping systems may be translated into a depletion of biodiversity, resilience and, in summary, a decrease in environmental attributes that would imply a decrease in the ecosystem services provided, included food provision. However, intercropping systems imply the coexistence of different crops in the same field plot and at the same time, which may imply changes on the use of inputs and the expected crop yield. Since inputs and crop yields have economic values at farm level, it is relevant from farmers' point of view to assess what intercropping contributes economically, in terms of GM.

Empirical evidence suggests that intercropping positively impacts on yields (Morugán-Coronado et al., 2020). However, more efforts are needed in order to better clarify the impact magnitude, as well as the expected effects of intercropping practice on input use. At this stage, the establishment of hypothesis about the changes of inputs and crop yields may be a key tool to investigate how intercropping works. Comparisons between monocropping and intercropping practices in terms of income, variable costs, fixed costs and GM allows to determine whether intercropping has a real effect on the farm economic profitability.

Following the framework of GM assessment, four levels of hypothesis have been considered: (0) hypothesis on monoculture economic performance on the long-term, and (1) hypothesis on revenues, (2) hypothesis on costs and (3) hypothesis on GM due to the implementation of intercropping systems. Since our purpose is to analyse how the farm economic performance changes due to both the maintenance of monoculture and the development of intercropping practices, the first hypothesis, or hypothesis zero, assesses what impacts are expected in the long-term, in case if no changes are implemented with regard to the current monocropping systems, while comparison among different intercropping practices and monocropping has been carried out in the three subsequent hypothesis. The proposed hypothesis are as follows:

Hypothesis 0. Changes in monocrop economic performance in the long-term

H10: Monocrop economic performance will not be different from now in the long-term

H1A: Monocrop economic performance will be different from now in the long-term

In the case of monocropping practices continue being applied, some environmental harmful damages could be expected in the long term. Climate change effects on Mediterranean semiarid areas (IPCC, 2014), together with the decrease in the provision of ecosystem services, may provide negative effects on farm level economic performance. The main environmental issues which may have an economic impact are related to soil and biodiversity loss, since IPCC (2014) models show an increase in temperature and extreme events as droughts and floods which will specially increase erosion rates in agrosystems like irrigated monocropping citrus orchards (García et al., 2012). Hence, the loss of soil organic matter may have a negative impact in farm profitability. On the one hand, mandarin yield may be negatively affected, and thus, farm revenues, in case farmers do not act to deal with these challenges. On the other hand, in case farmers act to avoid yield decrease, it may be translated into an increase in farm costs, since the loss of soil fertility might be replaced by using soil amendment practices, or increasing fertilization. All these economic values may be estimated using avoided and replacement cost methods. Erosion rates have been measured in the case study, reaching a value of 0.4 tons/ha/year of soil loss (Verschaeren et al., 2019).

**Hypothesis 1. Changes in farm revenues due to intercropping**

H10: Mean revenues are not different between intercropping and monocropping in mandarin orchard

H1A: Mean revenues are different between intercropping and monocropping in mandarin orchard

The inclusion of different crops within the same plot is expected to have a positive impact in the total revenues obtained in the farm or, at least, reduce the dependence from the main crop. Namely, alley crops are expected to have an effect size on farm revenues. Although there is no found empirical evidences that intercropping has an impact on yields in citrus orchards, previous intercropping experiences in other different crops tend to have positive impact on farm yields (Rosa-Schleich et al., 2019). Besides, the use of non-permanent crops as alley crops allows better management of the intercropping in order to avoid negative effects of mandarin yields (Morugán-Coronado et al., 2020).

**Hypothesis 2a. Changes in variable costs at farm level due to intercropping**

H2a0: Mean variable costs are not different between intercropping and monocropping in mandarin orchard

H2aA: Mean variable costs are different between intercropping and monocropping in mandarin orchard

The implementation of intercropping practices implies different crops growing simultaneously at the same plot. The number of agricultural management practices (tillage, fertilizer and pesticide application, …) is expected to increase due to this additional crops inclusion. Since non-permanent alley crops are employed, seeds and sowing should also be included as variable costs, and so they are expected to grow, comparing to monocropping systems. Besides, there is no evidences of the real impact on the current practices to the main crop (mandarin). Thus, the net effect of intercropping on these management practices is assessed through the cost they imply (energy, pesticides and fertilizers, seeds, ...).

**Hypothesis 2b. Changes in labour costs at farm level due to intercropping**

H2b0: Mean labour costs are not different between intercropping and monocropping in mandarin orchard

H2bA: Mean labour costs are different between intercropping and monocropping in mandarin orchard

The inclusion of additional crops in woody crop orchards may increment the number of labours in detriment the use of machinery (Rosa-Schleich et al., 2019). It finally may be translated into an increment in labour cost at farm level. However, intercropping may reduce the number of labours required to the main crop, for instance, application of crop protection. It is required to check if intercropping has a significant effect on the labour costs at farm level and how much this effect is.

**Hypothesis 2c. Changes in fixed costs at farm level due to intercropping**

H2c0: Mean fixed costs are not different between intercropping and monocropping in mandarin orchard

H2cA: Mean fixed costs are different between intercropping and monocropping in mandarin orchard

Fixed cost at farm level includes mainly the depreciation of machinery and crop plantation (mandarin orchard). Since alley crops are non-permanent, start-up costs are no required, and so no significant differences in fixed costs between monocropping and intercropping are expected.

**Hypothesis 3. Changes in GM at farm level due to intercropping**

H30: Mean GM is not different between intercropping and monocropping in mandarin orchard

H3A: Mean GM is different between intercropping and monocropping in mandarin orchard

Depending on the impact of intercropping on revenues and costs, the consequent effect on GM (GM-A, GM-B and GM-C) will be obtained. Revenue at farm level is expected to increase in such way that, despite some intercropping-related costs may increase, it allows to increase profitability.

To check the hypothesis established, analysis of variance (ANOVA), or alternatively Kruskal-Wallis test, have been carried out. It allows to test the statistically significant differences in revenues, costs and GMs among the different intercropping and monocropping practices. If significant differences among practices are found, Tukey's post-hoc test, or alternatively Dunn's post-hoc test, is used to determine which practices are different, especially regarding comparison between intercrop and low input farm practices and monocropping systems. Monocrop with herbicides application (MCh) subsystem has been used as reference in conventional monocrop in order to make these comparisons. Besides, comparisons have been made among the results within the same year and same irrigation strategy. Thus, they allow to determine how the use of different inputs, such conventional irrigation (CTL) and regulated deficit irrigation (RDI), and cropping systems (monocrop/intercrop) may impact on farm profitability.

## 3.3. Results

Soil amendment composed by bare soil and organic manure (Zhong et al., 2010) is proposed as a feasible alternative to replace soil loss and avoid as well the remarked decline in soil organic matter. It implies an increase in variable costs of less than 0.4%, which is not relevant and may not affect to mandarin's yield or require high investments. So, according to current data, hypotheses 0 cannot be rejected.

Intercropping systems have supposed a change in the number of farm management practices. As it is shown in Table 3.2, the number of practices developed annually in both intercropping systems increase substantially in regards to the monocrop, mainly due to the practices required to the alley crops (tillage pre-sowing, planting/sowing, harvesting, treatments…). Besides, monocrops with low input practices imply less management practices regarding to monocrop with geotextile cover and conventional irrigation (MCg).

***Table 3.2.*** *Agricultural management practices developed in CS2*

| | Farming systems | | |
|---|---|---|---|
| | MC | D1 | D2 |
| Tillage | $2^h$ / $1^g$ | 3 | 5 |
| Pruning | 1 | 1 | 1 |
| Treatments (pesticides, herbicides…) | $3^h$ / $2^g$ | 4 | 4 |
| Shredding crop/pruning rests | 1 | 2 | 2 |
| Planting/Sowing | | 2 | 2 |
| Harvesting | 1 | 3 | 5 |
| Irrigation programming | 1 | 1 | 1 |
| Drip maintenance | 1 | 2 | 2 |
| Others | $1^g$ | 1 / $2^c$ | 1 / $2^c$ |
| Total | $10^h$ / $9^g$ | 19 / $20^c$ | 23 / $24^c$ |

MC: Mandarin monocrop; D1: Mandarin intercropped with vetch/barley and fava bean;
D2: Mandarin intercropped with vetch/barley and fava bean in 2018 and with purslane in 2019

Results of costs, revenue and GM calculation are summarized in Table 3.3. It should be noted an increase of GMs in all farming systems from 2018 to 2019. This could be explained by two factors: (1) higher sales price of the mandarins in 2019, which substantially increased farm revenue; (2) the improvement of alley crop yields due to their consolidation after the first year of the change from monocrop to intercrop. At this point, it is important to notice that not all planed alley crops could grow in 2018. Vetch and barley did not grow due to the drought, and thus only fava bean was developed successfully in D1 and D2. It could also determine intercropping profitability for the first year of experiment.

Related to revenues, results seem to show that there are no significant differences among subsystems, except MCg-CTL, D1-CTL and D2-CTL in 2018 and D2c-RDI, in both years. On the one hand, the absence of differences in revenues show that intercrops could reduce the existing differences in main crop yield (mandarin). On the other hand, D2c-RDI seems to be the only subsystem which better improve the results with respect monocrop (MCh-RDI). Applying compost, together with RDI strategy, reveals better results in terms of revenues than its equivalent in monocrop. Therefore, hypothesis H10 cannot be accepted for one of the subsystems assessed, which integrates D2 (intercrop with fava bean in 2018 and purslane in 2019) with compost application and RDI strategy. However, for the rest of subsystems analysed, H10 cannot be rejected and thus, intercropping systems do not provide significant differences in revenues.

***Table 3.3.*** *GM results from CS2. System diversification effect.*

| | | MCh-CTL | | Mch-RDI | | MCg-CTL | | MCg-RDI | | D1-CTL | | D1-RDI | | D1c-RDI | | D2-CTL | | D2-RDI | | D2c-RDI | | *test* | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2018 | 2019 | 2018 | 2019 | 2018 | 2019 | 2018 | 2019 | 2018 | 2019 | 2018 | 2019 | 2018 | 2019 | 2018 | 2019 | 2018 | 2019 | 2018 | 2019 | 2018 | 2019 |
| Revenues | Mandarin | 5,918 | 18,032 | 3,958 | 9,771 | 3,776* | 14,475 | 4,585 | 8,759 | 3,255* | 13,325 | 4,151 | 7,309 | 5,216 | 14,254 | 3,372* | 13,821 | 2,468 | 7,227 | 5,562 | 10,541 | a | a |
| | Vetch and Barley | | | | | | | | | | 568 | | 607 | | 95 | | | | | | | | |
| | Fava Bean | | | | | | | | | 1,140 | 1,234 | 1,106 | 1,429 | 587 | 362 | 439 | | 412 | | 785 | | | |
| | Purslane | | | | | | | | | | | | | | | | 7,513 | | 7,682 | | 7,926 | | |
| | CAP subsides | 325 | 325 | 325 | 325 | 325 | 325 | 325 | 325 | 325 | 325 | 325 | 325 | 325 | 325 | 325 | 325 | 325 | 325 | 325 | 325 | | |
| | Total | 6,243 | 18,357 | 4,283 | 10,096 | 4,101* | 14,800 | 4,910 | 9,084 | 4,720 | 15,453 | 5,583 | 9,670 | 6,128* | 15,036 | 4,135* | 21,660 | 3,205 | 15,235 | 6,673* | 18,792* | a | a |
| Variable costs | Seeds | | | | | | | | | 371 | 470 | 371 | 470 | 371 | 470 | 371 | 2,100 | 371 | 2,100 | 371 | 2,100 | | |
| | Fertirrigation | 1,696 | 2,086 | 1,395 | 1,608 | 1,696 | 2,086 | 1,395 | 1,616 | 1,785* | 2,919* | 1,483* | 2,597* | 1,483* | 2,579* | 1,785* | 2,301* | 1,483* | 1,903* | 1,483* | 1,880* | b | b |
| | Treatments | 529 | 539 | 529 | 539 | 477* | 487* | 477* | 487* | 493* | 487* | 493* | 487* | 493* | 487* | 493* | 487* | 493* | 487* | 493* | 487* | b | b |
| | Machinery | 154 | 110 | 154 | 110 | 98* | 54* | 98* | 54* | 82* | 175* | 82* | 175* | 258* | 175* | 82* | 149* | 82* | 149* | 258* | 149* | b | b |
| | Other materials | | | | | | | | | | | | | 1,500 | | | | | | 1,500 | | | |
| | Total | 2,380 | 2,735 | 2,078 | 2,257 | 2,271 | 2,626 | 1,969 | 2,157 | 2,731* | 4,050* | 2,429* | 3,729* | 4,106* | 3,711* | 2,731* | 5,036* | 2,429* | 4,639* | 4,106* | 4,616* | b | b |
| | Gross Margin A | 3,864 | 15,622 | 2,205 | 7,838 | 1,830* | 12,173 | 2,941 | 6,928 | 1,989* | 11,402 | 3,153 | 5,941 | 2,022 | 11,325 | 1,404* | 16,623 | 776 | 10,596 | 2,567 | 14,176* | a | a |
| | Labour Force | 852 | 366 | 852 | 366 | 614* | 128* | 614* | 128* | 1,819* | 2,120* | 1,787* | 2,120* | 1,511* | 2,120* | 1,377* | 2,151* | 1,348* | 2,151* | 1,662* | 2,151* | b | b |
| | Gross Margin B | 3,012 | 15,256 | 1,354 | 7,473 | 1,216 | 12,045 | 2,326 | 6,800 | 170* | 9,283* | 1,366 | 3,822 | 511 | 9,206 | 27* | 14,472 | -572* | 8,445 | 905 | 12,025 | a | a |
| Fixed | Machinery | 290 | 282 | 290 | 282 | 170* | 162* | 170* | 162* | 175* | 344* | 175* | 344* | 259* | 344* | 175* | 239* | 175* | 263* | 259* | 263* | b | b |
| | Installations | 680 | 680 | 680 | 680 | 945* | 945* | 945* | 945* | 818* | 818* | 818* | 818* | 818* | 818* | 818* | 818* | 818* | 818* | 818* | 818* | b | b |
| | Total | 970 | 962 | 970 | 962 | 1,11* | 1,107* | 1,114* | 1,107* | 993* | 1,162* | 993* | 1,162* | 1,077* | 1,162* | 993* | 1,057* | 993* | 1,081* | 1,077* | 1,081* | b | b |
| | Gross Margin C | 2,042 | 14,294 | 384 | 6,510 | 101* | 10,938 | 1,212 | 5,693 | -822* | 8,121* | 373 | 2,660 | -566 | 8,044 | -966* | 13,415 | -1,565* | 7,364 | -172 | 10,944 | a | a |

MCh: Mandarin monocrop with herbicide treatment; MCg: Mandarin monocrop with geotextile cover

D1: Mandarin intercropped with vetch/barley and fava bean; D1c: D1 with compost application

D2: Mandarin intercropped with vetch/barley and fava bean in 2018 and with purslane in 2019; D2c: D2 with compost application

CTL and RDI refers to the irrigation strategy: conventional irrigation (CTL) and regulated deficit irrigation (RDI)

* Significant differences (p-value < 0.10) between the mentioned system (DX) and MCh by year and irrigation strategy following ANOVA or Kruskal-Wallis test ([a]*ANOVA;* [b]*Kruskal-Wallis)*

Results from costs reveals that substantial differences among the intercropping subsystems and monocrop are found, in terms of both variable and fixed costs. It shows that, despite treatment costs are lower and water savings are reached within RDI strategy at main crop (mandarin), intercropping costs related to alley crops (seeds and irrigation water requirements) increase deeply variable costs. Besides, other significant differences are found between D2 regarding to MCh in 2019, due to the high costs of purslane plants. Therefore, hypothesis H2a0 cannot be accepted for some of the assessed intercropping subsystems, which reveals that intercropping increases variable costs when purslane is used as alley crop and even when RDI strategies are applied.

Related to labour costs, significant differences are found between intercropping and monocropping subsystems in both years. Labour requirements, mainly related to harvesting by hand, are much higher in intercropping subsystems than in monocrop, specifically within fava bean and purslane. Thus, it seems that hypothesis H2b0 cannot be accepted, which implies that intercropping systems involve higher labour costs.

Finally, fixed cost are significantly higher in MCg and intercropping subsystems with respect to MCh. Thus, as expected, MCg subsystems involve higher fixed costs than MCh due to the depreciation of geotextile cover. However, differences between them have been found in terms of variable cost savings, since some herbicides treatments are avoided. Differences in fixed costs at intercropping subsystems arise due to the machinery practices related to sowing and harvest. Furthermore, compost application requires additional uses of machinery which is also translated into higher fixed cost in D1c-RDI and D2c-RDI in 2018. Therefore, depending on the management practices, fixed costs, mainly related to the depreciation of machinery or other fixed assets such as geotextile, could be higher in the subsystems assessed, and thus H2c0 cannot be accepted.

Despite some significant differences have been found in revenues and costs between monocrop and intercrop systems, not all of them have been finally translated into GMs (Figure 3.2). Within intercrop subsystems, significant differences with respect to monocrop have been found in MCg-CTL, D2-CTL and D2-RDI in 2018 and in D1-CTL in both years in terms of GM-C. Most differences in 2018 are due to the differences in mandarin's revenues together with the increase in variables and fixed cost associated with alley crops. On the other hand, differences in D1-CTL in 2019 have their origin in significantly higher variable and fixed costs, compared to monocrop. Therefore, hypothesis H30 cannot be totally accepted and the significant impact of intercropping in margins would depend on the management practices and alley crops.

Low input practices result previously summarised shows that geotextile cover implies higher fixed costs, but it is not translated into significant differences in GMs. So, using geotextile to cover the tree rows would not affect farm economic profitability. Also, the implications of RDI strategy in farm profitability can be analysed. Knowing the effect of RDI strategy on GMs is a key issue. Therefore, results from Tukey's and Dunn's post-hoc tests have been extended to compare differences between CTL and RDI strategies within each subsystem, and summarised in Table 3.4.

Results from Table 3.4 show that some differences have been found in terms of revenues regarding to the irrigation strategy. These differences take place in MCh in both years, and in MCg, D1 and D2, but only in 2019. However, these differences are not always translated into differences in GMs. In fact, only MCh and D2 show significant differences in 2019 in terms of GM-C. Thus, it seems that irrigation strategy may affect main crop yield, but these differences may not be maintained along the farm profitability. It also highlights that main crop yield (mandarin) continuous being the main driver of farm profitability.

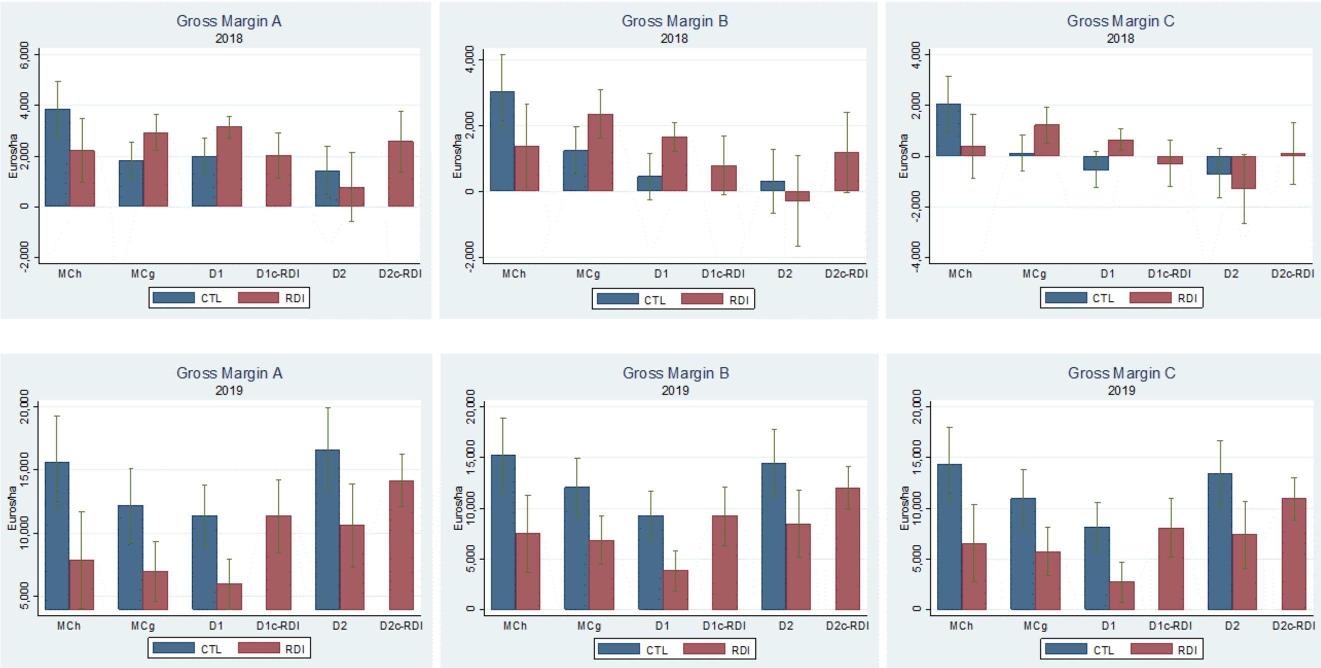


***Figure 3.2.*** *Gross Margins A, B and C per farming subsystem in 2018 and 2019. MCh: Mandarin monocrop with herbicide treatment; MCg: Mandarin monocrop with geotextile cover; D1: Mandarin intercropped with vetch/barley and fava bean; D1c: D1 with compost application; D2: Mandarin intercropped with vetch/barley and fava bean in 2018 and with purslane in 2019; D2c: D2 with compost application; CTL and RDI refers to the irrigation strategy: conventional irrigation (CTL) and regulated deficit irrigation (RDI)*

**Table 3.4.** *Significance of the differences between CTL and RDI irrigation strategies at different subsystems. Results from Tukey's and Dunn's post-hoc assessment (P-values).*

| | MCh | | MCg | | D1 | | D2 | |
|---|---|---|---|---|---|---|---|---|
| | 2018 | 2019 | 2018 | 2019 | 2018 | 2019 | 2018 | 2019 |
| Mandarin's revenues | 0.05 | 0.00 | 0.94 | 0.08 | 0.90 | 0.07 | 0.90 | 0.03 |
| Total revenues | 0.05 | 0.00 | 0.94 | 0.08 | 0.93 | 0.10 | 0.89 | 0.03 |
| Variable costs | 0.04 | 0.05 | 0.04 | 0.05 | 0.05 | 0.22 | 0.05 | 0.21 |
| Gross Margin A | 0.18 | 0.00 | 0.72 | 0.14 | 0.69 | 0.14 | 0.99 | 0.06 |
| Labour costs | 0.50 | 0.50 | 0.50 | 0.50 | 0.20 | 0.50 | 0.20 | 0.50 |
| Gross Margin B | 0.18 | 0.00 | 0.72 | 0.14 | 0.65 | 0.14 | 0.99 | 0.06 |
| Fixed costs | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 |
| Gross Margin C | 0.18 | 0.00 | 0.72 | 0.14 | 0.65 | 0.14 | 0.99 | 0.06 |

MCh: Mandarin monocrop with herbicide treatment; MCg: Mandarin monocrop with geotextile cover
D1: Mandarin intercropped with vetch/barley and fava bean
D2: Mandarin intercropped with vetch/barley and fava bean in 2018 and with purslane in 2019

## 3.4. Discussion

The present report aims to assess the farm economic performance of intercropping systems and low input practices under citrus crops in Spain, mainly focused on how this alternative practices may impact on farm profitability. Intensive monocropping causes a decrease in the provision of a great number of ecosystem services. Maintaining this kind of cropping systems over the long-term might have negative environmental effects that will have consequences at farm economic level. Although no experimental data has been found yet except erosion rates which are not especially high, the first estimations indicate that some negative impacts or an exacerbation of some problems related to climate change (including erosion) and biodiversity loss might be expected whether no farm systems are readapted. To overcome this challenge, intercropping and low input practices in rainfed almond orchards is seen as a feasible alternative. In fact, results show that no such high differences exist between economic performance in the current environmental conditions across the assessed systems and subsystems. Indeed, there are no differences between monocrop and intercropping in GM-C, except from D1-CTL. Therefore, it seems that there are no economic incentives to ensure that farmers would enrol these systems, as there are also no economic incentives to refuse diversification practices.

Hence, the key point now seeks to address what farm level economic results might be expected from intercropping in order to ensure farmers to enrol it. Since economic profitability needs to be higher than the expected from monocrop, three ways could achieve this objective:

i. Economic profitability of alley crops. Market revenues obtained from alley crops need to be such that compensate costs and even generate additional benefits. Namely, alley crops' GMs need to be positive. This is the case of D2.
ii. Better economic performance of the main crop in the long-term, that is, intercropping practices may enhance productivity of the main crop or even may reduce the inputs. Applied to our results, as an example, D1 should be expected to increase mandarin productivity, or reduce input requirements, in a range from 20% to 30% of GM-C.
iii. Non-market benefits associated with intercropping systems. It is proved that intercrop provides environmental and socio-cultural benefits which are socially valued. Thus, agri-environment policy may be reoriented in order to incorporate subsides related to intercropping practices. Payment for ecosystem services (PES) schemes could also deal with it. According to Alcon et al. (2020), these non-market benefits could reach around 1,300€/ha/year. In addition, since these products have added value, a market niche could be created in which customers payed for the environmental benefits associated to the product.

Intercropping systems are expected to mitigate market risks and improve farm economic sustainability in the long term. If it is so, price volatility of main crop would not affect farm economic performance greatly. However, to ensure that, economic profitability of alley crops needs to be such that increases farm GM. It could be proved within D2 intercropping systems in 2019, where purslane margins may improve farm economic performance, and thus, increase the economic resilience of the overall farming system. To illustrate that, for instance, 20% decrement in mandarin prices would be translated into a 19% decrement in GM for D2c-RDI, while the decrement raises to 25% in the case of MCh-CTL.

Another key point to discuss concerns the value chain development of intercropping products, which could even affect the feasibility and reproducibility of the present results. For instance, fava beans are greatly demanded at local markets as fresh products and so they have consolidated value chain in the Region of Murcia. However, some other alley crops, such as purslane, do not have associated value chains with such high degree of development locally. To cover this gap, it has been assumed that purslane could be export-oriented, for instance, to Netherlands, where it is a demanded crop and competitive enough to be sold there.

## 3.5. Conclusions

Intercropping systems represent feasible alternative to overcome main environmental issues that monoculture provides in Mediterranean South region, especially in irrigated perennial crops, such as citrus orchards. Farm level economic analysis lays bare that there are intercropping and low-input farming systems that would not negatively differ their incomes and GMs perceived by farmers in comparison with the ones from the origin monocropping. From this two-year experiment, geotextile cover and Diversification 2 seems to be the most profitable alternative systems to monocropping irrigated mandarin orchards although weak data related to purslane sale price have to be taken into account. Besides that, regulated deficit irrigated (RDI) subsystems results show that a decrease in water input does not compensate the crop yield decrease experienced. If we take into account that in the long term a better economic performance is expected due to an input decrease and an improvement in environmental conditions, the economic viability of transitioning to this alternative farming system seems more plausible.

However, the main driver of the economic benefit is still the main crop, mandarins, so price risk mitigation is not very high in most cases but could be relevant in others with profitable alley crops. Even, to ensure economic profitability, intercropping and low input practices should be more concerned with the economic performance of mandarins than with the alley crops.

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# 4. CS3. Irrigated and rainfed field crops in Spain

## 4.1. Case study description

The case study 3 is located in the Mediterranean pedoclimatic region within the Region of Aragón (NE Spain) (Figure 4.1). The aim of CS3 is to evaluate crop rotations and multiple cropping as alternatives to the common wheat and maize monocropping in rainfed and irrigated Spanish conditions, respectively.

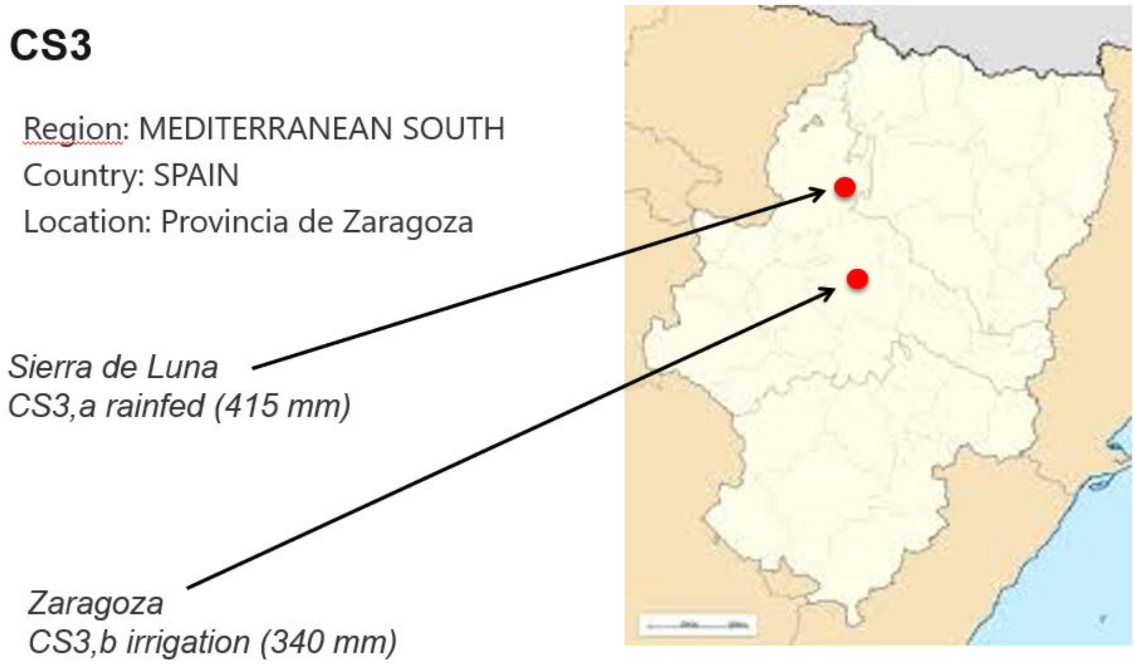


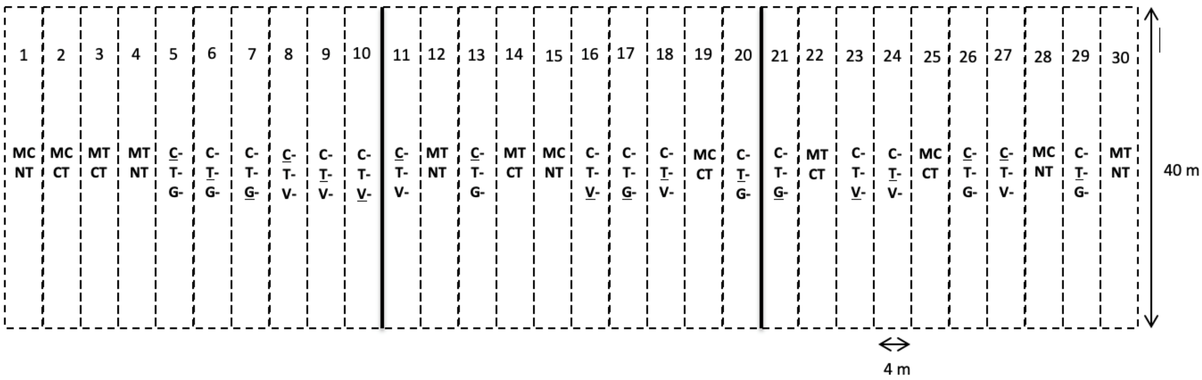

***Figure 4.1.*** *Location of case study 3 in northeast Spain*

### 4.1.1. CS3a: Rainfed field crops

Treatments which are being compared:

- Wheat monocropping under conventional tillage
- Wheat monocropping under no-tillage
- Wheat – barley – pea rotation under no-tillage
- Wheat – barley – vetch rotation under no-tillage

Plot size: 160 $m^2$ (4 m x 40 m) (Figure 4.2)




MC-NT: Non tillage Barley Monocropping
MC-CT: Conventional Barley Monocropping
MT-NT: Non tillage Wheat Monocropping
MT-CT: Conventional Wheat Monocropping
C-T-G: Barley in rotation Barley-Wheat-Peas non tillage
C-T-G: Wheat in rotation Barley-Wheat-Peas non tillage
C-T-G: Peas in rotation Barley-Wheat-Peas non tillage
C-T-V: Barley in rotation Barley-Wheat-Vetch non tillage
C-T-V: Wheat in rotation Barley-Wheat-Vetch non tillage
C-T-V: Vetch in rotation Barley-Wheat-Vetch non tillage

***Figure 4.2:*** *Field trials design in the rainfed experiment*

**Main characteristics of the rainfed farm:**

- Farm extension: 100 ha
- Diverfarming experimentation area: 1 ha
- Current crop: rainfed winter cereal
- Crop final use: Food and feed
- Current cropping system: conventional monocropping
- Harvest time: July
- Current management practices: - Intense tillage - Mineral fertilizers - Pesticides - Herbicides
- Current value chain: - Producer - Distribution - Agro-industry - Wholesaler - Supermarket

### 4.1.2. CS3b: Irrigated field crops

Treatments which are being compared:

- Maize monocropping no fertilized
- Maize monocropping medium fertilized
- Maize monocropping high fertilized
- Pea – maize intercropping no fertilized
- Pea – maize intercropping medium fertilized
- Pea – maize intercropping high fertilized
- Barley – maize multiple cropping no fertilized
- Barley – maize multiple cropping medium fertilized
- Barley – maize multiple cropping high fertilized

Plot size: 150 m$^2$ (6 m x 25 m) (Figure 4.3)


***Figure 4.3***. *Irrigated field crops layout*

**Main characteristics of the irrigated farm:**

- Farm extension: 40 ha
- Diverfarming experimentation area: 1 ha
- Current crop: maize
- Crop final use: Food and feed
- Current cropping system: conventional monocropping
- Irrigation system: flooding
- Harvest time: October
- Current management practices: - Intense tillage - Mineral fertilizers - Pesticides - Herbicides
- Current value chain: - Producer - Distribution - Agro-industry - Wholesaler - Supermarket

## 4.2. Materials and Methods

The economic analysis of the different diversification and management strategies evaluated in the case study has been carried out by extrapolating the management of each trial tested to the real crop economic balance sheets, obtained from the surveys carried out on producers. Therefore, the operating costs as well as the profits obtained correspond to the average of real cost and revenues from farms from the areas in which the tests have been carried out.

Labour costs have been considered as real market prices of work performed by service companies. In aims to obtain an objective price for each activity carried out, we have avoided the impact of machine depreciation on the costs of operations. Sometimes the equipment acquired by farmers is not well sized for the needs of the farm, or farms consider an erroneous hourly cost. Applying market prices offered by agricultural service companies guarantees a real cost. Under an economic point of view, a professional farm management should be able to operate below market prices.

Revenues have been calculated multiplying harvested yields with a reference of market price without adequately taking into account about real prices paid to farmers. However, these evaluations do not include the price opportunities that farmers have effectively obtained for their harvests over the years and among crops. Although the yield is a crucial point of the evaluations, the explicit and opportunity costs related to a rotation crop planning of arable land is also very important for a farm, especially when it is done under a multicrop contract.

Revenues obtained per hectare do not consider incomes from the CAP subsidies. In 2015, Spain changed the way of subsidies distribution, including new criteria according to the region and the historical production of each applicant, so we could find large differences in the subsidies received by farmers for a crop hectare within the same area.

In any case, an average CAP subsidy benefit could be included in the economic analysis. According to data from the Government of Aragon, in 2019 40,332 applications for farm support were send, linked to 2,032,604 has, resulting in a total farm support payment of 462,258,780 euros. According to this data, the average perception per crop hectare in Aragon was 228,40 euros/ha. The base payment value of extensive crops production aid in Aragon (basic rights exchange), without regard to additional aid for environmental actions, amounts to 143 euros/ha (according to MAPA´s 2019 annual report).

Extensive crops net profits could consider the summatory of the average value of payment rights for these crops in the community of Aragon, although adding an amount equal to the results of the profit comparison does not provide relevant information, so it has not been taken into account in the preparation of the report.

Farm level economic analysis is mainly based on gross margin (GM) calculations. Depending on what kind of revenues and which factors of production costs are accounted per each crop and plot. In this analysis three levels of GM have been differentiated as suggested (Deliverable 8.1).

- GM-A: Gross saleable production (GSP) and CAP subsides are considered as revenues and explicit costs for variable factors are considered, where: GSP + CAP - (Inputs Costs + Cultivation Operation). The first index highlights the GM, that farmers often look. This is the economic result determined solely to technical cultivation and pedoclimatic conditions referring to single agricultural year, without consider the own labor and the cost of own capital conferred directly by the landowner farmer.
- GM-B: Estimate the balance between GSP and CAP items and all variable factors, including own labour, and the fixed costs quota related to each plot cultivation, where; GSP + CAP - (Input Costs + Cultivation Operation+ Labour)
    - Compared to the previous one, this index considers variable costs related to the labour component.
- GM-C: Estimate the balance between GSP and CAP items and all variable factors, including own labour, and the fixed costs quota related to each plot cultivation, where; GSP + CAP - (Input Costs + Cultivation Operation+ Labour +Fixed)
    - This index includes also the estimated costs due to the depreciation of machines and tools used in observed crops management. This type of indicator is a reference to the profitability of one hectare of arable land, without taking into account the overheads of running the farm and the interest related to the crop’s advance capital across years (financial aspects).

In CS3, crops are managed directly by the farmers, but we have considered labour cost similar than an external contract management, looking for a market price. Avoiding the impact of errors in the choice of machinery or lack of working hours that affect the depreciation of the machinery and cost of labours.

***Hypothesis 1. Changes in farm revenues due to crop rotation***

Crop rotation is one of the main practices suggested to obtain ecological benefits by arable land systems. This Case Study tends to show added long-term benefits offers by crop rotation in land systems as the effect on costs saving, increase of gains or improve land profitability.

Crop rotation systems offers a balance in the environmental and agronomic environment of the land, which has an impact on better soil structure and use of natural resources, lower presence of weeds, reduction of fertilization needs, improvement of the quality of the grain... Aspects that greatly influence the reduction of production costs and therefore the profitability of the farms.

***Hypothesis b. Changes in labour costs at farm level due to no-tillage system***

No-tillage system is based on the use of cultivation techniques that do not alter the soil structure. In general, the application of deep labours is avoided. This practice reduces the necessary working power and therefore lowers the cost of labours. In the other way, it has the disadvantage of requiring the use of higher cost adapted sowing machines, and a management of crop fertilization that can be slightly more expensive. This Case study aims to demonstrate the reduce in labour costs in no tillage management that theoretical farm cost studies and that numerous publications reflect

***Hypothesis c. Economic optimization of fertilization in corn production***

In the case of study 3.b, the economic balance of irrigated maize production (monoculture versus rotating cultivation) will be evaluated according to three crop fertilization programmes: high nitrogen rate, medium nitrogen rate and 0 nitrogen rate. The results of the test would offer information on the reduction of nitrogen fertilization that can allow the application of a crop rotation system while maintaining or improving the economic profitability of the holding.

## 4.3. Results

### 4.3.1. CS3a: Rainfed field crops

CS3.a was sown in October of 2018. Thus, we have information of 2 years of trials, so rotation systems are not completed yet. The weather conditions suffered during the two years of trials have been totally opposite and away from the historical average conditions of the area.

**Harvest 2019**; unusually dry weather year, with rainfall less than 200 mm of water in spring. These conditions clearly benefit no tillage plots, as they offer better soil moisture conservation in critical periods. The absence of rainfall prevented the development of pea and vetch crops. Barley requires a lower water regimen in the final maturation phase than wheat.

**Harvest 2020**. This year was marked by rainfall well above the historical average, which came to prevent the control of weeds in crops by impossibility of access to plots. However, the precipitation received was responsible for a pea and vetch production above than usual in this area. In that climatic conditions the profitability of the cultivation of durum wheat was higher than barley production despite the market condition suffered with low cereal prices.

Weeds' competition generated a loss of production, greater in plots cultivated without tillage, than in conventionally managed plots. Preparation tillage labours allowed better control of adventitious plants.

**Table 4.1.** *GM results from CS3.a*

| Year | Rotation | Crop | Yield (kg/ha) | Net Revenues, after immediate costs | TOTAL VARIABLE COSTS | Gros margin A | Gros margin B | Gros margin C | NET PROFIT €/ha |
|---|---|---|---|---|---|---|---|---|---|
| 2019 | Barley-Wheat-Peas | Barley | 2.937,40 | 467,05 € | 366,24 € | 100,81 € | -49,19 € | -49,19 € | **-49,19 €** |
| | Barley-Wheat-Peas | Pea | - | - € | 243,50 € | -243,50 € | -393,50 € | -393,50 € | **-393,50 €** |
| | Barley-Wheat-Peas | Wheat | 1.592,48 | 404,49 € | 379,74 € | 24,75 € | -125,25 € | -125,25 € | **-125,25 €** |
| | Barley-Wheat-Vetch | Barley | 2.606,98 | 414,51 € | 366,24 € | 48,27 € | -101,73 € | -101,73 € | **-101,73 €** |
| | Barley-Wheat-Vetch | Wheat | 1.892,65 | 480,73 € | 379,74 € | 101,00 € | -49,00 € | -49,00 € | **-49,00 €** |
| | Barley-Wheat-Vetch | Vetch | 778,73 | 174,44 € | 243,50 € | -69,06 € | -219,06 € | -219,06 € | **-219,06 €** |
| | Barley monocrop Tillage | Barley | 2.032,52 | 323,17 € | 443,19 € | -120,02 € | -195,02 € | -195,02 € | **-195,02 €** |
| | Barley monocrop NonTillage | Barley | 2.685,64 | 427,02 € | 366,24 € | 60,78 € | -89,22 € | -89,22 € | **-89,22 €** |
| | Wheat monocrop Tillage | Wheat | 731,79 | 185,87 € | 443,19 € | -257,31 € | -332,31 € | -332,31 € | **-332,31 €** |
| | Wheat monocrop NonTillage | Wheat | 1.945,88 | 494,25 € | 379,74 € | 114,52 € | -35,48 € | -35,48 € | **-35,48 €** |
| 2020 | Barley-Wheat-Peas | Barley | 652,39 | 103,73 € | 339,24 € | -235,51 € | -385,51 € | -385,51 € | **-385,51 €** |
| | Barley-Wheat-Peas | Pea | 1.762,58 | 394,82 € | 243,50 € | 151,32 € | 1,32 € | 1,32 € | **1,32 €** |
| | Barley-Wheat-Peas | Wheat | 1.021,08 | 259,35 € | 379,74 € | -120,38 € | -270,38 € | -270,38 € | **-270,38 €** |
| | Barley-Wheat-Vetch | Barley | 507,74 | 80,73 € | 339,24 € | -258,51 € | -408,51 € | -408,51 € | **-408,51 €** |
| | Barley-Wheat-Vetch | Wheat | 1.144,48 | 290,70 € | 339,24 € | -48,54 € | -198,54 € | -198,54 € | **-198,54 €** |
| | Barley-Wheat-Vetch | Vetch | 1.498,71 | 335,71 € | 243,50 € | 92,21 € | -57,79 € | -57,79 € | **-57,79 €** |
| | Barley monocrop Tillage | Barley | 2.206,99 | 350,91 € | 443,19 € | -92,28 € | -167,28 € | -167,28 € | **-167,28 €** |
| | Barley monocrop NonTillage | Barley | 1.525,80 | 242,60 € | 339,24 € | -96,64 € | -246,64 € | -246,64 € | **-246,64 €** |
| | Wheat monocrop Tillage | Wheat | 1.086,17 | 275,89 € | 443,19 € | -167,30 € | -242,30 € | -242,30 € | **-242,30 €** |
| | Wheat monocrop NonTillage | Wheat | 814,19 | 206,80 € | 339,24 € | -132,43 € | -282,43 € | -282,43 € | **-282,43 €** |

We transfer the profitability of each crop from the rotation to obtain the total return of the rotations accumulated over the years.

**Table 4.2.** *GM rotation results from CS3.a*

| Rotation net profit | | | | |
|---|---|---|---|---|
| **rotation** | **2019** | **2020** | **2021** | **Total Rotation** |
| ***Wheat- Vetch-Barley*** | -49,00 € | -57,79 € | | -106,79 € |
| ***Wheat- Pea-Barley*** | -125,25 € | 1,32 € | | -123,93 € |
| ***Barley-Wheat-Vetch*** | -101,73 € | -198,54 € | | -300,27 € |
| ***Wheat monocrop NonTillage*** | -35,48 € | -282,43 € | | -317,92 € |
| ***Barley-Wheat-Peas*** | -49,19 € | -270,38 € | | -319,57 € |
| ***Barley monocrop NonTillage*** | -89,22 € | -246,64 € | | -335,86 € |
| ***Barley monocrop Tillage*** | -195,02 € | -167,28 € | | -362,29 € |
| ***Wheat monocrop Tillage*** | -332,31 € | -242,30 € | | -574,61 € |
| ***Vetch- Barley-Wheat*** | -219,06 € | -408,51 € | | -627,57 € |
| ***Pea- Barley-Wheat*** | -393,50 € | -385,51 € | | -779,01 € |

### 4.3.2. CS3b: Irrigated field crops

CS3.b was sown in January 2018, so we have information of 2 years of trials in winter cereals and one harvest for summer cereals, so rotation systems are not completed yet. Amount data results was not enough to analyse results of all the crop rotation sequence at this time.

**Table 4.3.** GM results from CS3.b

| *Rotation* | *Crop* | *Fertilizacion N* | *Yield (kg/ha)* | Net Revenues, after immediate costs | TOTAL VARIABLE COSTS (€/ha) | Gros margin A | Gros margin B | Gros margin C | NET PROFIT €/ha | ROTATION NET PROFIT €/ha |
|---|---|---|---|---|---|---|---|---|---|---|
| Monocrop | **Maize** | 0 | 7800,72 | 1.213,64 € | 1.077,70 € | 135,94 € | - 314,06 € | - 314,06 € | - 314,06 € | - 314,06 € |
| Monocrop | **Maize** | Medium | 14364,6 | 2.215,88 € | 1.299,61 € | 916,27 € | 466,27 € | 466,27 € | 466,27 € | 466,27 € |
| Monocrop | **Maize** | Hight | 15308,51 | 2.361,49 € | 1.436,99 € | 924,50 € | 474,50 € | 474,50 € | 474,50 € | 474,50 € |
| Pea-Maize | **Pea** | 0 | 2861,07 | 640,88 € | 407,75 € | 233,13 € | 158,13 € | 158,13 € | 158,13 € | |
| Pea-Maize | **Maize** | 0 | 4249,75 | 655,57 € | 1.077,70 € | - 422,13 € | - 872,13 € | - 872,13 € | - 872,13 € | - 714,00 € |
| Pea-Maize | **Pea** | Hight | 2347,4 | 407,75 € | 118,07 € | 43,07 € | 43,07 € | 43,07 € | 43,07 € | |
| Pea-Maize | **Maize** | Hight | 7517,31 | 1.159,62 € | 1.394,35 € | - 234,73 € | - 684,73 € | - 684,73 € | - 684,73 € | - 641,66 € |
| Pea-Maize | **Pea** | Medium | 2838,2 | 635,76 € | 407,75 € | 228,01 € | 153,01 € | 153,01 € | 153,01 € | |
| Pea-Maize | **Maize** | Medium | 5635,75 | 869,37 € | 1.250,41 € | - 381,04 € | - 831,04 € | - 831,04 € | - 831,04 € | - 678,03 € |
| Barley-Maize | **Barley** | 0 | 3591,94 | 589,08 € | 483,19 € | 105,89 € | 30,89 € | 30,89 € | 30,89 € | |
| Barley-Maize | **Maize** | 0 | 3438,34 | 530,40 € | 1.077,70 € | - 547,30 € | - 997,30 € | - 997,30 € | - 997,30 € | - 966,41 € |
| Barley-Maize | **Barley** | Hight | 4244,83 | 696,15 € | 691,69 € | 4,46 € | - 70,54 € | - 70,54 € | - 70,54 € | |
| Barley-Maize | **Maize** | Hight | 5088,15 | 784,90 € | 1.436,99 € | - 652,09 € | - 1.102,09 € | - 1.102,09 € | - 1.102,09 € | - 1.172,63 € |
| Barley-Maize | **Barley** | Medium | 5262,55 | 863,06 € | 627,19 € | 235,87 € | 160,87 € | 160,87 € | 160,87 € | |
| Barley-Maize | **Maize** | Medium | 4398,9 | 678,57 € | 1.299,61 € | - 621,04 € | - 1.071,04 € | - 1.071,04 € | - 1.071,04 € | - 910,16 € |

## 4.4. Conclusions

In the rainfed farm, the exceptional legume productions harvested in 2020 benefited crop rotations that had this crop. The most profitable rotations were those that have harvested a cereal and a legume. In general, the two harvests carried out showed that rotations of cereals and legumes have provided a higher return than non-rotated crops. The weather conditions suffered during the two years of trials have been totally opposite and away from the historical average conditions of the area. In 2019, the unusually dry weather year, with rainfall less than 200 mm of water in spring, clearly benefited non tillage plots, as they offered better soil humidity conservation in the critical periods. On the other side, in 2020, with rainfall well above the historical average, weeds' competition generated a loss of production, greater in plots cultivated without tillage, than in conventionally managed plots. Preparation tillage labours allowed better control of adventitious plants. In the irrigated farm, we only have data from a single agricultural campaign (2019). With one year of trials is too early to have results of crop rotations, because soil could be considered in transformation. In general, we appreciate that all crop management variables with high nitrogen fertilization have a higher return than those grown at medium fertilization rate, and that plots without nitrogen fertilization.

Hence, crop rotation (with legume) in rainfed case provided good and competitive gross margin while the situation looks the opposite in irrigated case where higher N fertilisation results in higher yields and gross margins in monoculture. Thus, the results up to now suggest that better avenues for crop rotation (with legumes) in rainfed production and not at all promising in the irrigated case. But more years of experimentation with different weather conditions may provide more results affecting this conclusion. It is also possible that early years after establishing crop rotation does not yet tell the full story of introducing crop rotation as it may change soil characteristics and may be also weeding, and crop protection needs at later years. This is why the continuation of the experiments and gross margin calculations are needed.

5. CS4. Rainfed olive grove in Spain

# 5. CS4. Rainfed olive grove in Spain

## 5.1. Case study description

The case study 4 (CS4) is located in the Mediterranean South pedoclimatic region in Jaen providence within the Region of Andalucia (SE Spain). Climate is defined by an important seasonal thermal contrast, the annual average precipitation was 493.2 mm, and monthly rainfall ranges from 2.1 mm (July) to 75 mm (December) (AEMET, 2020). The main crop in the area is olive (*Olea europaea* var. picual) with unirrigated conventional permanent monocropping system (12 m x 12 m pattern).

This case study was established in view of the severe environmental problems in which the cultivation of the olive grove is involved with great losses of soil due to erosion processes, low levels of organic matter, scarce biodiversity (Lozano-García et al., 2014). On the other hand, at present there are profitability problems in olive groves with a reduction of olive oil prices. Therefore, in the long term it is expected that with the diversification of crops in the olive grove alleys, the environmental quality of the olive grove can be improved offering interesting ecosystem services (Morugan-Coronado et al., 2019) and complementary revenue to the main crop through diversifications. In the case study 4 rainfed olive grove three types of diversifications were sown: saffron, lavender and oats. However, due to adverse climatic conditions and pests only yield data on diversification under oats could be obtained.

Diversification system 1 (D1) involves olive intercropped with oats (*Avena sativa*) for food during 2018, 2019 and 2020. Diversification 2 (D2) includes saffron (*Crocus sativus* permanent) for food during 2018, 2019 and 2020. Diversification 3 (D3) consists of olive intercropped with lavander (*Lavandula intermedia*, permanent) for essential oils during 2018, 2019 and 2020. These crops diversifications are cultivated between the olive tree rows and compared to the conventional olive monocropping system, which serves as a control plot (Figure 5.1).

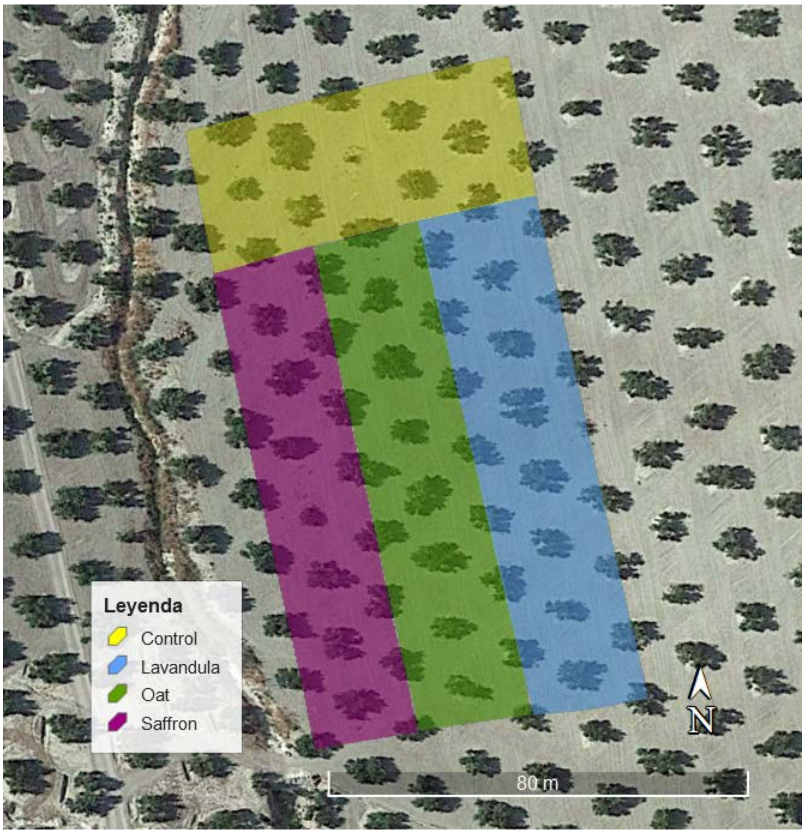



***Figure 5.1.*** *Example of one block of the experimental design in CS4*

## 5.2. Materials and methods

Data included in this report for economic analyses have been collected every year from the field experience in Diverfarming CS4 since 2018 with the different crops diversifications. In addition, for the cultivation of saffron and lavender, various farmers in Spain with a long tradition in the cultivation of these crops have been visited in order to have a better understanding of the costs, benefits and necessary management of the crops.

The experimental plots involve 52 olive trees that include a total of 7.500 $m^2$. In each type of diversification, 3 repetitions were realized including each subplot 3 olive trees. Crop diversifications are grown between olive tree rows this area involves around 30-40% although the calculations are based on olive grove street hectares. Data was collected for material and labour costs in the implementation of the diversified system (intercropping) in comparison to the costs for the olive monocrop. Labour costs have been considered as real market prices of work performed by service companies. In aims to obtain an objective price cost for each activity carried out, we have avoided the impact of machine depreciation on the costs of operations. Sometimes the equipment acquired by farmers is not well sized for the needs of the farm, or farms consider an erroneous hourly cost. Applying market prices offered by agricultural services companies we guarantee a real cost. Under an economic point of view, a professional farm management should be able to operate below market prices. The basis of the yield estimate is the samples taken in the oat crop at the case study experiment plots according to the Diverfarming Handbook of plant and soil analyses for agricultural systems (https://zenodo.org/record/2553445#.X5GyhNAzZPY). To estimate the data for saffron and lavender crops, in parallel to consulting other farmers, specific manuals on the cultivation of these crops have been used. Collected data from work packages 4 and 5 (impacts of diversification on biodiversity and environment) are an important basis for non-market values of the diversification.

On the basis of farm level economic analysis, two hypotheses were examined.

***Hypothesis 1. Changes in gross margin (GM) due to crop diversification.***

Diversified crop inclusion in olive grove is expected to influence the gross margin calculation. This impact could be variable according to the type of diversification proposed since managements, costs and benefits are different between the different diversifications.

Diversification plots increase the environmental and agronomic balance of the land, which has an impact on better soil structure and use of natural resources, lower presence of weeds, reduction of fertilization needs, among others environmental benefits. These aspects influence the production costs and therefore the profitability of the farms.

***Hypothesis 2. Changes in labour costs at farm level due to intercropping***

The implementation of diversified crops in olive groves may imply an increase in the labour cost and the hiring of personnel, especially in crops that require manual labours. Therefore, labour costs could be different between intercropping and monocropping in olive grove.

## 5.3. Results and Discussion

In the evolution of the management of Andalusian agroecosystems where olive groves are inserted, both the expansion and the intensification in olive groves have resulted in an increase in the production and, at the same time, in increasing environmental degradation. This is because of the loss of biodiversity, due to the elimination of vegetation cover with the consequent increase in erosion rates (Sastre et al., 2018). Contamination of water and soil has followed as a result of the excessive use of fertilizers and phytosanitary products.

In gross margin calculations the annual production and management changes in diversification were taken into consideration. Reduced numbers of labour hours were needed in the diversification management under low intensity of resource use and long- term sustainability. This is in fact one of the main objectives of diversifications management. In the olive monocrop plots several cultivator passes were made to maintain the management under which the farm was at the beginning of the investigation. In the plots with diversification a seedbed was prepared under minimum tillage for the sowing of the different crops. As it is obvious, the diversifications need a greater number of management practices for its implementation, although once installed, its management needs less labour than the conventional olive grove (table 5.1).

***Table 5.1.*** *Agricultural management practices (number) needed in each diversification system developed in CS4*

| | Farming systems | | | |
|---|---|---|---|---|
| | MC | D1 | D2 | D3 |
| Tillage | 2 | | 1 | |
| Pruning | 1 | 1 | 1 | 1 |
| Pesticide treatment | 1 | | | |
| Harvesting | 1 | 1 | 1 | 1 |
| Start-up intercropping practices | | 4 | 4 | 4 |
| Total | 5 | 6 | 7 | 6 |

The diversification management carried out without application of herbicides and no tillage has meant a reduction in the machinery operations. This implies both a reduced number of labour hours carried out and a lower expense from the purchase of phytosanitary products. In the following years we expect to verify if this management under low inputs allows to obtain acceptable production yields for the sowing of the diversification crops.

Another aspect to be taken into account in the next few years is the variability of the crop yields since their dependence on the weather conditions of the year is very high and there may be years with very low yields. There may be no harvest at all if the weather conditions are most adverse, especially in the area where the case study 4 is located due to the irregularity or absence of rain episodes.

In these years, the poor yields combined with the low olive oil prices cause economic losses in this type of traditional olive grove monocrop. In the following years it is important to assess the impact of diversification on the main crop (olive) in terms of crop yield as this can affect the profitability of the farm very significantly. If this introduction of cropping diversification does not significantly affect the main crop it seems to be an interesting option to address the many environmental problems that compromise the potential of ecosystem services in these agroecosystems.

In comparison with the management of olive groves monocrop, diversification with oats has the advantage that it could improve the physical and chemical conditions of the soil as the cover would remain in the olive grove street. In addition, due to its high density, oats could control the problems caused by the erosive processes.

Lavender oil is used in the cosmetic industry and can be sold at a relatively high price (24€/kg) however, the costs of plants (0.18 €) and the low oil yields of flowers (around 4-5%) make the economic benefits difficult to achieve.

The cultivation of saffron as intercrop does not require special inputs and treatments but has high starting costs both in personnel and in the installation of the crop. However, a familiar management of the crop where the cost in personnel is reduced and the sale of the cultivation of the saffron bulbs (5€/kg) at the end of the cycle so that they are sown again can make this crop profitable. The price of saffron is very high (1.750 €/kg) due to very low crop yields (0.45 kg/ha) on average in the crop cycle.

*Table 5.2. Revenues and costs of establishing and maintaining diversifications in olive grove.*

| Revenues | Price (€/kg, €/h) | | | | Quantity (Kg/ha) | | | | Value (€/Ha) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | MC | D1 | D2 | D3 | MC | D1 | D2 | D3 | MC | D1 | D2 | D3 |
| Market revenues | 2,15 | 0,15 | 1.750/ 5* | 24 | 121 | - | 0,45/300* | 13,15 | 271 | 271 | 2.559 | 587 |
| Subsidies | | | | | | | | | 450 | 450 | 450 | 450 |
| Total revenues | | | | | | | | | 721 | 721 | 3.001 | 1.037 |
| Production costs | | | | | | | | | | | | |
| Seed | | 0,40 | 0,05 U** | 0,18 U** | | 140 | 27.000 U** | 2.250 U** | | 28 | 1.35 | 405 |
| Tillage | 32,5 | 32,5 | 32,5 | 32,5 | 2 | 2 | 1 | 1,3 | 65 | 65 | 32,5 | 42,3 |
| Planting | | 32,5 | 32,5 | 32,5 | | 1 | 3 | | | 32,5 | 97,5 | 70 |
| Machinery operations | 32,5 | 32,5 | 32,5 | 32,5 | 2,5 | 2 | 2 | 2 | 255 | 336,3 | 368,8 | 341 |
| Fertiliser | 0,37 | 0,35 | 0,35 | 0,35 | 150 | 200 | 130 | 200 | 55,5 | 87,5 | 75,3 | 87,5 |
| Crop protection (Herbicide) | 19,9 | | | | 3 | | | | 59,7 | | | |
| Crop protection (Insect.) | 20,3 | | | | 0,34 | | | | 6,9 | 6,9 | 6,9 | 6,9 |
| Total variable cost | | | | | | | | | 377 | 538 | 1.864 | 903 |
| GM A | | | | | | | | | 344 | 184 | 1.146 | 134 |
| Labour cost (total) | | | | | | | | | 406 | 416 | 812 | 431 |
| GM B | | | | | | | | | -108 | -278 | 333 | -298 |
| GM C | | | | | | | | | -208 | -277 | 233 | -398 |

*Saffron stamens and bulbs. **U = Units, pieces

## 5.4. Conclusion

The preliminary gross margin analyses show that diversification involves extra costs which possibly cannot be compensated by the sales of yields. The results from farm level gross margin calculations in the short-term suggest that diversifications have significant effects on farm economy and management (land use and the use of inputs). It is also important to take into account that diversification may later affect the development of the main crop not considered yet in the gross margin calculation due to the lack of evidence, now data available from three years only. There is a high risk of economic losses due to the initial cost that must be made to install the crop in some cases.

The results suggest that economic benefit due to diversification is only possible in D2, olive intercropped with saffron. Low yields and prices of the olive crop result in negative gross margin in olive monocropping. An increase in olive oil prices or higher yields in the olive grove could bring the gross margin of olive monocropping, as well the gross margin of D1 (olive intercropped with oats) and D3 (olive intercropped with lavander) positive. However, the results suggest that the gross margins of D1 and D3 would still be lower than the gross margin of the olive monocropping. Nevertheless, it is important to ensure that the yield of the main crop is positively and not negatively affected by the inclusion of additional crops on the plots.

In the long term, diversification could increase soil quality, contribute to the yield and soil quality of the olive grove and provide soil cover to help farmers avoid the excessive costs that could result from the erosive processes. Therefore, implementing diversification strategies to transform olive groves agroecosystems could convert these areas in carbon sink areas and also contribute to reducing soil and nutrients loss. Olive orchards have a significant SOC storage capacity and therefore potential to be a climate change mitigator. The valorisation of these ecosystem services can be a fundamental aspect for the inclusion of crops within the olive grove. However, diversification options that provide positive economic gains for a famer already in the short-term (e.g. D2) look more promising than those which imply smaller gains (D1 and D3) compared to the monocrop, if the diversifications have no negative effects on the yields and quality of the main crop, but could still mitigate negative environmental effects of monocropping.

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# 6. CS5-7. Crop rotations in specialized arable land in North Med Italy

## 6.1. Case study description

### 6.1.1. North Mediterranean context features

Case studies 5-6-7 (CSs) are located in the Mediterranean North pedoclimatic region, CS 5 and 7 within Lombardia Region, in Mantova and Cremona provinces respectively, while CS6 is located in Emilia Romagna, in the province of Piacenza.

The overall area is characterized by structured professional farms specialized in arable crops, cereals and horticulture, and livestock production. In this area, the added value of the primary sector is relevant compared to other Italian regions, mainly due to the presence of many agri-food industries. Cultivation systems and pedo-climatic conditions are strictly connected to several environmental problems, natural resources exploitation and pollution, given the intensive production models across provinces, from the East to the West of Pianura Padana. The structure of the local economic systems, including the agricultural sector, have contributed to the rise of negative externalities across the last 40 years, such as water pollution, loss of biodiversity (Bani et al., 2010), loss of soil fertility, soil compaction, (Fava et al., 2010), high CO2eq emissions and simplification of the landscape (Perego et al., 2016).

All Italian CSs experimental fields take place on professional farms specialized in irrigated arable land cultivation, where the current cropping system is generally two-yearly food crops rotation, based on tomato (Solanum lycopersicum) followed mainly by cereals, especially rainfed wheat (Triticum aestivum or Triticum durum).

All CSs are real farms, CS7 is managed directly by Casalasco Cooperative officers, while the other two by professional farmers. The current management practices are characterized by intensive production schemes. The tomato cultivation is in compliance with integrated pest management (IPM) regional rules, suggesting the typology and the amount of pesticides and fertilizers allowed per each category and, at the same time, farmers have to take into account also Casalasco's requests listed on specifics cultivation standards.

### 6.1.2. Diversification strategy and farm level economic analysis: experiment co-design

North Mediterranean CSs are aimed to estimate the impact of diversification on productivity (ton/ha) and profitability (€/ha) during a specific agroecological transition period, as well as, to identify technical and managerial barriers and enablers useful to improve agro-ecosystems environmental assets in very intensive farming context.

The challenge is to pull farmers to adopt new arable land management schemes to mitigate the most serious environmental problem in their areas.

Looking to the reach of the research objective, the design of CSs aims to test if the introduction of nitrogen fixating crops (cash crop legumes - pea for food) within the rotation scheme is a solution to obtain positive effect on soils structure and to reduce water pollution risks due to mineral fertilization (mainly nitrogenous fertilisers) without squeezing arable land profitability in a mid-term period compared to current cropping systems.

To increase farms' willingness to the adoption of new practices, a co-decision process was proposed. The potential practices list proposed by WP2 have been validated by actors involved in the cultivation and observation of trial fields. At this stage, factors related to economic performances at field and farm level were also included in the practices' selection process. More widely, the CSs thesis was defined to test the increase or the stabilization of overall farm GM stability, along the years (middle term reference).

After a 1-year co-design process (Reseacher-Farmers-Technicians-Agro-industries), the North Med Diverfarming (DIV) protocol was defined, based on the following key points: i) new crops suitability; ii) farmers needs and new skills to manage new crops; iii) agri-food companies requests - quality, quantity, other requirements; iv) risks management (tomato quality attributes mismatch).

The DIV co-defined experimental protocol provides a multi-year diversification plan inspired by sustainable intensification principles (Tilman et al 2011; Struik & Kuyper, 2017). Eight practices were selected and all of them were recognized by the stakeholders as feasible to affect the following three dimensions:

1. Dimension - Increase diversity in the agro-ecosystems - (driver: Use of Land)
   - AE-D1 - introduction of a leguminous crop in the rotation (pea for food)
   - AE-D2 - introduction of tomato as second crop in the rotation after pea (multiple cropping)

2. Dimension - Reduce impact on soils and water quality - (driver: Technical Management)
   - LI-D1 - Use of organic fertilizer, pig slurry (CS5) and digestate (CS6 and CS7)
   - LI-D2 - Reduced tillage on soil preparation for wheat
   - LI-D3 - Pest and disease monitoring and treatment in compliance with regional Integrated Pest Management (IPM) requirements

3. Dimension - Mitigate economics risk - (driver: New business tool)
   - EC-D1 - Multi-year and multi-crop contract, products allocation guarantee
   - EC-D2 - Crop insurance scheme based on tomato yields references.
   - EC-D3 - New crop (Pea) introduction is supported by technical external services
   - EC-D3 - For durum wheat a quality incentive it's defined

All farms have dedicated around 20 ha of arable land to DIVERFARMING activities. All experimental surface was divided in 4 different plots, about 5 ha each, very close each other (see: Fig.6.1 and Table 6.1). Three of them are cultivated following the project research protocol, including crop rotation and low input management; the harvested products are sold according to multi-year contract requirements (DIV) (Table 4.1 - green line). The fourth plot is managed by farmers following a business as usual (BAU) management (See Table 4.1 - grey line).

For plots conducted under BAU conditions, farmers made crops management and decisions concerning land use crops allocation according to their market expectations as well as considering their structural and financial constraints. For this reason, in table 6.1 years 20-21 cells are left empty.

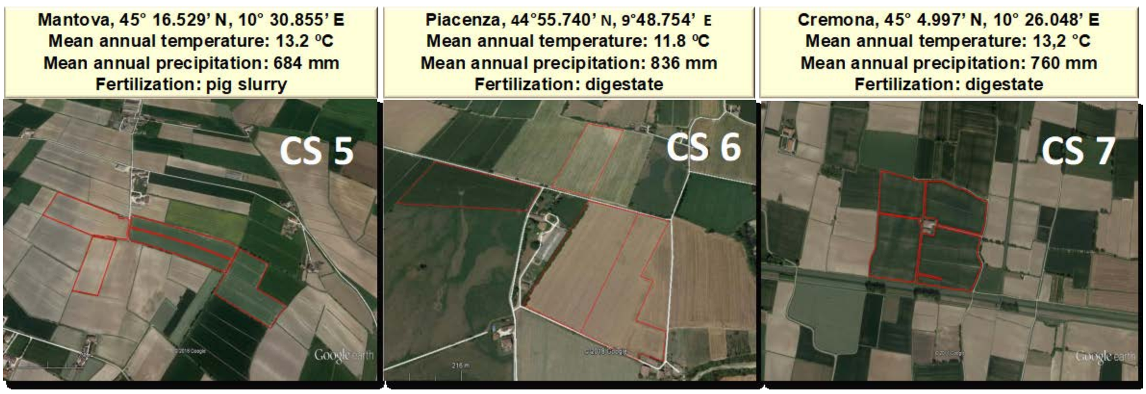



***Figure 6.1*** *Cases Studies plot design and main climatic characteristics for North Med*

*Table 6.1 North Med plot management per CS per agrarian years.*

| CS → Plot/AY | CS 5 - Spagnoli | | | | CS 6 -Ferrari | | | | CS 7 - Casalasco | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 17-18 | 18-19 | 19-20 | 20-21 | 17-18 | 18-19 | 19-20 | 20-21 | 17-18 | 18-19 | 19-20 | 20-21 |
| Plot1 | **T** | **PT** | DW | T | **DW** | **T** | PT | DW | **T** | **PT** | DW | T |
| Plot2 | **C** | **C** | C | | **PT** | **DW** | T | PT | **T** | **T** | DW | |
| Plot3 | **PT** | **DW** | T | PT | **T** | **PT** | DW | T | **PT** | **DW** | T | PT |
| Plot4 | **DW** | **T** | PT | DW | **W** | **B** | W | | **DW** | **T** | PT | DW |

B=Barley; C=Corn; DW=Durum Wheat; P=Pea; PT; Pea-Tomato; T=Tomato; W=Soft Wheat

Starting from 2020 yield from DIV plots will be compared taking into account a different sub-plot treatment proposed by CREA and CCP. In particular dimension LI-D1, organic manuring efficiency will be test using two doses treatment in sub-plot during the last two agrarian seasons.

## 6.2. Materials and methods

### 6.2.1. Diversification introduction: economic impact evaluation

Despite diversified crop rotation is one of the main practices suggested to obtain ecological benefits by arable land systems, there are few evidences about the impact on farmland profitability. As reported by Rosa-Schleich et al 2019 review, there are few systematic meta analyses useful to compare effect on costs saving, increase of gains or improve land profitability stability across regions.

Analyses that deals with the topic, despite use similar approaches, tests several practices in different experimental contexts, indeed results cannot be used to clarify significant trends on the impacts of diversification on farm yields and profitability (D'Annolfo et al 2017).

This gap is partly due to a lack of multidisciplinary approach in the definition of experimental treatments. Agronomist and plant scientist revealed significant links between cultivation technique, soil-plant relationships, genetic factors and yield level. Indeed, the revenues are often estimated using quantity of yields measured in plot where crops are grown and where produced crops are harvested in unusual ways compared to the actual fields management.

Generally, these harvested yields are multiplied with a reference of market price without adequately taking into account about real prices paid to farmers. However, these evaluations do not include the price opportunities that farmers have effectively obtained for their harvests over the years and among crops. Although the yield is a crucial point of the evaluations, the explicit and opportunity costs related to the multi-year crop planning of arable land is also very important for a farm, especially when it is specialized in the production of commodities.

To make impact evaluations about the feasibility of diversification practices introduction as truthful as possible, in all North-Med CSs real farmers were involved, operating in one of the most specialized areas in the production of tomatoes in Italy. They were asked to invest a large and significant share and amount of their arable land to the evaluation. These requests could improve meaningfulness of data on costs and yields revealed in real production conditions (fields vs exp. plot) and make communication to farmers more effective.

According to that “real condition”, it will be possible to identify specific problems related to the large-scale implementation of some diversification practices, including aspects related to technical inputs procurement, external services and workload management and (new) products allocation. These elements represent “ghost costs” that farmers, even unconsciously, take into account to define their land use and crops allocation.

In order to improve these evaluations on diversification effect and reach DIVERFARMING objectives, for CS 5-6-7 an economics assessment was defined to compare economics performance carried out from arable cropping system managed following diversified crop rotation and low input principles.

For all North-Med CSs these indications are reported as commitments in a multi-years and multi-crops hypothetical contract between farmers and both tomato and durum wheat processors. For this purpose, all costs and earnings are collected for each individual experimental plot, both DIV and BAU, while the baseline cropping system reference (BAS) have considered assuming most common crop-rotation scheme (tomato-tomato-durum wheat), as main reference.

In other words, the difference between the DIV and BAU scenarios with the BAS scenario is given by the origin of the data used and by the arable land surface in rotation used by each crop. In the first two cases both derive from what has been observed in the farms, while for the Baseline scenario (BAS) the land uses are reconstructed on the basis of the most common use of arable land for similar farms in the reference area.

The BAS scenario will be used as main references to compare economics and ecological performances in all North Med CSs managed following DIV and BAU both conditions.

### 6.2.2. GM diversification impact: productivity, entrepreneurship and ecological hypothesis

Farm level economic analysis is mainly based on gross margin (GM) calculations. Depending on what kind of revenues and which factors of production costs are accounted per each crop and plot. For all North Med CS the GM estimations are referred to arable land, without including general costs due to the overall farm structure and management.

In this analysis three levels of GM have been differentiated as suggested (Deliverable 8.1) whereas a supplementary GM typology is proposed to fit North-Med CSs experimental design assessment, aimed to evaluate the hypothetical multi-years diversification contract.

GM typologies are described as follow:

I. **GM-A**: Gross saleable production (GSP) and CAP subsides are considered as revenues and explicit costs for variable factors are considered, where:
GSP + CAP - (Inputs Costs + Cultivation Operation)

The first index highlights the GM, that farmers often look. This is the economic result determined solely to technical cultivation and pedoclimatic conditions referring to single agricultural year, without consider the own labour and the cost of own capital conferred directly by the landowner farmer.

II. **GM-B**: Estimate the balance between GSP and CAP items and all variable factors, including own labour, and the fixed costs quota related to each plot cultivation, where;
GSP + CAP - (Input Costs + Cultivation Operation+ Labour)

Compared to the previous one, this index considers variable costs related to the labour component. In CSs 5 and 6, crops are managed directly by the farmers, while in the CS7 all field management is given to external contract.

III. **GM-C**: Estimate the balance between GSP and CAP items and all variable factors, including own labour, and the fixed costs quota related to each plot cultivation, where;
GSP + CAP - (Input Costs + Cultivation Operation+ Labour +Fixed)

This index includes also the estimated costs due to the depreciation of machines and tools used in observed crops management. This type of indicator is a reference to the profitability of one hectare of arable land, without taking into account the overheads of running the farm and the interest related to the crop's advance capital across years (financial aspects).

IV. **GM-Ent** (Entrepreneurs): total revenues including subsides and insurance contributions, and all other factors, including insurance fee, are considered as costs:
GSP + CAP + PP + AEC + INS - (Input Costs + Cultivation Operation + Own Labour+Fixed+Insurance fees).

The last index can be useful to understand, how much a co-defined hypothetical contract could affect the profitability of land across CSs. To better evaluate networking and entrepreneur's components role on DIV results, data about crops premium price (PP), voluntary participation in environmental agro-environmental-climate measures (AEC) and the propensity to adopt risk management tools (INS) have been collected and added to revenues.

Following the framework of GM assessment, three hypotheses to evaluate the diversifications practices impact on profitability have been considered. All hypotheses will be tested at the end of the 4$^{th}$ year of experimental observations, when entire multiple cropping cycles will be ended.

Indeed, the first two were evaluated for the first intermediate period, considering 2017-2018 and 2018-2019 agricultural years GMs, comparing results of BAS, BAU and DIV cropping systems.

***Hypothesis 1: Positive change in overall GM due to DIV strategy***

*$H1_0$: GM observed is not different between DIV and BAS arable land management*

*$H1_A$: GM observed is different between DIV and BAS arable land management*

Despite uncertainty about the practices effectiveness in the short term, especially referred to irrigated cropping systems, literature reports many cases where the increase in productivity and yields per hectare has been positively influenced (Yigezu et al 2019; Bonciarelli et al 2016). To test this hypothesis a GM-A index is used to evaluate the consistence's of expected yield positive effects on revenues between system that adopts or not multiple-crop and low-input management practices.

***Hypothesis 2: Diversified crop rotation and multi-years contract affect land profitability***

*$H2_0$: There is no difference in GM-Ent compare DIV to BAU and BAS*

*$H2_A$: Diversification improve GM-Ent compare DIV to BAU and BAS*

Recent research attempts to show that a diversified system can generate higher incomes than conventional ones (Van Der Ploeg et al 2019). In this analysis it is possible to observe a difference between the economic results that can be obtained in scenarios driven or not by value-chain contract (Blasi et al. 2017) and subsidies AEC rural development measures.

Looking at GM-Ent it is possible observe at cropping systems economics performances considering benefits due to multi-year crop attributes, such as specifics aids for durum wheat cultivation, insurance contributions for tomato and external assistance for pea.

***Hypothesis 3: Ecological balance and GM show difference in DIV Vs BAU systems.***

*$H3_0$: There are not difference in EB/GM trade off*

*$H3_A$: Diversification improve EB /GM trade off*

An Ecological Footprint (gha/ha) rapid appraisal is proposed to evaluate trade-offs between economic and ecological balances across different cropping systems' scenario (Passeri et al 2014). A difference in ecosystems performance may be observed, measured by Ecological Balance (EB) and gross margin (GM) results, in DIV, BAU and BAS conditions and allow to validate positive effect of diversified cropping systems (Blasi et al 2016).

### 6.2.3. Data collection tool

Inputs, yields and agricultural management practices related data have been collected every year at crop and plot levels and aggregated by plot to farm level using a semi-automatic excel file, called DIFARMA.

DIFARMA tool was created and actually used to allow data collection useful to obtain variables necessary to assess, at the same time, Gross Margin, Ecological Footprint and Biocapacity values per crops/plot/farm per years.

With a total of 8 sheets integrated and consequential to each other, DIFARMA allows to collect data about all kind of explicit costs and revenues and, also, to manage experimental data input, i.e. data from soil and agronomy and plant scientists, mainly dedicated to up-date the Diary sheet, where all kind of technical operation are reported.

For each farm, the data imputation is sequential, starting from sheet "Plot Archive" up to the results that are viewable in sheet "Resume". In average sheets have to be refresh 3 time per agrarian year, except for Diary that have to be filled every time some things happen on the fields/plot. The 8 sheets are as follows:

i. Plot Archive: single plots and subplots of the case study are defined by basic information on crops, UAA surface and transplanting or seeding density.
ii. Seeds Pesticides Fertilizer: it's the archive of all input available (fertilizers, pesticides and seed/plants) in the farm warehouse. Per each input typology are described quantities and prices using value gathered directly by invoices.
iii. Labour costs: Archive in which are defined the worker daily rate and the main role and task done regarding operation. Farmer labour costs is defined as own labour cost, using as references the salary due by law to skilled worker (for details see next paragraph). Related inquiries are also included, like crop insurances fee and other full cost for other crop services.
iv. Machineries and services: this sheet provides three different tables where the following information is reported: i) information relating machineries and tools, including information about average diesel and oil consumption, purchase date, estimate of total hours of use per year, main operations for which it is used; ii) the cost of external services differentiated by activity; iii) crop insurances fee and other full cost for other crop services.
v. Diary: It is a logbook, where all the operation carried out on the single plot or subplot are reported by date. Several columns of these sheets are connected with the previously filled sheets. Thus, making available all the information previously collected.
vi. Subsides: Archive of all kind of subsides received by farmers and allocated per single plot, make different attribution considering the subsidy typology (Direct Payment decoupled - CAP) or coupled (Common Market Organization - CMO); Agro-environmental-climate schemes (RDP). In this sheet are collected also the eventually insurance contribution received per each crop.
vii. Revenue: Automatic collection of values relating to the observed quantities of product and the revealed price per unit, indeed are calculated gross sales value of single plot.

viii. Resume: Collection in the table of the revenues, variable costs, labour costs, external services, insurance differentiated for each single plot. By choosing the plot of interest it is possible to read the previous detailed data.

To improve data gathering accuracy, some GM key variables are imputed in DIFARMA following a double check and pre-assessment process, such as the yield value and the different type of subsidies and contribution. Instead, costs that are not reported in accounting documents and not measured on field, are derived through estimation process based on farm information collected by deep farmers' interviews and adjusted with official data published in technical documents. These data are, own labor costs, fixed costs. Finally, to operate comparisons between performance carry out from cropping systems driven by multi-years contract, special attention was dedicated to collected data of subsides and premium price and to define a baseline costs reference.

<u>Yields:</u>

To identify the yield, agronomists and plant scientist from CCP and CREA are in charge of on-field data collection, they weigh products collected in at least 3 standardized areas of 1 square meter per single plot or sub-plot. These data are checked and compared with 2 other product quantity data (ton) gathered at grain elevators and, for pea and tomato, at CCP Casalasco factory; data reported in sales invoices are also used to this purpose.

The total amounts reported in sales invoices are used to calculate the gross saleable product (GSP) for each plot reducing the risk of data mismatch for one of the most important variables to GM assessment and to allow effective communication to farmers enrolled in Be a Diverfarmer initiative.

<u>Own labour costs:</u>

Own labour costs are calculated only for CS 5 and CS 6 because in CS7 all worker costs are considered and accounted as an external services fee. To monetize the cost linked to own labour (without accounting document references), the total amount of hour dedicated to crop operations by the farmer and his/her family members are multiplied by the cost of a skilled worker as reported on provincial level references (Ministry of Labour, 2019).

Where cultivation operations are carried out by contractors, the costs are considered as full costs derived from specifics invoice's items. CSs 5 and 6 are equipped with machineries and tractors suitable for minimum tillage techniques and at the same time they use external services to harvest durum wheat, tomatoes and peas. CS 7 manages all operations paying an external service annual fee. For this reason, the GM-B and CM-C are quite similar.

<u>Fixed Costs:</u>

Fixed costs related to tractors, tools and irrigation durable equipment used for experimental plot cultivation have been estimated. To define a fixed costs quota per plot, the machineries' annual depreciation rate was divided by the total amount of estimated work hour per years. These values were adjusted taking into account the features of the operation (timing, with or without power take-off, timing and duration) carried out in each plot.

<u>Subsides and contributions:</u>

To highlight the farmer ability to manage extra-farming opportunities, DIFARMA allows to account separately the subsidies or contribution received by farmers. The categories of subsidies are: i) Direct decoupled CAP payment; ii) Partially coupled CAP payments (CMO); iv) Agro-environmental-climate measures subsides (AEC); v) product quality premium price due to pre-cultivation agreement (PP); vi) insurance contribution (INS)

Baseline account estimation:

To estimate diversification impact on economic performances a comparison between DIV, BAU and BAS conditions have been done. For the first two scenarios all data are gathering from experimental plot crops account (see 2.3 section), while for BAS the calculation of gross margin is based on the following data and costs level assumptions:

I. Gross Sales Production: yield and prices used to define GSP are the same of experimental DIV plot. For CS7 the yield value was obtain using also the BAU tomato yield level observed.
II. Cultivation Costs: data from DIV plot was used to define a current cultivation technique and operating some changes, as follow:
   - Durum Wheat, land preparation baseline including the ploughing costs instead minimum tillage (+70 euro)
   - Fertilizers, organic manuring costs have replaced by usual mineral fertilization costs;
   - Inputs pesticides - tomato cost are quite lower compare to the DIV one, assuming most probably the purchase of cheaper plant protection products, compared to those allowed by the IPM list and request to tomato DIV cultivation.
III. Own Labour and Fixed Costs: these two typologies of costs are estimated referring on technical data about changing in time per unit of work considering no-tillage and numbers of passages for fertilization and treatment operations.

## 6.3. Results

### 6.3.1. Cropping systems Gross Margin estimation

To be consistent with CSs design the object of comparison will be the cropping systems economics performances referred to entire crop rotation years. As reported above, data was gathered annually to analyse first two-year GM at plot, crops and scenario levels.

First consideration is about prices and yields level among years and CSs. Looking at the data collected (6.2), it is clear how a real business analysis allows to appreciate how prices and yields, despite they are linked respectively to the same contractual and technical farming schemes, assume very different values in three homogeneous farms. This heterogeneity is explained more by the quality characteristics of the products than a market price trends over the years. In particular, this uncertainty has influenced the results of the food pea, the nitrogen fixer crop introduced in the DIV scenario. In CSs the pea price values show a difference of 119 €/ton if looking at CS7 and CS6 pea prices in 2018 and of 80 €/ton looking at CS6 and CS5 prices obtained for 2019 harvest. Although the reference market price is the same for all CSs, the qualitative characteristics have led to significant differences, of 50% and 30% respectively in 2018 and 2019 compare to the observed average values.

Although CS are all in the same geographical area, some differences have been recorded in the face of site-specific problems related mainly to the rainfall trend. In particular, tomato crops in the CS7 was affected by two complicated agrarian years. In both years plots yields are lower than expected and also there are lower than the mean area yields which were equal to 68 ton/ha in 2018 and 65 ton/ha in 2019 (see Official Statistics Datawarehouse http://dati.istat.it/ superfici e produzione dati in complesso).

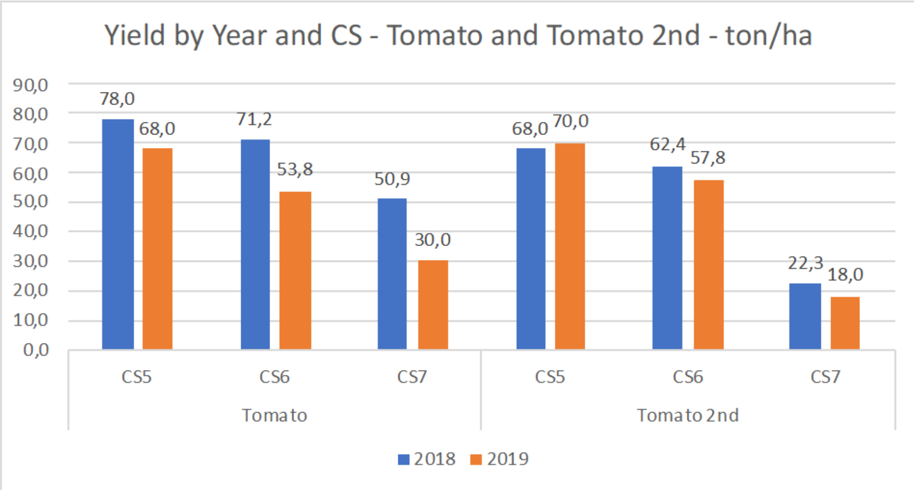
**Table 6.2.** *Yield and price observed in all CS.*

| | Case study | CS5 | | | | CS6 | | | | CS7 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | year | 2018 | | 2019 | | 2018 | | 2019 | | 2018 | | 2019 | |
| Plot and Crop | | *t/ha* | *€/t* | *t/ha* | *€/t* | *t/ha* | *€/t* | *t/ha* | *€/t* | *t/ha* | *€/t* | *t/ha* | *€/t* |
| DIV | Tomato | 78,0 | 75 | 68,0 | 72 | 71,2 | 72 | 53,8 | 85 | 50,9 | 75 | 30,0 | 81 |
| | Tomato 2nd | 68,0 | 75 | 70,0 | 75 | 62,4 | 72 | 57,8 | 85 | 22,3 | 75 | 18,0 | 81 |
| | Durum Wheat | 5,8 | 233 | 6,0 | 240 | 3,0 | 257 | 5,79 | 210 | 5,3 | 207 | 3,0 | 240 |
| | Pea | 3,8 | 210 | 4,2 | 220 | 5,8 | 178 | 3,1 | 300 | 2,8 | 297 | 3,9 | 270 |
| BAU | Corn | 16,5 | 130 | 15,0 | 132 | | | | | | | | |
| | Wheat | | | | | 4,0 | 210 | | | | | | |
| | Barley | | | | | | | 5,2 | 180 | | | | |
| | Tomato | | | | | | | | | 27,0 | 79 | 30,0 | 81 |

As shown in Figure 6.2, the tomato yield values decrease in all three cases, recording -13% CS5, -24% CS6 down to -41% in CS7. Net of CS5, yields are also lower than expected in 2018 for the second-harvest tomato, by 7% and 19% in CS6 and CS7 respectively, while they recorded a slight increase of 3% in CS5.

For durum wheat, the yields show a high instability across the years considered, in two out of three cases. Yields of durum wheat increase or decrease by about 50% (in CS6 and CS7, respectively); a similar situation is reported for the pea, with only one case study (CS5) showing a stable yield across the two years considered.

Starting from these conditions, economic performances assume very different features year by year. Tables 6.3; 6.4; 6.5 show the costs and revenues assessed by plots, reporting all values per hectare.



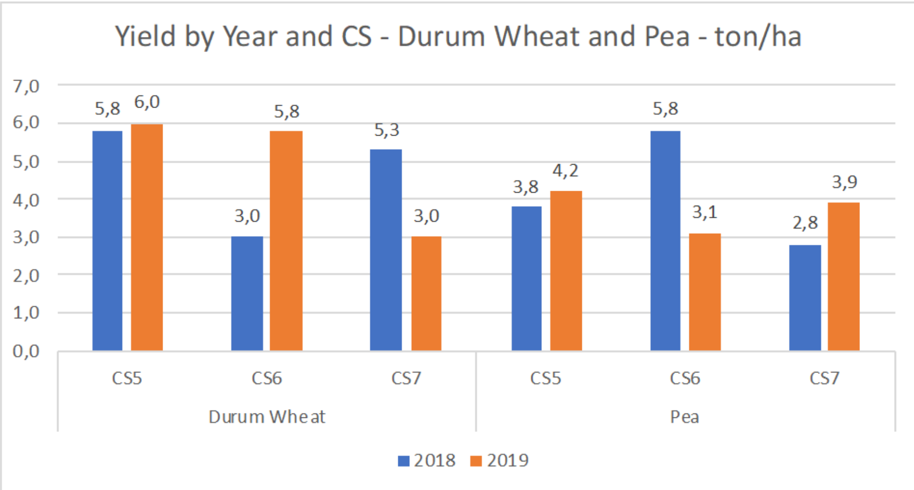




***Figure 6.2.*** *Yields observed in all DIV plot for each crops and CSs.*

**Table *6.3:*** *CS5 - Per hectare Gross Margin accounting*

| CS5 - GM 18-19 | BAS18 | | BAS19 | | BAU18 | BAU19 | DIV18 | | | DIV19 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CS | CS5 | CS5 | CS5 | CS5 | CS5 | CS5 | CS5 | CS5 | CS5 | CS5 | CS5 | CS5 |
| Plot | BAS | BAS | BAS | BAS | Plot 2 | Plot 2 | Plot 1 | Plot 3 | Plot 4 | Plot 1 | Plot 3 | Plot 4 |
| Year | 2018 | 2018 | 2019 | 2019 | 2018 | 2019 | 2018 | 2018 | 2018 | 2019 | 2019 | 2019 |
| Crop | T | DW | T | DW | C | C | T | (P)T | DW | (P)T | DW | T |
| **Revenue** | **€ 6.230** | **€ 1.731** | **€ 5.276** | **€ 1.820** | **€ 2.525** | **€ 2.360** | **€ 7.438** | **€ 6.448** | **€ 1.831** | **€ 6.724** | **€ 1.920** | **€ 7.366** |
| GSP | € 5.850 | € 1.351 | € 4.896 | € 1.440 | € 2.145 | € 1.980 | € 5.850 | € 5.898 | € 1.351 | € 6.174 | € 1.440 | € 4.896 |
| Direct Payment CAP | € 380 | € 380 | € 380 | € 380 | € 380 | € 380 | € 380 | € 380 | € 380 | € 380 | € 380 | € 380 |
| Coupled Subs. (PP;AEC) | € - | € - | € - | € - | € - | € - | € 170 | € 170 | € 100 | € 170 | € 100 | € 170 |
| Insurance | € - | € - | € - | € - | € - | € - | € 1.038 | € - | € - | € - | € - | € 1.920 |
| **Technical Inputs** | **€ 1.633** | **€ 440** | **€ 1.639** | **€ 443** | **€ 743** | **€ 743** | **€ 1.553** | **€ 1.806** | **€ 440** | **€ 1.811** | **€ 443** | **€ 1.544** |
| Seed | € 465 | € 155 | € 465 | € 155 | € 300 | € 300 | € 465 | € 640 | € 155 | € 680 | € 155 | € 465 |
| Fertilizers | € 674 | € 171 | € 690 | € 171 | € 160 | € 160 | € 574 | € 570 | € 171 | € 601 | € 171 | € 570 |
| Pesticide | € 494 | € 114 | € 484 | € 117 | € 283 | € 283 | € 514 | € 596 | € 114 | € 531 | € 117 | € 509 |
| **Cultivation Operations** | **€ 1.797** | **€ 349** | **€ 1.797** | **€ 342** | **€ 648** | **€ 648** | **€ 1.797** | **€ 1.796** | **€ 289** | **€ 1.982** | **€ 289** | **€ 1.797** |
| Land preparation | € 132 | € 119 | € 132 | € 112 | € 61 | € 61 | € 132 | € 110 | € 49 | € 110 | € 49 | € 132 |
| Seeding/Transplant | € 254 | € 25 | € 254 | € 25 | € 147 | € 147 | € 254 | € 170 | € 25 | € 212 | € 25 | € 254 |
| Treatment | € 180 | € 30 | € 180 | € 30 | € 60 | € 60 | € 180 | € 100 | € 40 | € 194 | € 40 | € 180 |
| Fertilization | € 30 | € 45 | € 30 | € 45 | € 56 | € 56 | € 30 | € 34 | € 45 | € 43 | € 45 | € 30 |
| Secondary Works | € - | € - | € - | € - | € - | € - | € - | € - | € - | € - | € - | € - |
| Irrigation | € 101 | € - | € 101 | € - | € 195 | € 195 | € 101 | € 152 | € - | € 193 | € - | € 101 |
| *Harvest* | € 1.100 | € 130 | € 1.100 | € 130 | € 130 | € 130 | € 1.100 | € 1.230 | € 130 | € 1.230 | € 130 | € 1.100 |
| **Insurance** | **€ -** | **€ -** | **€ -** | **€ -** | **€ -** | **€ -** | **€ 500** | **€ 535** | **€ 35** | **€ 535** | **€ 35** | **€ 500** |
| **Own labour** | **€ 332** | **€ 78** | **€ 332** | **€ 78** | **€ 234** | **€ 234** | **€ 332** | **€ 576** | **€ 56** | **€ 576** | **€ 56** | **€ 332** |
| **Fixed cost** | **€ 573** | **€ 51** | **€ 573** | **€ 51** | **€ 200** | **€ 200** | **€ 573** | **€ 581** | **€ 46** | **€ 675** | **€ 46** | **€ 573** |
| GM-A | € 2.800 | € 943 | € 1.840 | € 1.035 | € 1.133 | € 968 | € 2.880 | € 2.676 | € 1.003 | € 2.761 | € 1.088 | € 1.935 |
| GM-B | € 2.468 | € 865 | € 1.509 | € 957 | € 900 | € 735 | € 2.548 | € 2.101 | € 947 | € 2.185 | € 1.033 | € 1.604 |
| GM-C | € 1.895 | € 814 | € 935 | € 907 | € 700 | € 535 | € 1.975 | € 1.520 | € 901 | € 1.511 | € 987 | € 1.030 |
| **GM-Ent** | **€ 1.895** | **€ 814** | **€ 935** | **€ 907** | **€ 700** | **€ 535** | **€ 2.683** | **€ 1.155** | **€ 966** | **€ 1.146** | **€ 1.052** | **€ 2.620** |

**Table *6.4:*** *CS6 - Per hectare Gross Margin accounting*

| **CS6 - GM 18-19** | BAS18 | | BAS19 | | BAU19 | BAU19 | DIV18 | | | DIV19 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CS | CS6 | CS6 | CS6 | CS6 | CS6 | CS6 | CS6 | CS6 | CS6 | CS6 | CS6 | CS6 |
| Plot | BAS | BAS | BAS | BAS | Plot 4 | Plot 4 | Plot 1 | Plot 2 | Plot 3 | Plot 1 | Plot 2 | Plot 3 |
| Year | 2018 | 2018 | 2019 | 2019 | 2018 | 2019 | 2018 | 2018 | 2018 | 2019 | 2019 | 2019 |
| Crop | T | DW | T | DW | W | B | DW | (P)T | T | T | DW | (P)T |
| **Revenue** | **€ 5.507** | **€ 1.148** | **€ 4.935** | **€ 1.596** | **€ 1.220** | **€ 1.316** | **€ 1.283** | **€ 6.441** | **€ 6.224** | **€ 8.719** | **€ 1.696** | **€ 9.824** |
| GSP | € 5.127 | € 768 | € 4.555 | € 1.216 | € 840 | € 936 | € 768 | € 5.514 | € 5.127 | € 4.555 | € 1.216 | € 5.840 |
| Direct Payment CAP | € 380 | € 380 | € 380 | € 380 | € 380 | € 380 | € 380 | € 380 | € 380 | € 380 | € 380 | € 380 |
| Coupled Subs. (PP;AEC) | € - | € - | € - | € - | € - | € - | € 100 | € 170 | € 340 | € 350 | € 100 | € 170 |
| Insurance | € - | € - | € - | € - | € - | € - | € 35 | € 377 | € 377 | € 3.434 | € - | € 3.434 |
| **Technical Inputs** | **€ 1.871** | **€ 440** | **€ 1.974** | **€ 379** | **€ 449** | **€ 178** | **€ 440** | **€ 1.969** | **€ 1.791** | **€ 1.879** | **€ 379** | **€ 2.545** |
| Seed | € 797 | € 142 | € 797 | € 128 | € 120 | € 178 | € 142 | € 989 | € 797 | € 797 | € 128 | € 1.152 |
| Fertilizers | € 593 | € 192 | € 576 | € 128 | € 319 | € - | € 192 | € 466 | € 493 | € 456 | € 128 | € 522 |
| Pesticide | € 481 | € 106 | € 600 | € 122 | € 10 | € - | € 106 | € 514 | € 501 | € 625 | € 122 | € 871 |
| **Cultivation Operations** | **€ 1.573** | **€ 336** | **€ 1.615** | **€ 440** | **€ 214** | **€ 379** | **€ 279** | **€ 1.847** | **€ 1.561** | **€ 1.615** | **€ 384** | **€ 2.284** |
| Land preparation | € 140 | € 115 | € 120 | € 152 | € 36 | € 214 | € 45 | € 210 | € 140 | € 120 | € 89 | € 315 |
| Seeding/Transplant | € 117 | € 22 | € 122 | € 28 | € 22 | € 28 | € 22 | € 153 | € 117 | € 122 | € 28 | € 144 |
| Treatment | € 194 | € 37 | € 117 | € 14 | € 10 | € - | € 50 | € 186 | € 194 | € 117 | € 22 | € 99 |
| Fertilization | € 12 | € 32 | € 8 | € 35 | € 16 | € - | € 32 | € 11 | € 12 | € 8 | € 35 | € 26 |
| Secondary Works | € 16 | € - | € - | € - | € - | € 8 | € - | € 16 | € 16 | € - | € - | € 15 |
| Irrigation | € 94 | € - | € 249 | € - | € - | € - | € - | € 140 | € 94 | € 249 | € - | € 555 |
| *Harvest* | € 1.000 | € 130 | € 1.000 | € 211 | € 130 | € 130 | € 130 | € 1.130 | € 1.000 | € 1.000 | € 211 | € 1.132 |
| **Insurance** | **€ -** | **€ -** | **€ -** | **€ -** | **€ -** | **€ -** | **€ 33** | **€ 754** | **€ 754** | **€ 812** | **€ 57** | **€ 812** |
| **Own labour** | **€ 318** | **€ 144** | **€ 336** | **€ 208** | **€ 80** | **€ 75** | **€ 124** | **€ 429** | **€ 318** | **€ 336** | **€ 188** | **€ 588** |
| **Fixed cost** | **€ 367** | **€ 51** | **€ 467** | **€ 71** | **€ 34** | **€ 52** | **€ 48** | **€ 323** | **€ 367** | **€ 467** | **€ 68** | **€ 438** |
| GM-A | € 2.063 | € 372 | € 1.346 | € 778 | € 558 | € 759 | € 429 | € 2.078 | € 2.155 | € 1.441 | € 833 | € 1.392 |
| GM-B | € 1.745 | € 228 | € 1.009 | € 570 | € 477 | € 685 | € 305 | € 1.650 | € 1.837 | € 1.104 | € 645 | € 804 |
| GM-C | € 1.378 | € 177 | € 542 | € 499 | € 444 | € 633 | € 258 | € 1.327 | € 1.470 | € 637 | € 578 | € 366 |
| **GM-Ent** | **€ 1.378** | **€ 177** | **€ 542** | **€ 499** | **€ 444** | **€ 633** | **€ 360** | **€ 1.120** | **€ 1.433** | **€ 3.610** | **€ 621** | **€ 3.158** |

**Table *6.5:*** *CS7 - Per hectare Gross Margin accounting*

| **CS7 - GM 18-19** | BAS18 | | BAS19 | | BAU19 | BAU19 | DIV18 | | | DIV19 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CS | CS7 | CS7 | CS7 | CS7 | CS7 | CS7 | CS7 | CS7 | CS7 | CS7 | CS7 | CS7 |
| Plot | BAS | BAS | BAS | BAS | Plot 2 | Plot 2 | Plot 1 | Plot 3 | Plot 4 | Plot 1 | Plot 3 | Plot 4 |
| Year | 2018 | 2018 | 2019 | 2019 | 2018 | 2019 | 2018 | 2018 | 2018 | 2019 | 2019 | 2019 |
| Crop | T | DW | T | DW | T | T | T | (P)T | DW | (P)T | DW | T |
| **Revenue** | **€ 3.375** | **€ 1.540** | **€ 2.810** | **€ 1.100** | **€ 2.586** | **€ 2.810** | **€ 6.250** | **€ 6.334** | **€ 1.640** | **€ 6.692** | **€ 1.224** | **€ 6.267** |
| GSP | € 2.925 | € 1.090 | € 2.430 | € 720 | € 2.136 | € 2.430 | € 3.822 | € 2.427 | € 1.090 | € 2.509 | € 720 | € 2.430 |
| Direct Payment CAP | € 450 | € 450 | € 380 | € 380 | € 450 | € 380 | € 450 | € 450 | € 450 | € 380 | € 380 | € 380 |
| Coupled Subs. (PP;AEC) | € - | € - | € - | € - | € - | € - | € 170 | € 170 | € 100 | € 170 | € 100 | € 170 |
| Insurance | € - | € - | € - | € - | € - | € - | € 1.808 | € 3.287 | € - | € 3.633 | € 24 | € 3.287 |
| **Technical Inputs** | **€ 1.591** | **€ 361** | **€ 1.842** | **€ 442** | **€ 1.378** | **€ 2.062** | **€ 1.511** | **€ 2.414** | **€ 361** | **€ 2.549** | **€ 442** | **€ 1.767** |
| Seed | € 702 | € 120 | € 813 | € 154 | € 602 | € 853 | € 702 | € 1.409 | € 120 | € 1.160 | € 154 | € 813 |
| Fertilizers | € 490 | € 79 | € 576 | € 104 | € 390 | € 776 | € 390 | € 465 | € 79 | € 801 | € 104 | € 476 |
| Pesticide | € 400 | € 163 | € 453 | € 184 | € 386 | € 433 | € 420 | € 539 | € 163 | € 588 | € 184 | € 478 |
| **Cultivation Operations** | **€ 1.929** | **€ 611** | **€ 2.094** | **€ 463** | **€ 1.830** | **€ 2.001** | **€ 1.929** | **€ 2.546** | **€ 531** | **€ 2.488** | **€ 383** | **€ 2.094** |
| Land preparation | € 207 | € 160 | € 231 | € 160 | € 207 | € 231 | € 207 | € 514 | € 120 | € 462 | € 120 | € 231 |
| Seeding/Transplant | € 320 | € 45 | € 320 | € 45 | € 320 | € 300 | € 320 | € 365 | € 45 | € 365 | € 45 | € 320 |
| Treatment | € 350 | € 172 | € 400 | € - | € 225 | € 275 | € 350 | € 390 | € 172 | € 275 | € - | € 400 |
| Fertilization | € 48 | € 114 | € 48 | € 138 | € 48 | € 48 | € 48 | € 62 | € 74 | € 171 | € 98 | € 48 |
| Secondary Works | € 39 | € - | € - | € - | € 39 | € - | € 39 | € 39 | € - | € - | € - | € - |
| Irrigation | € 65 | € - | € 195 | € - | € 91 | € 247 | € 65 | € 156 | € - | € 195 | € - | € 195 |
| *Harvest* | € 900 | € 120 | € 900 | € 120 | € 900 | € 900 | € 900 | € 1.020 | € 120 | € 1.020 | € 120 | € 900 |
| **Insurance** | **€ -** | **€ -** | **€ -** | **€ -** | **€ -** | **€ -** | **€ 829** | **€ 896** | **€ 48** | **€ 635** | **€ 32** | **€ 600** |
| **Own labour** | **€ -** | **€ -** | **€ -** | **€ -** | **€ -** | **€ -** | **€ -** | **€ -** | **€ -** | **€ -** | **€ -** | **€ -** |
| **Fixed cost** | **€ -** | **€ -** | **€ -** | **€ -** | **€ -** | **€ -** | **€ -** | **€ -** | **€ -** | **€ -** | **€ -** | **€ -** |
| GM-A | -€ 145 | € 568 | -€ 1.125 | € 196 | -€ 622 | -€ 1.252 | € 832 | -€ 2.083 | € 648 | -€ 2.147 | € 276 | -€ 1.050 |
| GM-B | -€ 145 | € 568 | -€ 1.125 | € 196 | -€ 622 | -€ 1.252 | € 832 | -€ 2.083 | € 648 | -€ 2.147 | € 276 | -€ 1.050 |
| GM-C | -€ 145 | € 568 | -€ 1.125 | € 196 | -€ 622 | -€ 1.252 | € 832 | -€ 2.083 | € 648 | -€ 2.147 | € 276 | -€ 1.050 |
| **GM-Ent** | **-€ 145** | **€ 568** | **-€ 1.125** | **€ 196** | **-€ 622** | **-€ 1.252** | **€ 1.982** | **€ 478** | **€ 699** | **€ 1.021** | **€ 368** | **€ 1.807** |

### 6.3.2. GM scenario comparison

DIV and BAU scenarios allow to compare the overall economic results obtained across the two years by these 2 different cropping systems, compare their results with performances obtained by the most common use of land, identified by the BAS scenario.

The DIV scenario reports the data from the experimental plots where the farmers follow the indications on rotation and multiple cropping defined by the hypothetical contractual agreement. In all CSs diversification practices were driven by the same co -defined items, that included strategic aspects (use of land), technical indications (low input) and management (new business tool).

The BAU scenario refers to the economic performance calculated with the data from the plots that farmers manage according to their market expectations and business decisions.

In other word, in these scenario, crops are distributed according to the experimental schemes reported above, where arable land was allocated in equal amount per each crop yearly.

The BAS scenario instead reconstructs a condition in which the allocation of crops follow the most practiced cropping scheme in the reference area. For the BAS scenario, it was assumed that tomato crop occupied every year the 2/3 of the total used arable area, while the remaining 1/3 was cultivated with durum wheat. In this way the comparison is made possible, observing the average profitability of one hectare in rotation according to the common Tomato-Tomato-Durum Wheat scheme.

So, considering an intermediate period of two years, the annual costs and revenues of each crop have been allocated according to the land uses proposed in different scenarios.

Based on data shown in previous tables, costs, revenues and GMs values were reported to a common land unit (1 hectare under rotation) defined under the three-scenario conditions. Table 6.6 shows the results, expressed as the weighted sum of the results obtained in the two years, for all three scenarios in each CS.

To better understand the impact of diversification on CSs arable land profitability, the 2 year GMs per hectar values obtained from DIV and BAU scenario was compared to the baseline GMs calculated in the referring BAS scenario.

As shown in the table 6.7, CS5 and CS6 GM-A level on DIV systems respectively report a positive increase of 10% and 5% compared to the BAS condition, while CS7 reveals a substantial negative difference, with the GM amount under the DIV scenario being 98% less than in the BAS scenario.

In CS7, crops' management is entrusted by contract to and external manager, so GMs A-B-C have the same value. However, in both BAU and DIV scenarios GM is worse than the BAS.

CS7 result is due to unpredictable negative conditions recorded for the second harvest of tomato and the introduction of the pea crop, in both agrarian years. Nevertheless, the DIV system allows to reduce the amount of losses by 37%, also where BAU scenario provides tomato monoculture in both years.

**Table 6.6.** *CSs - 2 year crop rotation scenario - Per hectare Gross Margin accounting*

| CROP ROTATION | CS5 | | | CS6 | | | CS7 | | |
|---|---|---|---|---|---|---|---|---|---|
| 2Years | BAS | BAU | DIV | BAS | BAU | DIV | BAS | BAU | DIV |
| Land Use | T-T-DW | C-C | T-(P)T-DW | T-T-DW | W-B | T-(P)T-DW | T-T-DW | T-T | T-(P)T-DW |
| **Revenues** | **€ 8.854** | **€ 4.885** | **€ 10.576** | **€ 7.875** | **€ 2.536** | **€ 11.395** | **€ 5.003** | **€ 5.396** | **€ 9.469** |
| GSP | € 8.094 | € 4.125 | € 8.536 | € 7.115 | € 1.776 | € 7.673 | € 4.173 | € 4.566 | € 4.333 |
| Direct Payment CAP | € 760 | € 760 | € 760 | € 760 | € 760 | € 760 | € 830 | € 830 | € 830 |
| Coupled Subs. (PP;AEC) | € - | € - | € 293 | € - | € - | € 410 | € - | € - | € 293 |
| Insurance | € - | € - | € 986 | € - | € - | € 2.552 | € - | € - | € 4.013 |
| **Technical Inputs** | **€ 2.476** | **€ 1.487** | **€ 2.533** | **€ 2.836** | **€ 626** | **€ 3.000** | **€ 2.556** | **€ 3.439** | **€ 3.014** |
| Seed | € 723 | € 600 | € 853 | € 1.153 | € 298 | € 1.335 | € 1.101 | € 1.454 | € 1.452 |
| Fertilizers | € 1.024 | € 320 | € 886 | € 886 | € 319 | € 753 | € 772 | € 1.166 | € 771 |
| Pesticide | € 729 | € 567 | € 793 | € 797 | € 10 | € 913 | € 684 | € 819 | € 790 |
| **Cultivation Operations** | **€ 2.626** | **€ 1.296** | **€ 2.649** | **€ 2.384** | **€ 593** | **€ 2.657** | **€ 3.039** | **€ 3.830** | **€ 3.323** |
| Land preparation | € 253 | € 122 | € 194 | € 262 | € 250 | € 306 | € 399 | € 438 | € 551 |
| Seeding/Transplant | € 355 | € 293 | € 313 | € 176 | € 50 | € 195 | € 457 | € 620 | € 487 |
| Treatment | € 260 | € 120 | € 245 | € 225 | € 10 | € 223 | € 557 | € 500 | € 529 |
| Fertilization | € 70 | € 113 | € 76 | € 35 | € 16 | € 41 | € 147 | € 95 | € 167 |
| Secondary Works | € - | € - | € - | € 11 | € 8 | € 16 | € 26 | € 39 | € 26 |
| Irrigation | € 135 | € 389 | € 182 | € 229 | € - | € 346 | € 173 | € 338 | € 204 |
| Harvest | € 1.553 | € 260 | € 1.640 | € 1.447 | € 260 | € 1.535 | € 1.280 | € 1.800 | € 1.360 |
| **Insurance** | **€ -** | **€ -** | **€ 713** | **€ -** | **€ -** | **€ 1.074** | **€ -** | **€ -** | **€ 1.014** |
| **Own labour** | **€ 494** | **€ 467** | **€ 642** | **€ 553** | **€ 155** | **€ 661** | **€ -** | **€ -** | **€ -** |
| **Fixed cost** | **€ 798** | **€ 401** | **€ 831** | **€ 596** | **€ 85** | **€ 570** | **€ -** | **€ -** | **€ -** |
| GM-A | € 3.753 | € 2.102 | € 4.115 | € 2.655 | € 1.317 | € 2.776 | -€ 593 | -€ 1.874 | -€ 1.175 |
| GM-B | € 3.259 | € 1.635 | € 3.472 | € 2.102 | € 1.162 | € 2.115 | -€ 593 | -€ 1.874 | -€ 1.175 |
| GM-C | € 2.460 | € 1.234 | € 2.641 | € 1.506 | € 1.077 | € 1.545 | -€ 593 | -€ 1.874 | -€ 1.175 |
| **GM-Ent** | **€ 2.460** | **€ 1.234** | **€ 3.207** | **€ 1.506** | **€ 1.077** | **€ 3.434** | **-€ 593** | **-€ 1.874** | **€ 2.118** |

**Table 6.7.** *2 year crop rotation GMs delta between DIV, BAS and BAU conditions*

| 2 years - Scenarios | GM-A | | | GM-B | | | GM-C | | |
|---|---|---|---|---|---|---|---|---|---|
| (Cropping Systems) | €/ha | *Δ BAS* | *Δ BAU* | €/ha | *Δ BAS* | *Δ BAU* | €/ha | *Δ BAS* | *Δ BAU* |
| **CS-5** | | | | | | | | | |
| BAS (T-T-DW) | € 3.753 | - | - | € 3.259 | - | - | € 2.460 | - | - |
| BAU (C -C) | € 2.102 | *-44%* | - | € 1.635 | *-50%* | - | € 1.234 | *-50%* | - |
| DIV (T -PT-DW) | € 4.115 | *10%* | *96%* | € 3.472 | *7%* | *112%* | € 2.641 | *7%* | *114%* |
| **CS-6** | | | | | | | | | |
| BAS (T-T-DW) | € 2.655 | - | - | € 2.102 | - | - | € 1.506 | - | - |
| BAU (W-B) | € 1.317 | *-50%* | - | € 1.162 | *-45%* | - | € 1.077 | *-28%* | - |
| DIV (T-PT-DW) | € 2.776 | *5%* | *111%* | € 2.115 | *1%* | *82%* | € 1.545 | *3%* | *43%* |
| **CS-7** | | | | | | | | | |
| BAS (T-T-DW) | -€ 593 | - | - | -€ 593 | - | - | -€ 593 | - | - |
| BAU (T-T) | -€ 1.874 | *-216%* | - | -€ 1.874 | *-216%* | - | -€ 1.874 | *-216%* | - |
| DIV (T-PT-DW) | -€ 1.175 | *-98%* | *37%* | -€ 1.175 | *-98%* | *37%* | -€ 1.175 | *-98%* | *37%* |

Looking at GM-B and GM-C, that also include implicit variable costs (own and family work and fixed costs quota respectively), □BAS values confirms a positive impact of DIV options in CS5 and CS6.

In CS5 a positive trend is reported in all GMs levels, these show on average a better performance of DIV scenario compared to the BAS one. For CS6, the DIV scenario shows a general positive impact, with a slight increase of GM-B and GM-C levels (1% and 3%, respectively).

These results confirm that in the observed farms, specialized on industrial crops, the increase of workloads and the higher use of machineries due to the introduction of multiple cropping do not substantially affect the potential of land profitability.

Looking at BAU, it is clear that in all cases the multiple-crop and low-input practices options improve the GMs results with respect to the BAU condition; this also happens in CS7, where BAU scenario includes two-year tomato monoculture.

These results allow to accept $H1_A$: despite the uncertainty of prices and yields for the new crops introduced, DIV systems are able to improve GM levels compared to BAS conditions and to improve gains (CS5, CS6) or reduce losses (CS7) compared to BAU monoculture scenarios.

To contextualize the total impact of DIV scenario, table 6.8 show how the entrepreneurship dimension positively affects the land profitability. Looking at GM-Ent delta in both DBAS and DBAU condition, positive differences are recorded in all CSs. Profitability of DIV arable land increases by 30% in CS5, 128% in CS6 and 457% in the CS7 compared to the BAS scenario.

As described before, unfavorable weather conditions negatively affect crops production, especially for CS7; when these situations occur, insurance tools may help avoiding economic losses. Across the two years, the GM level moves from -593 €/ha to 2,118 €/ha in CS7 and from 1,545 to 3,434 in CS6. For CS5, there aren't serious yield losses, and multi-year contract conditions allow farmer to obtain the 30% of positive increase compared to BAS condition.

**Table 6.8.** *2 year GM-C and GM-Ent delta BAS an BAU comparison*

| 2 years Scenario (Cropping Systems) | GM-C | | | GM-Ent | | |
|---|---|---|---|---|---|---|
| | €/ha | *Δ BAS* | *Δ BAU* | €/ha | *Δ BAS* | *Δ BAU* |
| **CS-5** | | | | | | |
| BAS (T-T-DW) | € 2.460 | - | - | € 2.460 | - | - |
| BAU (C -C) | € 1.234 | *-50%* | - | € 1.234 | *-50%* | - |
| DIV (T -PT-DW) | € 2.641 | *7%* | *114%* | € 3.207 | *30%* | *160%* |
| **CS-6** | | | | | | |
| BAS (T-T-DW) | € 1.506 | - | - | € 1.506 | - | - |
| BAU (W-B) | € 1.077 | *-28%* | - | € 1.077 | *-28%* | - |
| DIV (T-PT-DW) | € 1.545 | *3%* | *43%* | € 3.434 | *128%* | *219%* |
| **CS-7** | | | | | | |
| BAS (T-T-DW) | -€ 593 | - | - | -€ 593 | - | - |
| BAU (T-T) | -€ 1.874 | *-216%* | - | -€ 1.874 | *-216%* | - |
| DIV (T-PT-DW) | -€ 1.175 | *-98%* | *37%* | € 2.118 | *457%* | *213%* |

Other interesting findings are related to DIV and BAU GM-Ent levels comparison. In CS5 and CS6, DIV scenarios show positive high values, mainly due to the absence of tomato in the BAU cropping systems. Instead, in CS7, where the BAU condition consists of two-year monoculture, the 213% increase is due to insurance compensation, subsides and the premium price provided by multi-year contracts.

Looking at the first two years, hypothesis 2 can be accepted. All CSs performances confirm that diversified cropping systems implementation should be driven by risks mitigation tool and multi-year contracts. These solutions can improve the GMs level compared to the baseline situation, as well as to monoculture scenarios both in worst and normal climatic conditions.

## 6.4. Discussion

In all North-Med cases, the transition to a DIV system led to an improvement in the average profitability of one hectare of arable land compared to the BAS and BAU scenarios. The results are based on a "cash-flow" approach, minimizing assumptions on yields and prices to return a picture as close as possible to reality. This approach also helps to be more convincing towards farmers, who request neutrality and an appropriate jargon to their usual speaking especially when results are shown to them.

The choice of the multiple-crop option has allowed tomato cultivation in both years and facilitated farmers' access to available and well-known insurance systems. At the same time, in the first two years this choice allowed farmers to recognize the difficulties caused by the activation of the second harvest tomato. In contrast to the initial expectations, the technical problems of growing this crop in a very short cycle (less than 4 months) can reflect negatively on the overall GMs result. To avoid this risk, in the future, a multi-year contract should include stricter restrictions on the activation of this crop.

Similarly, the yields of pea cultivation should be included in an insurance system, designed similarly to that of tomato. In this case, insurance systems applicable for all the duration of the rotation required by the contract might be envisaged.

As reported, the higher profitability of DIV systems compared to BAS is mainly due to the contractual component. In addition to insurance benefit, the extra-revenues due to other multi-year commitments also played an important role. In the DIV scenario, the subsidies of the RDPs' AEC measures and the per hectare premium for durum wheat allowed farmers to recognize an overall positive result.

Nevertheless, to evaluate the potential impact on GM values due to transition from high specialized to most diversified cropping systems, it is necessary to compare the results obtained during the entire period of the rotation examined. More attention should be dedicated to the estimation of other costs, especially those related to implicit or hidden costs at farm and processor gate level, taking into account financial and organizational aspects related to long term economic evaluation.

The re-configurations of agri-food industries forms generate the so called transition costs (Grandori, 2015) as well as including potential additional fees due to the introduction of new crops, e.g. costs to acquire new knowledge about technical issues (including variety and input choice and doses) and to manage the risks due to "unknown" crops and their market. With respect to the latter issue, during the first year of experiment, seed and plant procurement was more complicated with respect to farmers' usual business. In all CSs, Casalasco's technicians provided unusual extension services to engaged farmers, they dedicated to them more time and faced new and more numerous requests. Hence, to obtain similar results in a real condition, farmer should be involved in additional activities focused to increase their competence and knowledge about new crops and new arable land management.

Looking at agri-food buyers' activities, some extra costs should be accounted, especially considering that they have to deal with new ways to manage the supply of their raw materials. Thanks to this collaboration potential constraints about multi-year and multi-crops agreements will be discussed and their impact will be mitigated through multi-actor negotiation processes (Pancino et al, 2019). Following the diversification experience, food processors' managers should change their usual pre-agreement activities to set up new modes to define contracts that are suitable for farmers and for other agri-food industries managers.

Finally, risks' management and multi-year contract will be facilitated by more consistent output-based payment schemes. Namely, a partially-guaranteed price system might be able to meet farmers' requests and, at the same time, to distribute the risk of crop diversification failure among all up-stream supply chain operators.

## 6.5. Conclusion

This report presents a first impact assessment of the adoption of diversification practices adoptions on GMs levels in North-Med CSs. Synergies between multiple crop-rotation and new business tools are evaluated considering Diverfarming farming activities developed on CS5-6-7. Looking at the first two years of experiment we can affirm that co-defined and multidimensional diversifications options mitigated the effect of climatic and market instability on gross margin, compared to current crop management in the area.

In the cases analysed, the land profitability achieved can be used to evaluate the impacts of medium-term real choices suitable to several upstream food supply chain actors' capabilities. The analysis showed how proposing a package of technical and business practices highlights the convenience to follow a diversification approach even in highly specialized settings.

To validate the effectiveness of the diversified multi-year system, the three hypotheses will be subject to further analysis at the end of the third year of rotation. In particular, the quantification of the environmental benefits will be done using data gathered in WP3-5 and 7, and applying an ecological footprint approach.

Thanks to these new analyses, starting from the third year the DIV proposal might emerge as a win-win solution (Garbach et al 2016), where both economic and ecological indicators show positive trend compared to BAS and BAU systems.

The environmental benefits associated with DIV management compared to the other scenarios will be monetized using data from GMs assessment and results carried out from non-market evaluation, already done in the same areas (D8.2). This analysis has shown that the citizens of the area have a willingness to pay for the protection of ecosystem services, especially for the quality of water and the protection of biodiversity, both of which are facilitated by the crop diversification systems proposed in the CSs.

Results confirm that public policies have to continue supporting the transition from BAS to DIV scenario to obtain benefits that can reach social demands, looking at citizens and rewarding agri-food operators. Considering the CSs framework, the -Farm-To-Fork EU strategy and CAP reform, might be useful to reframe clustering and networking across supply chains, by supporting them in the identification of new market-based tools to minimize the risk of failure associated to the adoption of diversification schemes.

To pull farmers in this new technical-managerial path, it is necessary to increase the relationships between farmers & farmers as well as between farmers and other value chain actors and advisors. For this reason, Be a Diverfarmer as well as other communities of practitioner, have to include specific strategies focused on adapting new managerial and contract solutions to socioeconomic, pedo-climatic and supply chain features in their agenda.

## 6.6. References

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# 7. CS 8 Biodynamic dairy farm in the Netherlands – Intercropping for fodder (maize/beans)

## 7.1. Case study description

Case study 8 is a biodynamic dairy farm that is organic and Demeter certified. Demeter Biodynamic Certification is used in over 50 countries to verify that biodynamic products meet international standards in production and processing (Biodynamic Association, 2020a). The farm is located in the northern province of Groningen in the Netherlands. This case study focuses on crop production for fodder. The farm has about 90 cows producing approximately 700,000l of milk per year (averaging to 7,778 kg/cow/year). The farm owns 73 ha of land and rents an additional 10 ha. Currently, the rotation used on the farm uses approximately 7 years of grass clover, followed by 1 year of a maize monocrop, followed by 1 year of a triticale-peas intercrop.

The farm currently sells both raw milk, as well as dairy products, such as cheese, butter and yoghurt, processed on the farm. It is run by the farmer himself and his wife who focuses on dairy processing. The farm work is supported by the farmer’s parents who work part time. The total family work input at the farm is approximately 3 full -time equivalents (FTE). Additionally, the milk and dairy production is often supported by 2-3 interns at a time.

Roughly 83% of milk production is sold as raw milk to a dairy processor. This is the source of approximately 71% of the farms revenues. The remaining 17% of milk are processed on-farm in the family-operated cheese factory and sold to organic supermarkets and local stores.

Some cows are also sold for slaughter as well as to other farmers for milk production or breeding. However, this is peripheral to the farm operation.

Since this is an organic and biodynamic farm, there are few purchases of external inputs (Biodynamic Association 2020b). Sources of costs lie mostly with the purchase of seeds, and machine maintenance and rental. Most fodder is produced on farm. Still, the farmer purchases a high protein feed concentrate as additional fodder for the cows in the winter months. Most of the work is covered by family labour, supported by interns.

## 7.2. Materials and methods

### 7.2.1. Diversification strategy pursued

The diversification strategy tested as part of the Diverfarming project diversifies the farmer’s maize monocrop with beans as an intercrop. Two ratios were tested against the maize monocrop: a 70%-30% maize-bean ratio, and a 60%-40% ratio (Figure 7.1).

In these experimental plots no difference in yields was observed (approximately 50 tons per ha for all plots). Further, in this case, we do not expect a yield decline for the monoculture field over time. The current rotation on the farm is 7 years of grass clover, followed by maize, then a triticale-peas intercrop. Thus, even in the case of monoculture of maize, the overall rotation is quite diversified already and includes long periods of grass clover for soil restoration.

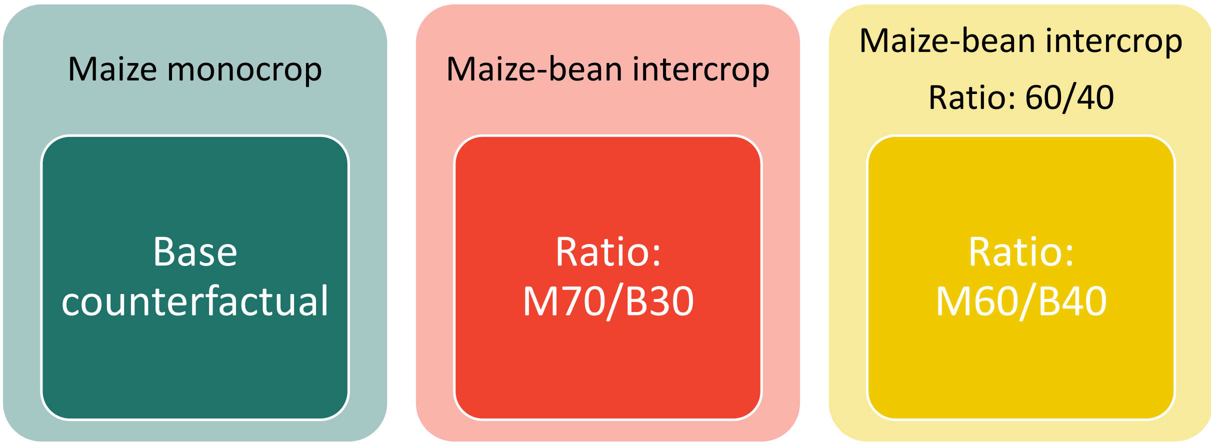


***Figure 7.1:*** *Experimental setup in CS8*

### 7.2.2. Motivation

For this farmer, the feeling of stewardship for land and soil, and increased autonomy and self-sufficiency are the main drivers to pursue an additional diversification strategy. The intercropping of maize and beans increases the protein content of this source of fodder and as a consequence reduces the reliance on purchased feed concentrate. The farmer would thus be less affected by market changes for this input and be more autonomous. This autonomy has also another benefit according to the farmer. He wants to tell a story with his products. For that purpose, he aims to be fully local and wants to have full control over everything that goes into the cows. He would rather feed them with the best grass all year around, than concentrate or maize. However, this is not possible, and the maize and beans combination may be the solution to provide sufficient protein for the cows in the winter months while still improving the farm's self-sufficiency and preserving milk quality.

### 7.2.3. Methods and data

This analysis is based on data collected in 2019 and 2020 directly from the farmer. It uses the farm's real input use (seeds and feed concentrate) and prices paid. The calculations are based on the assumption that the farmer switches all current maize monocrops (5 ha) over to a maize-bean intercrop. According to the farmer, the switch to either intercrop would replace 10-15% of the farm's current 60 ton feed concentrate purchases while holding milk quantity and quality constant. This implies that despite the potentially higher protein content of the 60/40 intercrop compared to the 70/30 intercrop, we will assume that their replacement rate of feed concentrate is the same. The reason for this assumption is that the replacement rate could not be based on an in-depth analysis of actual protein content in the intercrop and/or real-life testing of the effects of replacing the feed concentrate. Therefore, the different replacement rates of each intercrop cannot be accurately determined. Instead, in order to improve the analysis' robustness, the outcomes are calculated not just for the estimated 10% and 15% replacement of feed concentrate, but also for 5% and 20% replacement. This gives an overview of different replacement rates for both intercrops, even should the real replacement rates differ between the intercrops. Further, a price sensitivity analysis was executed to challenge the results' sensitivity to both increases in seed as well as feed concentrate prices.

The case study managers and farmer believe this calculation to be useful for estimating the financial feasibility of further diversifying the farm's fodder production. Further, due to the farmer's long-term experience with the triticale-pea intercrop on his farm, the farmer is deemed to be best and most knowledgeable source to make such a replacement rate estimate.

### 7.2.4. Expected effects on costs and revenues

Since the case study farm is a biodynamic farm that uses no chemical and hardly any external inputs in crop production regardless of diversification, we do not expect a change in, e.g., fertiliser use for this case study. All manure used on the fields comes from the farm itself and is used equally on all experimental plots. According to the farmer, there is also no difference in labour or machinery use across the experimental plots for all activities such as land preparation and seeding, harvesting or storage. The only difference in cost is the cost of seeds for the different experimental plots since seeds for beans are more expensive than those for maize. Farm revenues do not change due to diversification since the crop production is for internal use as fodder and output value chains do not change.

Thus, for this case, it was decided that calculating gross margins is less useful than in other cases. We are not expecting any cost reduction in inputs, yield effects are likely very small and the crops grown with diversification never actually leave the farm since they are used as fodder in dairy production. Thus, there is no revenue from crop production to be calculated either. However, if the maize-bean intercrop can indeed replace the purchased feed concentrate, there is an economic impact of the diversification strategy to be calculated. Accordingly, the below hypotheses are not based on scientific literature but on the needs of the empirical context.

The hypotheses proposed take into account cost savings on additional fodder purchases that could now be replaced with the intercrop grown on-farm. The intercrop with beans, in comparison to the maize monocrop is higher in protein and can therefore replace (part of) the high-protein feed concentrate the farmer currently buys to supplement fodder for his cows, while maintaining dairy production and quality. Since input use is the same for both the mono- and the intercrop, the only expected extra cost of the intercrop is the cost of seeds.

### 7.2.5. Hypotheses

The following hypothesis is being modelled and illustrated in Figure 7.2:

**H0: Diversification will give no significant cost savings.**

**H1: Cost savings from concentrate will outweigh extra cost of seeds.**

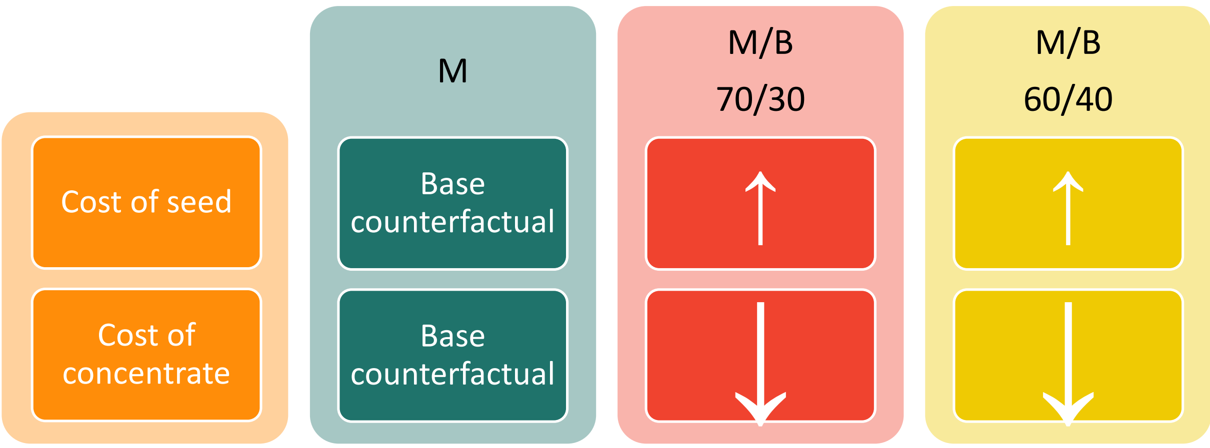


***Figure 7.2:*** *Hypothesis to be modelled in CS8*

# 7.3. Results

## 7.3.1. Results at current prices

The first calculation estimated possible cost savings at current reported prices (Table 7.1). The estimated results are based on the assumption of a switch from 5 ha maize monocrop to a 5 ha intercrop, either at a 70-30 ration or a 60-40 ration of maize to beans. Each hectare is planted with 100,000 seeds.

***Table 7.1:*** *Current prices*

| Current prices as reported by the farmer | | |
|---|---|---|
| Seeds for maize | 129 € | €/50,000 seeds |
| Seeds for beans | 240 € | €/30,000 seeds |
| Feed concéntrate | 0.42 € | €/kg |

The results are estimated for an assumed 5%, 10%, 15% and 20% decrease in feed concentrate to add robustness to the farmers' estimation of a 10%-15% reduction. As shown in Table 7.2, even if feed concentrate is reduced by only 5%, the cost savings are still large enough to justify the extra cost of the more expensive bean seeds. However, cost savings are rather modest. At higher replacement rates, the yearly cost savings become much more significant, especially considering that there is no extra labour or other extra cost associated with the switch to the intercrop. While the cost savings are smaller for the 60/40 intercrop ratio due to the higher percentage of the more expensive bean seeds, this may still be desirable if the experimental plots for this ratio show additional improvements in soil health. In comparison to the monocrop, the financial results of the 60/40 intercrop are still positive. Further, while the farmer does not expect this to make a difference, a higher percentage of beans in the intercrop could also lead to higher protein content and thus a larger reduction in feed concentrate. Hence we assume that the protein content of feed grown at 70/30 and 60/40 shares are the same and thus the same amount of purchased protein feed supplement can be avoided at both shares of maize/beans seeds. Overall, at current prices, even modest decreases of feed concentrate due to the intercrop are estimated to lead to modest cost savings. These cost savings become increasingly more significant if more feed concentrate can be replaced by the intercrop.

***Table 7.2:*** *Cost savings at current prices*

| Cost savings in € per year when reducing purchases of feed concentrate | | | | |
|---|---|---|---|---|
| **Treatment** | **At 5% reduction** | **At 10% reduction** | **At 15% reduction** | **At 20% reduction** |
| Maize mono | 0 | 0 | 0 | 0 |
| Maize-bean 70/30 | 447 | 1,707 | 2,967 | 4,227 |
| Maize-bean 60/40 | 176 | 1,436 | 2,696 | 3,956 |

### 7.3.2. Results at 5% price increase for bean seeds

This calculation assumes a 5% increase in the price of bean seeds (Table 7.3). The estimated results are again based on the assumption of a switch from 5 ha maize monocrop to a 5 ha intercrop, either at a 70-30 ration or a 60-40 ration of maize to beans. Each hectare is planted with 100,000 seeds.

***Table 7.3:*** *Prices with 5% price increase for bean seeds*

| Prices as reported including 5% increase in price of bean seeds | | |
|---|---|---|
| Seeds for maize | 129 € | €/50,000 seeds |
| Seeds for beans | 252 € | €/30,000 seeds |
| Feed concentrate | 0.42 € | €/kg |

Again, the results are estimated for an assumed 5%, 10%, 15% and 20% decrease in feed concentrate to add robustness to the farmers estimation of a 10%-15% reduction. As Table 7.4 shows, even if bean seeds become 5% more expensive than measured, even at only a 5% reduction in feed concentrate, there are still small cost savings estimated. At higher replacement rates, savings are of course smaller than at current prices but still significant.

***Table 7.4:*** *Cost savings at 5% increase in bean seed prices*

| Cost savings in € per year when reducing purchases of feed concentrate | | | | |
|---|---|---|---|---|
| **Treatment** | **At 5% reduction** | **At 10% reduction** | **At 15% reduction** | **At 20% reduction** |
| Maize mono | 0 | 0 | 0 | 0 |
| Maize-bean 70/30 | 387 | 1,647 | 2,907 | 4,167 |
| Maize-bean 60/40 | 96 | 1,356 | 2,616 | 3,876 |

### 7.3.3. Results at 10% price increase for bean seeds

This calculation assumes a 10% increase in the price of bean seeds (see table 7.5). The estimated results are again based on the assumption of a switch from 5 ha maize monocrop to a 5 ha intercrop, either at a 70-30 ration or a 60-40 ration of maize to beans. Each hectare is planted with 100,000 seeds.

*__Table 7.5:__ Prices with 10% price increase for bean seeds*

| Prices as reported including 10% increase in price of bean seeds | | |
|---|---|---|
| Seeds for maize | 129 € | €/50,000 seeds |
| Seeds for beans | 264 € | €/30,000 seeds |
| Feed concentrate | 0.42 € | €/kg |

Again, the results are estimated for an assumed 5%, 10%, 15% and 20% decrease in feed concentrate to add robustness to the farmers estimation of a 10%-15% reduction. Table 7.6 indicates that at a 10% price increase for bean seeds, intercropping may become riskier if the replacement rate is set at 5%. This implies that particularly in the case of increasing bean seed prices, choosing for the 70/30 ratio in intercropping would likely be the less risky decision. For this ratio, cost savings remain even at increased bean seed prices and lower replacement rates of feed concentrate. This, however is dependent on the assumption that the same protein content of the feed is attained at both 70/30 seed and 60/40 seed mix.

*__Table 7.6:__ Cost savings at 10% increase in bean seed prices*

| Cost savings when reducing purchases of feed concentrate | | | | |
|---|---|---|---|---|
| **Treatment** | **At 5% reduction** | **At 10% reduction** | **At 15% reduction** | **At 20% reduction** |
| Maize mono | 0 | 0 | 0 | 0 |
| Maize-bean 70/30 | 327 | 1,587 | 2,847 | 4,107 |
| Maize-bean 60/40 | 16 | 1,276 | 2,536 | 3,796 |

### 7.3.4. Breakeven point for bean seed price increases

This section shows at what increase of bean seed prices the intercrop breaks even, assuming the lowest estimate of replacement of feed concentrate of 5%. As Table 7.7 illustrates, while the 60/40 maize bean ratio is more sensitive to bean price increases and starts costing money at a price increase of 11%, the 70/30 maize bean ratio is rather robust and provides cost savings up until a price increase of over 37%. Of course, if the replacement rate of feed concentrate is higher than 5%, as estimated by the farmer, the cost savings become even more robust to bean seed price increases.

*Table 7.7:* Breakeven points for the different maize-bean intercrop ratios

| Cost savings breakeven points for increased bean seed prices | | |
|---|---|---|
| | Bean seed price increase of 11% (266.40€ per 30.000 seeds) | Bean seed price increase of 37.25% (329.40€ per 30.000 seeds) |
| Maize-bean 70/30 | 315 € per year | 0 € per year |
| Maize-bean 60/40 | 0 € per year | -420 € per year |

### 7.3.5. Results at 5% price increases for feed concentrate

This section describes the cost savings estimated if feed concentrate increases by 5%. All other assumptions remain the same. Table 7.8 shows the prices on which this calculation is based.

**Table 7.8:** Prices with 5% price increase for feed concentrate

| Cost savings when reducing purchases of feed concentrate | | | | |
|---|---|---|---|---|
| Treatment | At 5% reduction | At 10% reduction | At 15% reduction | At 20% reduction |
| Maize mono | 0 | 0 | 0 | 0 |
| Maize-bean 70/30 | 510 | 1,833 | 3,156 | 4,479 |
| Maize-bean 60/40 | 239 | 1,562 | 2,885 | 4,208 |

The results show that costs savings due to intercropping range between approximately 200€ and almost 4500€, depending on the seed ratio used and the amount of feed concentrate replacement rate. Regardless, there are cost savings and, of course, the more concentrate prices rise, the more financially attractive it becomes to use the intercrop and reduce the purchase of feed concentrate.

*Table 7.9:* Cost savings at 5% increase in feed concentrate prices

| Cost savings when reducing purchases of feed concentrate | | | | |
|---|---|---|---|---|
| Treatment | At 5% reduction | At 10% reduction | At 15% reduction | At 20% reduction |
| Maize mono | 0 | 0 | 0 | 0 |
| Maize-bean 70/30 | 510 | 1,833 | 3,156 | 4,479 |
| Maize-bean 60/40 | 239 | 1,562 | 2,885 | 4,208 |

### 7.3.6. Results at 10% price increases for feed concentrate

This section describes the cost savings estimated if feed concentrate increases by 10%. All other assumptions remain the same.

***Table 7.10:*** *Prices with 10% price increase for feed concentrate*

| Prices as reported including 10% increase in price of feed concentrate | | |
|---|---|---|
| Seeds for maize | 129 € | €/50,000 seeds |
| Seeds for beans | 240 € | €/30,000 seeds |
| Feed concéntrate | 0.46 € | €/kg |

The results show that, of course, with rising prices for feed concentrate, the financial payoff of the intercrop increases. If 10% increase in feed concentrate prices, there is a rather stable payoff of the intercrop across different estimates of replacement rates that reaches up to 4700 € per year.

***Table 7.11:*** *Cost savings at 10% increase in feed concentrate prices*

| Cost savings when reducing purchases of feed concentrate | | | | |
|---|---|---|---|---|
| **Treatment** | **At 5% reduction** | **At 10% reduction** | **At 15% reduction** | **At 20% reduction** |
| Maize mono | 0 | 0 | 0 | 0 |
| Maize-bean 70/30 | 573 | 1,959 | 3,345 | 4,731 |
| Maize-bean 60/40 | 302 | 1,688 | 3,074 | 4,460 |

## 7.4. Discussion and limitations

The main motivation and economic benefits of diversification indicated by the farmer are difficult to quantify. For this farmer, the feeling of stewardship for land and soil, and increased autonomy and self-sufficiency due to less reliance on purchased feed concentrate were named as the main drivers for diversification. While we can analyse whether there is indeed potential for a decrease in purchased feed, the above benefits cannot be accurately quantified.

A further issue is the exact quantification of feed concentrate replaced by the intercrop. This requires not only the measurement of yields but technically also a measurement of the exact protein contents of the crop, or a controlled real-life test. This was unfortunately not feasible as part of this project. Therefore, we relied on the farmer's estimates on feed replacement and then we calculated the resulting economic consequences based on the results of the experimental fields as reported by the farmer (crop yields, amount of seeds used, inputs and labour used). This is however expected to be a good estimate since the farmer already has experience with a similar intercrop (triticale-peas). The use of different price levels gives further robustness to the results.

We assume these results to apply particularly to organic livestock farmers that currently already produce maize some protein rich fodder (e.g triticale-pea) for their livestock but additionally purchase protein rich feed. Organic farmers are likely to also have no change in other inputs with the exception of the protein crop seeds. If they are already producing similar fodder, they are likely to already own the machinery needed. Since the crop never leaves the farm but is fed to livestock on farm, no separation of the intercrop is needed. It should be noted that no decrease of overall yield was observed between the different experimental plots. However, this may not always be the case in different pedoclimatic regions.

## 7.5. Conclusions

The presented calculations show that at current prices, there is a rather clear financial gain to the maize bean intercrop tested in this project if used to replace feed concentrate, at little to no extra effort. These gains become smaller if bean seed prices increase. However, particularly for the 70/30 maize bean intercrop, gains are rather robust to price increases. Even at an assumed replacement rate of just 5%, prices of bean seeds would have to rise more than 37% to take away the financial gains of this intercrop. At the estimated replacement rates given by the farmer (10-15%), across all price scenarios, cost savings are above 1000€ per year and reach up to above 3000€ per year. These calculations show that, given the results of the experimental plots of the Diverfarming project and the estimated replacement rates of feed concentrate, there is a clear financial gain from implementing crop diversification in the described manner.

## 7.6. References

Biodynamic Association 2020a. Demeter past and present Referenced July 8 2020 https://www.biodynamics.com/demeter-past-and-present

Biodynamic Association 2020b. Biodynamic Principles and Practices. Referenced July 8 2020 https://www.biodynamics.com/biodynamic-principles-and-practices

# 8. CS 9 Economic assessment of a diversified vineyard (intercropping with herbs) in Germany

## 8.1. Case study description and motivation of the study

This vinery is located is located in the village of Kanzem at the Saar-River (wine region Mosel in Germany). The vinery with organic certification produces typical regional grape wines (Riesling and Weißburgunder (pinot blanc)) because these are best adapted to soil and climate of steep slate hills (https://www.weingutdrfrey.de/html/vinery.html).

We are investigating the effects of intercropping herbs (thyme and oregano; Thymus vulgaris and Origanum vulgare) on vine plants, wine quality and quantity as well as on farm economy in a wineyard (0.3 ha). In general, the current land management practises take care that the area under the vine plant is free of vegetation (mechanical or chemical). The vineries follow the assumption that this area is most important for the water- and nutrient supply of the vine plants, so competing weeds are unwanted. Organic wineries use specialized machines or hand-hoes for weeding. Conventional wineries often use herbicides.

Answers are expected to the following questions:

- Is a successful cultivation of these herbs in the wineyard possible without negative effects on the quantity and quality of the wine? Are there positive (or negative) effects on the vine plant and wine-quality and –quantity?
- Which are the impacts on soil (erosion, water-capacity and water-availability, humus-balance), on other abiotic factors (e.g. greenhouse gas emission) and on biodiversity?
- Which are the direct and indirect quantifiable economic effects related to the wine-production and the production of the herbs? Which are the short-term and the long-term impacts on the profit of the winery?

## 8.2. Data

The project-idea is to implement an additional crop with the vine (intercropping). Selected crops should have a low demand to water and nutrients and a narrow growing habit as well. It could be seen that implementation of herbs in steep-sloping vineyards under the climatic conditions of the past two years is difficult, but possible. To get reliable figures for the economic analyses there have to be at least two years of establishment to see a more or less “normal” yield of the herbs. From 2019 on herbs could be harvested. At the time of writing, 2020 harvest is just ongoing.

For economic analyses following data was and will be collected: material- and labour-costs for the implementation of the diversified system (intercropping) in comparison to the costs for the monocrop wine-production on the test field. Furthermore, costs for post-harvest-treatments are measured and recorded. The view on the full-costs will show the short-time economic consequences for the winery, performing the intercropping system.

Different potential markets for the “co-product” herbs will be considered and their effect on the economic balance of the winery will be checked and compared. Gross-margin-analyses’ with and without an “intercropped-system” provide information on the economic value of intercropping for the vinery depending on different marketing-opportunities for the herbs. Collected data from work packages 4 and 5 (impacts of diversification on biodiversity and environment) are an important basis for non-market values of the diversification. These results, if made available in the context of CS 9, can be included in the economic view of the diversification (intercropping vineyards with herbs) in later studies.

# 8.3. First results

## 8.3.1. Costs and revenues

As far as it can be evaluated, intercropping with herbs has no negative effect on the costs of the wine-production, so profit of the wine-production remains the same in the short-term view with or without intercrops. Light variations in the harvest-quantity of wine cannot be explained by the intercrops.

The implementation of the considered intercropping system is labour-intensive and mainly for that reason it is also expensive. This is mostly due to the fact that machinery for planting and harvesting the herbs does not exist and most work has to be done by hand. Costs for the seedlings are quite high, too. Upscaling the production would reduce the costs in the future.

It was assumed that the herbs were planted for not less than 10 years, which can qualify the costs for implementation (gross-margin Tables 8.1 and 8.2). One direct cost-benefit of the intercrop-system is that costs for weeding the grapes (by machine, hand or with herbicide) can be reduced. Particularly in organic viticulture weeding can be a major cost-factor. Avoiding this cost must be considered as a revenue for intercropping activity. Gross-margin tables 8.1 and 8.2 show the effect: Without further processing (-costs) of the herbs, the reduced weeding costs can balance out the costs for the intercrop-implementation and management.

***Table 8.1.*** *Revenues (avoided viticulture weeding costs) and costs of establishing and maintaining Thymus as a cover crop, no oil extraction.*

| | € | quantity | value (€) | | | | |
|---|---|---|---|---|---|---|---|
| Market revenues | 0,00 € | 0 | 0,00 € | | | | no sales value |
| avoided weeding costs in vine skilled labour | 18,00 € | 25 | 450,00 € | | | | |
| avoided weeding costs in vine ordinary labour | 12,00 € | 60 | 720,00 € | | | | |
| avoided weeding costs machinery operation costs | 1,50 € | 60 | 90,00 € | | | | |
| **Gross on-farm value** | | | 1 260,00 € | | | | |
| | €/plant | quantity (pieces) | value (€) | | | | |
| **Total plant cost** | 0,15 | 25000 | 3 750,00 € | | once in 10 years ! | 375,00 € | costs/year |
| **Irrigation** | 1,75 | 140 | 245,00 € | | once in 10 years ! | 24,50 € | costs/year |
| | € | quantity | value (€) | | | | |
| Ordinary labour | 12,00 € | 324 | 3 888,00 € | | once in 10 years | 388,80 € | costs/year |
| Skilled labour | 18,00 € | 5,56 | 100,08 € | | once in 10 years | 10,01 € | costs/year |
| weeding herbs first and second year | 12,00 € | 100 | 1 200,00 € | | first 2 years | 120,00 € | costs/year |
| weeding herbs year 3-10 | 12,00 € | 30 | 360,00 € | | year 3-10 | 36,00 € | costs/year |
| mowing without collecting every year | 18,00 € | 2 | 36,00 € | | | 36,00 € | |
| **Total labour cost** | | | 5 584,08 € | | | 590,81 € | costs/year |
| Tractor | 11,41 | 2,55 | 29,1 | | | | |
| mulcher | 5,1 | 2 | 10,2 | | | | |
| electrical hand-hoe | 1,5 | 13 | 19,50 | | | | |
| **Total machinery operations cost** | | | 58,80 | | | | |
| **TOTAL VARIABLE COSTS (€/ha)** | | | **1 049,11 €** | | | | |
| GM A | | | **210,89** | | **€/ha** | | |
| GM B (no family labour utilized) | | | **210,89** | | **€/ha** | | |

*Table 8.2*. *Revenues (avoided viticulture weeding costs) and costs of establishing and maintaining Oregano as a cover crop, no oil extraction.*

| | € | quantity | value (€) | | | |
|---|---|---|---|---|---|---|
| Market revenues | 0,00 € | 0 | 0,00 € | | | no sales value |
| avoided weeding costs in vine skilled labour | 18,00 € | 25 | 450,00 € | | | |
| avoided weeding costs in vine ordinary labour | 12,00 € | 60 | 720,00 € | | | |
| avoided weeding costs machinery operation costs | 1,50 € | 60 | 90,00 € | | | |
| **Gross on-farm value** | | | 1 260,00 € | | | |
| | €/plant | quantity (pieces) | value (€) | | | |
| **Total plant cost** | 0,15 | 20000 | 3 000,00 € | once in 10 years | 300,00 € | costs/year |
| **Irrigation** | 1,75 | 140 | 245,00 € | once in 10 years ! | 24,50 € | costs/year |
| | €/h | quantity (h) | value (€) | | | |
| Ordinary labour | 12,00 € | 324 | 3 888,00 € | once in 10 years | 388,80 € | costs/year |
| Skilled labour | 18,00 € | 5,56 | 100,08 € | once in 10 years | 10,01 € | costs/year |
| weeding herbs first and second year | 12,00 € | 100 | 1 200,00 € | first 2 years | 120,00 € | costs/year |
| weeding herbs year 3-10 | 12,00 € | 30 | 360,00 € | year 3-10 | 36,00 € | costs/year |
| mowing without collecting every year | 18,00 € | 2 | 36,00 € | | 36,00 € | |
| **Total labour cost** | | | 5 584,08 € | | 590,81 € | costs/year |
| Tractor | 11,41 | 2,55 | 29,1 | | | |
| mulcher | 5,1 | 2 | 10,2 | | | |
| electrical hand-hoe | 1,5 | 13 | 19,50 | | | |
| **Total machinery operations cost** | | | 58,80 | | | |
| **TOTAL VARIABLE COSTS (€/ha)** | | | **974,11 €** | | | |
| GM A | | | **285,89** | **€/ha** | | |
| GM B (no family labour utilized) | | | **285,89** | **€/ha** | | |

DIVERFARMING

*Table 8.3.* Revenues (avoided viticulture weeding costs) and costs of establishing and maintaining Thymus as a cover crop, with oil extraction.

| | € | quantity | value (€) | | | |
|---|---|---|---|---|---|---|
| Market revenues | 0,00 € | 0 | 0,00 € | | | oil price? |
| avoided weeding costs in vine skilled labour | 18,00 € | 25 | 450,00 € | | | |
| avoided weeding costs in vine ordinary labour | 12,00 € | 60 | 720,00 € | | | |
| avoided weeding costs machinery operation costs | 1,50 € | 60 | 90,00 € | | | |
| **Gross on-farm value** | | | 1 260,00 € | | | |
| | €/plant | (pieces) | value (€) | | | |
| **Total plant cost** | 0,15 | 25000 | 3 750,00 € | once in 10 years | 375,00 € | costs/year |
| **Irrigation** | 1,75 | 140 | 245,00 € | once in 10 years | 24,50 € | costs/year |
| | €/h | quantity (h) | value (€) | | | |
| Ordinary labour | 12,00 € | 324 | 3 888,00 € | once in 10 years | 388,80 € | costs/year |
| Skilled labour | 18,00 € | 5,56 | 100,08 € | once in 10 years | 10,01 € | costs/year |
| weeding herbs first and second year | 12,00 € | 100 | 1 200,00 € | first 2 years | 120,00 € | costs/year |
| weeding herbs year 3-10 | 12,00 € | 30 | 360,00 € | year 3-10 | 36,00 € | costs/year |
| harvest | 12,00 € | 44 | 528,00 € | | | costs/year |
| **Total labour cost** | | | 6076,08 € | | 1082,81 € | costs/year |
| Tractor | 11,41 | 2,55 | 29,1 | | | |
| electrical cutter | 2 | 44 | 88 | | | |
| electrical hand-hoe | 1,5 | 13 | 19,50 | | | |
| **Total machinery operations cost** | | | 136,6 | | | |
| electricity for drying herbs | 0,06 | 900 | 54 | | | |
| oil extraction, purchased | 0,5 | 900 | 450 | | | |
| **TOTAL VARIABLE COSTS (€/ha)** | | | **1 586,81 €** | | | |
| GM A | | | -326,81 | **€/ha** | | |
| GM B (no family labour) | | | -326,81 | **€/ha** | | |

### 8.3.2. Processing and marketing of the intercrops

If marketing of the intercrops is aspired it is not possible to sell wineyard-grown herbs directly for the customers for human consumption because of plant protection in the wine production. Hence, other ways for marketing have to be found, or herbs have to be processed in a way that residues of spraying (in particular copper) are eliminated or do not matter in the end-use.

Other marketing-ways are possible e.g. selling the herbs for animal-feed, non-food applications or using the extracted aromatic oil of the herbs. Although the extraction of the oil is associated with additional costs, this way opens some interesting marketing opportunities. The oil can be sold directly or aromatic-oil-based products can be produced and re-sold. This seems to be interesting for a winery, which sells about 80% of its wine directly to the customers. In gross margin table 3 costs for oil-extraction are estimated, but a real price is not known at present and the selling price for the oil is not known yet either. Hence the gross margin calculation in table 3 does not include any price for oil and thus this GM calculation should not be referenced as a validated result yet. Nevertheless, one can calculate, using the GM calculation in Table 8.3, that the selling price of oil should be higher than 18,2 €/kg to reach zero GM A. Price 20 €/kg would imply 33 € GM A and price 30 €/kg would imply 213 €GM A.

In the long term it could be interesting to cooperate with other wineries in intercropping. This could reduce costs (sharing of machines and labour, collective post-harvest-treatment, buying seedlings) and even more marketing-ways could be realised by offering a larger quantity of herbs or products.

### 8.3.3. Other values related to intercropping

**Wine-Quality:**

First results indicate that the chosen intercropping system has no negative effects on the wine-quality. Rather there are indications that health of the wine-berries at harvest is better in the intercropped variation, especially within the test variation with oregano. Nutrient-uptake of the herbs during grape-ripening could be one reason.

Analyses of the plant-available potassium of the soil show a significant difference between the intercropping variations and the control: In 2019 the supply of potassium for the grapes was in an optimal range in the intercropping-variations while control-variations showed an over-supply. An over- as well as an undersupply of potassium can be negative for the wine-quality. Wine-Samples of the different intercropping-variants will be analysed soon and give more information about influences of intercropping on wine-quality.

**Soil-erosion, humus-balance and water-capacity:**

To implement the intercropping based on herbs it is necessary to open the soil for sowing and in the first month of growth the land cover of the herbs is not yet extensive. The risk of soil-erosion because of heavy rainfall in that stage is high. To avoid that, it could be necessary to use a compostable mulch-film as soil-cover which is an additional expense not considered in this study. From the second year on it is expected that the intercrops avoid soil erosion under the grapes. The collected data of that issue have to be analysed precisely to give a reliable statement. Similarly, data of humus-balance and water-capacity have to be analysed, assessed and valuated before they can be accounted for in evaluating environmental and economic effects.

**Biodiversity:**

It is obvious that implementation of a second crop in a monocrop system is an enrichment for the fauna, particularly for insects. The value of the chosen intercropping-system for biodiversity, as well as the influence of harvest of the flowering herbs, have to be analysed and assessed in separate more specific studies.

## 8.4. Conclusion

The gross margin calculations show only very short-term effects of crop diversification on farm economy. One can evaluate already that the avoided costs of weeding in viticulture, because of diversification, may very well outweigh the costs of intercropping with thyme and oregano. Nevertheless, with two or three “normal” harvests of the herbs and the corresponding wine-harvests in 2019, 2020 (and 2021) it will be possible to give reliable information about the economic impact of the intercropping-system in a vineyard. Quality of wine will be analysed. If possible to be assessed monetarily, different marketing-ways for the herbs will be examined and evaluated. One has to find different ways to evaluate the impacts of intercropping on abiotic and biotic environment to give them a value. This is challenging and requires more efforts than was possible in this study.

# 9. CS10 Economic assessment of diversified asparagus production (intercropping with peas and oats) in Hungary

## 9.1. Case study description and motivation of the study

CS10 is connected to asparagus (*Asparagus officinalis*) production in Hungary. With the diversification (field pea and oats in the interrows of asparagus) the recharge of soils with nutrients is expected to improve. This improvement would spare part of the fertilization costs. Diversification could also contribute to higher biodiversity. Another point where change is expected is soil erosion control. In this respect the cover crops, oats and peas, will certainly help. Some environmental benefits difficult to quantify are also expected. In soil moisture budget positive alterations are predicted. This may have a feedback on the yields of the main crops. The application of intercrops in asparagus cultivation is a novel idea, not yet accepted or applied by farmers in Hungary. The environmental problems to be solved by diversification, however, are well known. Professional (agronomic) literature concentrates on nutrient supply and water demand concerning asparagus production.

## 9.2. Materials and methods

The cropping diversification in CS10 is based on the following hypotheses:

- With the diversification (diversification 1: asparagus and field pea, diversification 2: asparagus and oats in the interrows) the recharge of soils with nutrients is expected to improve. Economically, this improvement could provide additional income by the pea and oat crops, and save part of the fertilization costs.
- Diversification could also contribute to a higher biodiversity.
- Diversification can contribute to soil erosion control. However, areas between the asparagus ridges (potentially 60% of total area) are prone to wind erosion, causing damage to soil as well as nutrient losses. Uncovered soil surface increases evapotranspiration (soil moisture losses).

In this respect the cover crops will certainly help. As regards the goals of WP8, the economic feasibility of the intercrop is a question. How much income the marketing of the crop should bring in to cover extra costs of its cultivation? The higher prices of fertilizers, the higher the hazard of ground desiccation in the sandy region and the requirement of preventing the damage caused by sand storms. All this calls for diversification which would add extra crops to the profile of the farm.

Differences between the two intercrops-strategy were assumed. Field peas (diversification 2) as fodder crops had a much higher price on the market (on the average, 250-280 € per tonne in 2019) than oats. Diversification 2, oats, are probably not profitable on the market since their average price was 150-170 € per tonne in 2019. The advantage, however, is the relatively low cost of cultivation. To calculate the effect of the intercrop as cover plant on the water budget is very difficult.

The preparation of soil for sowing field pea and oats is combined with the preparation of asparagus ridges and, thus, no rise in costs are expected compared to the separate cultivation of both crops. Considerable extra costs of storage after harvest are not expected as opposed to asparagus which needs cleaning and packing in cool storage. However, seeding is less problematic but further treatments (weed control) present problems: chemicals cannot be used during asparagus harvesting. The ecological importance is nearly equal to potential economic benefit since organic matter recharge to soil (calculated from experiment: 416 kg/ha and 998 kg/ha of carbon and 58 and 48 kg/ha of nitrogen for pea and oats, respectively.), i.e. 30 % of annual fertilizer need.

For a calculation, the nitrogen-content of biomass was converted and expressed in Euros based on the value of the different nitrogen content in fertilizers. As results, biomass of field pea and oats are approximately the same, average values are 122 and 109 €/ha (value of N if bought as mineral fertilizer).

## 9.3. Results

***Table 9.1.*** *Gross margins (€/ha) of asparagus monocropping and diversifications 1 and 2.*

| | (€/ha) | Asparagus | Div1 Asparagus + field pea | Div2 Asparagus + oat | pea | oat |
|---|---|---|---|---|---|---|
| **GROSS MARGIN A (no own labour, no overheads, no capital depreciation)= GrossRev - TotVarCosts** | **GM A** | 15973 | 16110 | 16120 | 137 | 147 |
| **GROSS MARGIN B (no overheads, no capital depreciation)= GM A - ALL LabCosts** | **GM B** | 14099 | 14221 | 14235 | 122 | 136 |
| **GROSS MARGIN C (no land costs)= GM B - (overhMach+overhBui)** | **GM C [Eu/ha]** | 12820 | 12900 | 12926 | 80 | 106 |
| **PRODUCTION VALUE** | **ProdVal** | 19375 | 19689 | 19587 | 314 | 211 |
| **TOTAL VARIABLE COSTS (€/ha)** | **TotVarCosts** | 3610 | 3787 | 3674 | 177 | 64 |
| **Gross Revenues = Gr ON-FARM Pr + FarmSub** | **GrosRev** | 19583 | 19897 | 19795 | 314 | 211 |
| **Gross ON-FARM PRICE (€/ha) , no costs subtracted** | **Gr ON-FARM Pr** | 19375 | 19689 | 19587 | 314 | 211 |
| **Net Revenues, after immediate costs = Net ON-FARM Pr + FarmSub** | **NetRev** | 19583 | 19897 | 19795 | 314 | 211 |
| **Total farm subsidies** | **FarmSub** | 208 | 208 | 208 | 0 | 0 |
| **ALL labour costs** | **All LabCosts** | 1874 | 1889 | 1885 | 15 | 11 |
| **OVERHEAD, total machinery costs MAINTENANCE AND DEPRECIATION RELATED TO MACHINERY** | **OverhMach** | 104 | 116 | 110 | 12 | 6 |
| **OVERHEAD, MAINTENANCE AND DEPRECIATION RELATED TO BUILDINGS** | **OverhBui** | 1175 | 1205 | 1199 | 30 | 24 |
| **Overhead costs** | **OverhCost** | 3153 | 3210 | 3194 | 57 | 41 |

The market value of the main crop is by orders of magnitude higher than the income from the intercrop. The production cost of the intercrop is low and the profit from it is low – but still slightly positive - as well, hence it has very little influence on total income (Table 9.1). Another possible long-term benefit, not explicitly priced in this gross margin calculation, is the predictable improvement of soil structure and nutrients availability in the soil. Fodder pea biomass contributes to aggregate soil particle formation in the loose sand soil, while as a legume it also improves the nitrogen supply.

## 9.4. Discussion

Diversification would add extra crops to the profile of the farm. The higher prices of fertilizers, the higher the economic risk due to the hazard of ground desiccation in the sandy region and the requirement of prevention of damage caused by sand storms. All this calls for diversification. Fodder pea biomass contributes to aggregate formation of soil particles (important for water and nutrient retention) in the loose sand soil, while as a legume it also improves the nitrogen supply.

Sales of intercropped products is only envisioned for field pea as a higher value product in the future. However, the point is not the cultivation of side-crops as they are only sowed so that the features of the soil are improved. Actually it would be much cheaper to grow common field pea or oats in itself since this intercropping way of cultivation makes it more expensive in the short run. In the long run, the improved soil quality may nevertheless contribute in the yield and quality of asparagus and provide ground-cover for the interridges of asparagus and help farmers to avoid excessive costs which could arise by the erosion.

The preliminary gross margin analysis shows that diversification involves extra costs which possibly cannot be compensated by the sales of by-products. Novel kinds of mechanization are needed for efficient work organisation of the intercropping and some low-width mechanisation, feasible to be used between ridges of asparagus (e.g. robots), may be a good solution for weed control.

## 9.5. Conclusions

Diversification would add extra crops to the profile of the farm. There is an economic risk of hazard of ground desiccation in the sandy region and the requirement of prevention of damage caused by sand storms. All this calls for diversification. Fodder pea biomass contributes to aggregate formation of soil particles in the loose sand soil, while as a legume it also improves the nitrogen supply.

Marketing of products is only envisioned for field pea as a higher value product in the future. However, the point is not the cultivation of side-crops as they are only sowed so that the features of the soil are improved. In fact, it would be much cheaper to grow common field pea or oats in itself since this intercropping way of cultivation makes it more expensive in the short run. In the long run, the improved soil quality may nevertheless contribute in the yield and quality of asparagus and provide ground-cover for the inter-ridges of asparagus and help farmers to avoid excessive costs which could arise by the erosion.

The preliminary gross margin analyses show that diversification involves extra costs which possibly cannot be compensated by the marketing of by-products. Novel kinds of mechanization are needed for efficient work organisation of the intercropping and some low-width mechanisation, feasible to be used between ridges of asparagus (e.g. robots), may be a good solution for weed control.

# 10. CS11 Economic assessment of a diversified organic wine production (intercropping with yarrow and grass) in Hungary

## 10.1. Case study description and motivation of the study

CS11 is connected to organic wine production in Hungary. There are two kinds of diversifications, as alternatives for vine monocropping: either (1) a grass mixture or (2) yarrow (*Achillea millefolium* as an aromatic plant) as intercrops between rows of vinestock applied in organic farming. In vineyard there is ca. 30% „free" area located between vine rows which has a huge (but hidden) agro-economic potential.

The idea of intercropping with vine (inter-row coverage with plants) is to combat soil erosion. Plants used in intercropping in vineyards are usually leguminous plants, which, in addition to reducing soil erosion, are also suitable for enriching the soil with nutrients, due to their symbiotic nitrogen-fixing bacteria in the structures of root nodules. Among aromatic plants common yarrow is sowed, which is a densely growing herb providing ground-cover to control soil erosion. Two rows of this plant were sowed.

Requirements of the plants used in inter-rows were: they should not grow too high so as not to induce too high air humidity which would threaten grapes (fungi, mould); they should grow on calcareous soil and tolerate drought, as the soil has a high carbonate content and the climate is continental (cold, no dry season, warm summers, Dfb by Köppen; c.f. Kottek et al. 2006) with periods of drought; and they should be able to grow from seeds, so that seedlings need not to be grown in the farm. Crops sown in interrows should also tolerate reaping (scything) well and should provide value added as a utilisable product (e.g. drug). Common yarrow meets all these criteria. The price of the grapes (per ton) is not influenced by these cultivation methods. However, in the long run better soil quality may result in higher yield and/or quality of grapes and revenues of the main crop. The 76% of the medicinal plants grown in Hungary were exported to Austria and Germany in 2019. Both countries represent a stable market for Hungarian farmers. Using grass mixture as fodder is only possible for local livestock.

## 10.2. Materials and methods

Gross margin calculation was used in investigating how profitable is the cultivation of grass mixture or yarrow as cover crop under the given conditions (in interrows on a dry hillslope) – in the short-term, disregarding ecological implications. For the calculations two types of wine (as end products) and two and two yield variations were chosen. According to the regulations for classicus red wine the allowed maximum yield is 13 tons $ha^{-1}$ grapes, which means 8 $m^3$/ha of wine, for premium red wine maximum allowed yield is 8.5 tons/$ha^{-}$ of grapes, i.e. 5.5 $m^3$/ha of wine.

Yarrow as a medicinal plant which is grown in the interrows and not yet used for food or feed purposes. The proportion of unused interrows between vinestock amounts to 25-30 % regarding the entire wine-producing disctrict. The interrow distance is 2.3 m between the vinestock rows and the middle part of interrow (about 1-1.5 m) can be determinated as potential space for diversification. In the case of yarrow, the decision also lies with the management what size the area to be harvested is. If weather does not favour yarrow growth (drought), considering loading from machinery, the middle strips of interrows (30% of sown area) is harvested to avoid the deterioration of quality. In the case of yarrow, 0.3 ha seeding per one hectare vinestock is reasonable. However, using special machinery the farmers could reach 0.6 ha yarrow per one hectare vinestock area. Seeding grass mixture as intercrop belongs to the low input practices. The first benefit is controlling erosion, secondary is growing as a marketable product (fodder).

## 10.3. Results

***Table 10.1.*** *Main elements of Gross Margin (GM) calculation, including revenues and costs per year for different input values*

| | A classicus red wine | B premium red wine | C yarrow | D yarrow | E grass mixture | F grass mixture | A + B | B + D | A+E | B+F |
|---|---|---|---|---|---|---|---|---|---|---|
| | *$m^3$ /ha* | *$m^3$ /ha* | *liter/ha* | *liter/ha* | *dry ton* | *dry ton* | | | | |
| | 8 | 5.5 | 1.2 | 2.4 | 0.8 | 1 | | | | |
| **Market revenues** | €/ha | €/ha | €/ha | €/ha | €/ha | €/ha | | | | |
| **grape for classicus red wine** | 48000 | | | | | | | | | |
| **grape for premium red wine** | | 82500 | 0 | | | | | | | |
| **Aromatic plant (Achillea oil)** | | | 4800 | 9600 | | | | | | |
| **Fodder (grass mixture)** | | | | | 72 | 91 | | | | |
| **Processing and other immediate costs per ha** | 22071 | 15172 | 3110 | 6220 | 3 | 3 | 25181 | 21392 | 22074 | 15175 |
| **Gross ON-FARM PRICE** | 48000 | 82500 | 4800 | 9600 | 72 | 91 | 52800 | 92100 | 48072 | 82591 |
| **Net ON-FARM PRICE** | 35948 | 74216 | 2590 | 5180 | 67 | 84 | 38538 | 79396 | 36015 | 74300 |
| **NET market income** | 35948 | 74216 | 777 | 1554 | 53 | 84 | 36725 | 75770 | 36001 | 74300 |
| **Gross revenue** | 48873 | 83373 | 4800 | 9600 | 72 | 91 | 53673 | 92973 | 48945 | 83464 |
| **Total harvest costs** | 915 | 915 | 30 | 87 | 48 | 49 | 945 | 1002 | 963 | 964 |
| **Total Variable Costs** | 5070 | 5052 | 346 | 720 | 130 | 173 | 5416 | 5772 | 5200 | 5225 |
| **GROSS MARGIN A** | 43803 | 78321 | 4454 | 8880 | -58 | -83 | 48257 | 87201 | 43745 | 78238 |
| **GROSS MARGIN B** | 41533 | 76051 | 4388 | 8748 | -73 | -102 | 45921 | 84799 | 41460 | 75949 |
| **GROSS MARGIN C** | 40239 | 75901 | 4321 | 8614 | -89 | -121 | 44559 | 84515 | 40149 | 75779 |
| **NET PROFIT** | **40239** | **75901** | **4321** | **8614** | **-89** | **-121** | **44559** | **84515** | **40149** | **75779** |

In gross margin calculations the annual production and management changes in diversification were also taken into consideration. In production process year by year the decision of the management defines the regulated amount of yield depending on whether classicus or premium quality is targeted. In the case of vine and yarrow the decision is based on the actual meteorological conditions.

Total farm revenue is not influenced considerably even if grass mixture can be an unprofitable activity in itself (if low value as a fodder). Grass mixture is seeded over the entire area or in 80% of it. Summarized GM calculation is shown in Table 10.1.

Obviously, yarrow is economically profitable and not only economically. The highest net profit is achievable if yarrow is grown over 60% of the area along with grapes for premium category red wine. It is worthwhile to replace grass mixture with yarrow even if the yield of yarrow is lower (Table 10.1, column C).

Yarrow oil is used in the cosmetic industry. Therefore, it can be sold at a relatively high price, while grasses as hay do not bring a considerable income. In the second year one could successfully achieve a more uniform ground cover with yarrow in the interrows. On the other hand, planting has a great requirement on labour which involves high extra costs (Table 10.1). Furthermore, chemical weed control cannot be applied in organic farming. Mechanical weeding, with significant labour requirement, is needed since the ruining of intercrops has to be avoided.

Still yarrow (*Achillea millefolium*) as intercrop does not require special inputs and treatments but some profit is expected from its marketing and sales especially in case the quality of its oil content (noble varieties) can be guaranteed. Nevertheless much profit gain depends on the access to the markets of high quality oil for cosmetics. Some environmental benefits, difficult to be quantified, are also expected from both inter-crops. In soil moisture budget positive alterations are predicted. This may have a feedback on the yields of the main crop in the long run.

## 10.4. Discussion

Applying grass mixture as cover crop is commonly used in vineyard management. The reason of this agrotechnological solution is to avoid a catastrophic erosion events. In the long run farmers need to pay the costs of road repairs, additional field works, etc, due to erosion. The estimated cost is 167 €/ha/yea. There are no significant nitrogen input differences related to the yarrow and grass since both same plants provide less than 2 kg of nitrogen per ha to the soil.

Results from experiments suggest that carbon and nitrogen accumulations reach higher values if the stem and grass mixture will be reworked in the soil. Benefits: grass mixture and yarrow intercrops contribute to higher soil C in the long run if reworked in the soil, but much less if harvesting their above-ground biomass. However, harvesting the intercrops may provide additional market revenues (no subsidy for intercrops) and hence harvesting is likely to be more lucrative for a farmer than reworking the intercropped biomass in the soil. In that case significant economic effects due to slightly increased soil C cannot be expected. Intercropping with grass mixtures and yarrow reduces soil erosion risk. Over a 10-year period damage due to erosion can be highly variable, ranging from moderate to total destruction of the plantation, depending on the weather conditions.

## 10.5. Conclusions

Yarrow as a medicinal plant is grown in the interrows which are not yet used for economic purposes. Water erosion hazard is high in the steep sloping vineyards. The proportion of unused interrows between vinestock amounts to 30-60 % of the land area regarding the entire wine-producing disctrict. This has a considerable economic potential.

The results suggest that both yarrow and grass mixtures may decrease soil erosion and improve soil structure, with better water and nutrient retention, at relatively low costs when intercropped with vine rows. Thus both inter-crops can be economically viable and profitable alternatives for vine monocropping since costs due to erosion and decreasing soil quality may be significant in the long-term.

Instead of grass, useful in erosion control and as animal feed, yarrow can be adviced to be used as intercrop. No considerable extra labour is required for seeding or care. Although weed control is not yet solved, a relatively high profit can be achieved with low input through the marketing of Achillea oil, if access to the market. Otherwise, grass can still be considered a useful and low-cost means for erosion control since the intercropped grass is likely to cost less than the costs of erosion damage in the long run. Suitable low-yielding grass or yarrow intercrops have also soil improving functions, such as increased soil carbon and organic nitrogen content, if re-worked in the soil.

## 10.6. References

Kottek, M., J. Grieser, C. Beck, B. Rudolf, and F. Rubel, 2006. World Map of the Köppen-Geiger climate classification updated. Meteorol. Z., 15, 259-263. doi:10.1127/0941-2948/2006/0130.

# 11. CS12 Economic assessment of a diversified feed cereals production in Finland

## 11.1. Case study description

The main idea of case study number 12 is to analyse a change from cereal monocultures to diversified crop rotations in southern Finland. The long-term field experiment has already produced data on cereals monocultures, both in case of conventional tillage and no-till. Cereal cropping is diversified with winter crop and catch crop + tillage or no-till (4 treatments).

The hypothesis: Improved crop yields, or reduced need for inputs, and lower losses in terms of nutrients will realise in diversified cropping. The study site is Kotkanoja experimental field in Jokioinen, southern Finland.

Diversified feed production is studied under three treatments:

- Cereal monocropping in no-till
- Cereal, winter rapeseed, cereal, cereal
- Cereal + catch crop

Our analysis and modelling are implemented assuming typical production conditions, use of inputs and average crop yields in Varsinais-Suomi province located in south-west Finland. This region is among the most favourable agricultural regions in Finland, but the crop yields (cereals approximately 4 tons/ha) are still significantly lower than in many countries in western and central Europe. In the period 1981–2010, the average length of the thermal growing season was 180–200 days. The effective temperature sum was 1300–1450 degrees, and the average precipitation in the growing season was 350–400 mm (Pirinen et al., 2012). The growing season usually starts in the last week of April and ends at the end of October. 55% of farms are cereal farms in this region (Tike, 2014). The average size of all farms in 2011 was 45.75 ha (Tike, 2012). Most farms in the region apply short crop rotations or monocropping (Vuorio et al., 2006). Varsinais-Suomi cereal farms are affected by the 5% minimum area requirement for an ecological area under the EU's CAP (set-aside is accepted as an ecological area), and by the maximum area restriction (15%) under nature management fields (NMF) and maximum overall set-aside area (set-aside and NMF) restriction (25%), as specified in the CAP agri-environmental scheme implemented at the national level.

## 11.2. Materials and methods

Historical data comprises 15 years (2000–2015) for crop yields, variable costs and subsidy data. Crop yields are extracted from official farm statistics (OFS, 2018) for the Varsinais-Suomi region in Finland. The average crop yield per crop is the mean value of the annual yield over 15 years obtained from official agricultural statistics of Finland (OFS, 2018). The average variable costs and subsidies of the crops are derived from a recent version of a dynamic regional sector model of Finnish agriculture (DREMFIA) (Lehtonen, 2001; Lehtonen and Niemi, 2018), which relies on validated approximations of the average use of inputs per crop in each region. Since a large part of the costs of farms is machinery costs, not measured in the case study experiments (measuring crop yield quantity and quality, environmental variables), it is important that the machinery costs are close to the costs of average, typical farms.

In our case study 12 at hand, a slightly more diversified rotation is oats-barley-wheat as a 3-year rotation. No-till cultivation of barley monoculture is also used as an alternative to conventionally (with ploughing) cultivated barley monoculture. Barley monoculture with Italian ryegrass as a catch crop is included as one alternative. However, a real diversification is barley – winter rapeseed – barley –rotation. This rotation is in our main focus in economic analysis. Even this barley-barley-oilseed rape-barley-barley –rotation is in fact barley production with a break crop, and not really any highly diversified rotation with several highly different crops.

Existing empirical material and expert knowledge suggest that diversification indeed impacts input use or crop yields, but there is uncertainty how much. Field experiments of case study 12 (located in Jokioinen, southern Finland) were conducted in 2018 and 2019. Summer 2018 was very dry and thus crop yields were also low in rainfed production of barley on that year. There were also relatively small changes in the observed crop yields between conventional tillage and no-till field plots (crop yields were slightly higher in no-till plots 2018 while normally the crop yields under no-till management are clearly smaller). Summer 2019 was relatively favourable for cereals crop production at the whole country level but when oilseed rape was cultivated on that year in the field experiments very small yields were harvested. This is because severe plant pest and disease problems of oilseeds locally and also elsewhere in the country 2019, implying smaller than normal yields of oilseed crops. Differences in harvested yields between the field plots in the field experiment were also relatively small 2019. It is hard to make any robust conclusions on crop yield effects of different crop rotations based on data from 2018-2019.

For these reasons it is not rational to use observed experimental yields of 2018 and 2019 directly in the economic assessment. Instead it is useful to consider other literature and other expert assessment and then make hypothesis on the changed use of inputs and crop yields and then investigate what they mean in terms of gross margins for a farmer.

First we specify “Input use hypothesis”.

**Input use hypothesis 1: Reduced need for nitrogen fertiliser**

For example, empirical findings, as well as experience of farmers (Lehtonen at al. 2018), suggest that oilseed crops, or legumes or other nitrogen fixating crops, leave some nitrogen in the soil after harvest, unlike cereals which are much dependent on annually added inorganic chemical nitrogen fertilizer, if cultivated in monocultures. In other words, a farmer may have an opportunity to use less nitrogen fertilizer when cultivating a crop following oilseeds or legumes, than would be needed in the case of cultivating after another type of crop, with little or no increase in nitrogen in the soil.

A catch crop, intercropped with the main crop (e.g. Italian ryegrass sown under barley) may release some nitrogen in the soil in the following spring after harvest, if ploughing the soil in spring before sowing spring crops. This is another way of reducing nitrogen fertilization by diversification.

Here we simply assume, based on reported findings, that nitrogen fertilization is reduced by 25% (appr. 20 kg N/ha) if cultivating barley after oilseeds.

**Input hypothesis 2**: **Reduced need for crop protection**

Similarly, the need for crop protection could be reduced if more diversified crop rotations, compared to the case of monocropping, or cultivating similar crops (e.g. barley and wheat) in a sequence. In the case of boreal production conditions where pest and disease pressure is still relatively low, fungicide use for barley or wheat could be even fully avoided when cultivating wheat or barley after cultivation of another type of crop, e.g. grass forage, oilseed or legumes, at the same field plot. The value of reduced crop protection for a farmer is not only the value of avoided quantity of crop protection chemical, but also the avoided labour and machinery hours as well as fuel costs needed in the avoided crop protection activity. If the crop protection activity is usually purchased from an outside operator, the operator service costs can be avoided if certain kinds of crop rotations. Here we simply assume that fungicide use is avoided if cultivating barley after oilseeds.

**Input use hypothesis 3**: **Additional seeding imply seed costs and reduced nitrogen fertilisation**

Increased production costs due to diversification may realise if cover or catch crops imply increased seed costs or more difficult harvesting, e.g. increased machine hours, for a farmer. For example, catch crops may be used in order to increase winter time vegetation coverage on the field plot and thus nutrient leaching decreases. The catch crop may have little or no effect on the crop yields of the primary crop if the growth of the catch crop will realise largely after the harvest of the main crop in autumn. The catch crop, such as Italian ryegrass sown as an intercrop with barley in case study 12, can be ploughed in the soil at following spring and this may release some soluble nitrogen in the soil, available for the spring crop and thus reducing the need of fertilization (see input use hypothesis 1). However, the seed costs will realise already when sowing the catch crop. Here we assume that seed costs of the catch crop are appr. 45 €/ha and 20 kg N/ha is released during the next growing period following the sowing of the catchcrop.

**Crop yield loss hypothesis 1**

Another way of approaching the benefits and costs of cropping diversification is estimating crop yield losses (e.g. pest and disease or any other reasons) due to monoculture, and assessing how these crop yield losses may be decreased or eliminated completely by different kinds of crop (rotation) diversifications. The crop yield loss matrix is used to estimate yield effect of monocropping. We first set up (1) hypothetical crop yield loss matrices based on earlier studies and expert judgement (this approach is used in e.g. Liu et al. 2016 and Purola et al. 2018); and (2) based on empirically estimated pre-crop values calculated by Peltonen-Sainio et al. 2019 based on large scale data.

We calculate gross margins per hectare in each land use (crop rotation) alternative over a 5-year period. We thus extend the crop rotations from 3 years up to 5 years. This helps us to show the yield and other effects of the rotations more clearly.

The crop yield loss matrix we use is below. It means that crop yield drops 5% every year at the following year(s) if the same cereals crop is cultivated again at the same field plot. The gross margins over 5 years are first calculated over a 5-year period at one field plot. Since barley and wheat are rather similar kind of crops, they are assumed to impose a similar crop yield loss for each other if cultivated in a sequence. Oats, however, is somewhat different from barley and wheat and hence cultivating barley or wheat after oats causes a smaller yield loss.

Furthermore, we assume that monocultural yield loss is "inherited" from the last 5-year period of cultivating any cereals – wheat, barley, oats – or if cultivating oilseeds in a sequence. Hence barley yields decrease 5% (2.5% in the case two different but rather similar crops) every year from the previous year if cultivated as a monoculture (Table 11.1). Thus, barley monoculture over years 1,2,3 and 4 may cause 18.5% yield loss at the 5$^{th}$ year, compared to the first year when no yield loss is assumed.

***Table 11.1***. *Crop yield loss for different pre-crop – current crop -pairs, assuming high crop yield loss due to monoculture. Note that the cumulative crop yield loss is calculated over 5 years,*

| | **current crop: wheat** | **current crop: barley** | **current crop: oats** | **current crop: oilseed rape** |
|---|---|---|---|---|
| precrops (below) | Wheat | Barley | Oats | Oilseed rape |
| Wheat | 0.95 | 0.95 | 0.975 | 1 |
| Barley | 0.95 | 0.95 | 0.975 | 1 |
| Oats | 0.975 | 0.975 | 0.95 | 1 |
| Oilseed rape | 1 | 1 | 1 | 0.75 |

### Crop yield loss hypothesis 2

Since the exact percentage of monocultural yield loss is hypothetical we also use a different crop yield loss matrix where the annual crop yield loss from monoculture is only 2% (1% in the case two different but rather similar crops), annually (Table 11.2), but the crop yield loss accumulates over 5 years, as well as in crop yield loss hypothesis 1. Note that oilseed rape is assumed to have no negative effects on the yields of crops, and vice versa, but oilseed monoculture is assumed to imply a large 25% yield loss.

***Table 11.2.*** *Crop yield loss for different pre-crop – current crop -pairs, assuming low crop yield loss due to monoculture. Note that the cumulative crop yield loss is calculated over 5 years,*

| | current crop: wheat | current crop: barley | current crop: oats | current crop: oilseed rape |
|---|---|---|---|---|
| precrops (below) | Wheat | Barley | Oats | Oilseed rape |
| Wheat | 0.98 | 0.98 | 0.99 | 1 |
| Barley | 0.98 | 0.98 | 0.99 | 1 |
| Oats | 0.99 | 0.99 | 0.98 | 1 |
| Oilseed rape | 1 | 1 | 1 | 0.75 |

### Precrop value hypothesis

Since both crop yield loss estimates above are hypothetical (even if they have been actively discussed with crop research experts and farmer; see e.g. Lehtonen et al. (2018)) we see it important to have an empirically estimated set of parameters, estimated recently from a large data sample from Varsinais-Suomi region by Peltonen-Sainio et al. (2019). The precrop effects are estimated as increments to yields obtained from monocultures, e.g. diagonal elements are one, i.e. zero precrop value (Table 11.3).

***Table 11.3****. Pre-crop values for different pre-crop – current crop -pairs. Note that the pre-crop values consider only 1-year time steps*

| | current crop: wheat | current crop: barley | current crop: oats | current crop: oilseed rape |
|---|---|---|---|---|
| precrop | | | | |
| Wheat | 1 | 0.979 | 1.036 | 1.034 |
| Barley | 1.079 | 1 | 1.055 | 1.049 |
| Oats | 1.057 | 0.998 | 1 | 1.028 |
| Oilseed rape | 1.130 | 1.054 | 1.077 | 1 |

## 11.3.Results

We first set up GM calculation in Excel for cereals monocropping. Use of input per crop and prices of inputs were derived based on Lehtonen & Niemi (2018), Lankoski et al. (2018) and official crop yield and crop price statistics. Once GM for the "base" case of monocropping is calculated (Table 11.4) it is easy to calculate changes in GMs implied by the different hypothesis given above.

***Table 11.4.*** *Gross margin calculation of barley monocropping, as a base of comparison.*

CONVENTIONAL

| | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|
| Rotation | Barley | Barley | Barley | Barley | Barley | TOTAL over 5 years |
| Crop yield | 3814.0 | 3814.0 | 3814.0 | 3814.0 | 3814.0 | 19070.0 |
| Market revenues | 489.9 | 489.9 | 489.9 | 489.9 | 489.9 | 2449.4 |
| Subsidies | 479.0 | 479.0 | 479.0 | 479.0 | 479.0 | 2395.0 |
| Variable costs | 517.3 | 517.3 | 517.3 | 517.3 | 517.3 | 2586.6 |
| Gross margin A | 451.6 | 451.6 | 451.6 | 451.6 | 451.6 | **2257.8** |
| Labour costs | 194.4 | 194.4 | 194.4 | 194.4 | 194.4 | 972.0 |
| Gross margin B | 257.2 | 257.2 | 257.2 | 257.2 | 257.2 | 1285.8 |
| Machinery costs etc | 668.0 | 668.0 | 668.0 | 668.0 | 668.0 | 3340.0 |
| Gross margin C | -410.8 | -410.8 | -410.8 | -410.8 | -410.8 | -2054.2 |

**Effects of reduced input use hypothesis 1 on gross margin**

We first calculate how much reduced nitrogen use for barley (-25% based on input use hypothesis 1) following oilseeds contributes to gross margin. This is easily implemented by decreasing the nitrogen fertilizer use by 25% at year 4, following oilseeds, in the calculation. Since the N fertilization is 77 kg N/ha this 25% reduction in the need of fertilization means that there is 19.25 kg N/ha already available in the soil in the following year after oilseed cultivation. The price of fertilizer (fertilizer product "YaraMila Pellon Y 5 (22-5-5) 8") is 0,5 €/kg, the N content 0.22, the price of nitrogen is 2.27 eur/kg. Since the use of this fertiliser product is 350 kg/ha (77 kg N/ha), the value of fertilizer is 175 eur/ha in the monocropping case. A 25% reduction in fertilization and in the use of nitrogen of nitrogen  implies a cost reduction of 43.75 eur/ha, if cultivating barley after oilseeds. This saving in fertilizer cost and increase in a 5-year gross margin (2257.8 eur) is thus only 1.9%. This alone is a weak motivation for a farmer to cultivate oilseeds. However, in this case oilseeds have a higher GM per ha than barley (541 €/ha vs 452 €/ha); however this depends on market prices and yields of oilseed crop. Thus, the overall gain in introducing oilseeds once in 5 years in the barley monocropping is 133.2 €/ha in a 5-year period (Table 11.5). From this gain the reduced need of fertliser on year 4 is only 43.75 €/ha.

The main increase in Gross Margin A (the gross margin after variable inputs excluding labour) comes primarily from the higher GM of oilseeds compared to barley, and relatively less from the reduced need of fertilizer of crop protection for barley after oilseeds. Thus one may ask why a farmer does not cultivate barley-barley-oilseed rape-barley-barley rotation in the first place? The answer often lies in the limited demand for oilseed and thus limited local / regional demand. Other reasons might be unsuitable soils, or some extra marketing and other costs, e.g. limited number of production contracts, or contracts with unfair / difficult conditions for a farmer. A farmer may also have limited knowledge and experience related to oilseeds. In any case the relatively small gain from reduced fertilization is clearly a secondary motive for a farmer in this case.

*Table 11.5. Gross margin calculations assuming reduced nitrogen fertilization due to diversification.*

CONVENTIONAL

| | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|
| Rotation | Barley | Barley | Oilseed rape | Barley | Barley | TOTAL |
| Crop yield | 3814.0 | 3814.0 | 2000.0 | 3814.0 | 3814.0 | 17256.0 |
| Market revenues | 489.9 | 489.9 | 595.1 | 489.9 | 489.9 | 2554.6 |
| Subsidies | 479.0 | 479.0 | 552.0 | 479.0 | 479.0 | 2468.0 |
| Variable costs | 517.3 | 517.3 | 606.0 | 473.6 | 517.3 | 2631.5 |
| Gross margin A | 451.6 | 451.6 | 541.1 | 495.3 | 451.6 | **2391.1** |
| Labour costs | 194.4 | 194.4 | 194.0 | 194.4 | 194.4 | 971.6 |
| Gross margin B | 257.2 | 257.2 | 347.1 | 300.9 | 257.2 | 1419.5 |
| Machinery costs etc. | 668.0 | 668.0 | 684.0 | 668.0 | 668.0 | 3356.0 |
| Gross margin C | -410.8 | -410.8 | -336.9 | -367.1 | -410.8 | -1936.5 |

**Results concerning the increased seeding due to catch crops**

This input use hypothesis means that additional seeding is used due to catch crops. It was assumed that seed costs of the catch crop are appr. 45 €/ha and 20 kg N/ha is released during the next growing period following the sowing of the catch crop.

In the case of reduced nitrogen fertilization, we already found that reduction of nitrogen fertilization for barley by 19.2 kg N /ha implies a reduction in fertilizer costs by 43.75 €/ha. This is very close to the seeding costs. Hence the seeding costs and the value of reduced fertilization for a farmer roughly cancel out each other, and little or no economic loss or gain is realized.

However, if any reduction in nutrient leaching or GHG emissions, they might be valuable for environment and society. These values are not accounted yet in the farm level analysis, but will be compared to the market based economic changes in the later stage of WP 8. In some cases, the value of reduced nutrient leaching and reduction in GHG emissions could be calculated using various price estimates, e.g. from non-market valuations, published results on abatement costs, or tradable emission permits.

**Results concerning crop yield loss hypothesis 1**

Analysing the effects diversification assuming crop yield loss hypothesis 1 requires us to calculate crop yield losses over a 5-year period. This is done in Excel sheets with specific formulas (available by request / available in Diverfarming OneDrive, WP 8 folder). The calculations (Table 9.6 a-e) also include no-till and conventional tillage cases since they are also included in case study 12 experimental setting. The decreasing trend of profitability in cereals production – increase in the prices of inputs has been clearly faster than the increase in crop prices - has led to a situation where saving costs using reduced or no tillage provides a higher GM C than conventional tillage which nevertheless results in 20-30% higher crop yields. Price development, as well as some agricultural policies offering risk free payments for reduced fertilization, has been discouraging for increasing crop yields and thus the crop yields have been stagnating (Peltonen-Sainio et al. 2015). Nevertheless, increasing crop yields and overall productivity is important for economic viability of agriculture in the long run.

We can see in Table 11.6.e our main result that adding oilseeds in barley monoculture increases gross margin (GM) A by 13.5% and GM B by 26%, over a 5-year period. This is because oilseed eliminates the accumulating yield loss of barley monoculture at year 3. One should note that no discounting is employed in these results calculated over a 5-year period.

***Table 11.6.a.*** *Gross margin calculations assuming crop yield loss hypothesis 1 – no tillage and spring cereals*

| NO TILL | oats | barley | spring wheat | oats | barley | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | |
| Rotation | Oats | Barley | Wheat | Oats | Barley | TOTAL |
| Crop yield | 3118.7 | 3501.3 | 2191.0 | 2816.5 | 3162.0 | 14789.5 |
| Market revenues | 384.1 | 449.7 | 323.5 | 346.9 | 406.1 | 1910.4 |
| Subsidies | 479.0 | 479.0 | 479.0 | 479.0 | 479.0 | 2395.0 |
| Variable costs | 494.7 | 479.2 | 578.7 | 494.7 | 479.2 | 2526.5 |
| Gross margin A | 368.5 | 449.5 | 223.9 | 331.2 | 405.9 | **1779.0** |
| Labour costs | 145.8 | 145.8 | 145.8 | 145.8 | 145.8 | 729.0 |
| Gross margin B | 222.7 | 303.7 | 78.1 | 185.4 | 260.1 | 1050.0 |
| Machinery costs etc | 644.3 | 634.3 | 625.3 | 644.3 | 634.3 | 3182.4 |
| Gross margin C | -421.6 | -330.6 | -547.2 | -458.8 | -374.2 | -2132.5 |

***Table 11.6.b.*** *Gross margin calculations assuming crop yield loss hypothesis 1 – conventional tillage and spring cereals.*

| CONVENTIONAL | oats | barley | spring wheat | oats | barley | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | |
| Rotation | Oats | Barley | Wheat | Oats | Barley | TOTAL |
| Crop yield | 3807.0 | 3718.7 | 3445.7 | 3438.1 | 3358.3 | 17767.7 |
| Market revenues | 468.9 | 477.6 | 508.8 | 423.5 | 431.4 | 2310.2 |
| Subsidies | 479.0 | 479.0 | 479.0 | 479.0 | 479.0 | 2395.0 |
| Variable costs | 532.7 | 517.3 | 616.7 | 532.7 | 517.3 | 2716.8 |
| Gross margin A | 415.2 | 439.3 | 371.1 | 369.7 | 393.0 | **1988.3** |
| Labour costs | 194.4 | 194.4 | 194.4 | 194.4 | 194.4 | 972.0 |
| Gross margin B | 220.8 | 244.9 | 176.7 | 175.3 | 198.6 | 1016.3 |
| Machinery costs etc | 678.0 | 668.0 | 659.0 | 678.0 | 668.0 | 3351.0 |
| Gross margin C | -457.2 | -423.1 | -482.3 | -502.7 | -469.4 | -2334.7 |

***Table 11.6.c.*** *Gross margin calculations assuming crop yield loss hypothesis 1 – no tillage and barley monoculture.*

| NO TILL | barley 1 | barley 2 | barley 3 | barley 4 | barley 5 | |
|---|---|---|---|---|---|---|
| Rotation | Barley | Barley | Barley | Barley | Barley | TOTAL |
| Crop yield | 3591.0 | 3411.5 | 3240.9 | 3078.9 | 2924.9 | 16247.2 |
| Market revenues | 461.2 | 438.2 | 416.3 | 395.5 | 375.7 | 2086.9 |
| Subsidies | 479.0 | 479.0 | 479.0 | 479.0 | 479.0 | 2395.0 |
| Variable costs | 479.2 | 479.2 | 479.2 | 479.2 | 479.2 | 2396.2 |
| Gross margin A | 461.0 | 437.9 | 416.0 | 395.2 | 375.4 | **2085.6** |
| Labour costs | 145.8 | 145.8 | 145.8 | 145.8 | 145.8 | 729.0 |
| Gross margin B | 315.2 | 292.1 | 270.2 | 249.4 | 229.6 | 1356.6 |
| Machinery costs etc | 634.3 | 634.3 | 634.3 | 634.3 | 634.3 | 3171.4 |
| Gross margin C | -319.1 | -342.1 | -364.1 | -384.9 | -404.6 | -1814.8 |

***Table 11.6.d.*** *Gross margin calculations assuming crop yield loss hypothesis 1 – conventional tillage and barley monoculture.*

CONVENTIONAL

| | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|
| Rotation | Barley | Barley | Barley | Barley | Barley | TOTAL |
| Crop yield | 3814.0 | 3623.3 | 3442.1 | 3270.0 | 3106.5 | 17256.0 |
| Market revenues | 489.9 | 465.4 | 442.1 | 420.0 | 399.0 | 2216.4 |
| Subsidies | 479.0 | 479.0 | 479.0 | 479.0 | 479.0 | 2395.0 |
| Variable costs | 517.3 | 517.3 | 517.3 | 517.3 | 517.3 | 2586.6 |
| Gross margin A | 451.6 | 427.1 | 403.8 | 381.7 | 360.7 | **2024.8** |
| Labour costs | 194.4 | 194.4 | 194.4 | 194.4 | 194.4 | 972.0 |
| Gross margin B | 257.2 | 232.7 | 209.4 | 187.3 | 166.3 | 1052.8 |
| Machinery costs etc | 668.0 | 668.0 | 668.0 | 668.0 | 668.0 | 3340.0 |
| Gross margin C | -410.8 | -435.3 | -458.6 | -480.7 | -501.7 | -2287.2 |

*Table 11.6.e.* *Gross margin calculations assuming crop yield loss hypothesis 1 – conventional tillage and breaking barley monoculture with oilseed rape.*

CONVENTIONAL

| | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|
| Rotation | Barley | Barley | Oilseed rape | Barley | Barley | TOTAL |
| Crop yield | 3814.0 | 3623.3 | 2000.0 | 3814.0 | 3623.3 | 16874.6 |
| Market revenues | 489.9 | 465.4 | 595.1 | 489.9 | 465.4 | 2505.6 |
| Subsidies | 479.0 | 479.0 | 552.0 | 479.0 | 479.0 | 2468.0 |
| Variable costs | 517.3 | 517.3 | 606.0 | 517.3 | 517.3 | 2675.3 |
| Gross margin A | 451.6 | 427.1 | 541.1 | 451.6 | 427.1 | **2298.3** |
| Labour costs | 194.4 | 194.4 | 194.0 | 194.4 | 194.4 | 971.6 |
| Gross margin B | 257.2 | 232.7 | 347.1 | 257.2 | 232.7 | 1326.7 |
| Machinery costs etc | 668.0 | 668.0 | 684.0 | 668.0 | 668.0 | 3356.0 |
| Gross margin C | -410.8 | -435.3 | -336.9 | -410.8 | -435.3 | -2029.3 |

**Results concerning crop yield loss hypothesis 2**

If crop yield loss due to monoculture is small, it is likely that the economic benefits of avoiding yield loss is also small (Table 11.7.a). In this case we can see that adding oilseeds in barley monoculture increases gross margin (GM) A by 7.7% and GM B by 14%, over a 5-year period assuming average 2000-2016 prices (Table 11.7.b). Now the increase in GM due to adopting oilseed in rotation is relatively small since also assumed yield loss is small. Again, one should note that no discounting is employed in these results.

*Table 11.7.a.* *Gross margin calculations assuming crop yield loss hypothesis 2 – conventional tillage and barley monoculture*

CONVENTIONAL

| | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|
| Rotation | Barley | Barley | Barley | Barley | Barley | TOTAL |
| Crop yield | 3814.0 | 3737.7 | 3663.0 | 3589.7 | 3517.9 | 18322.3 |
| Market revenues | 489.9 | 480.1 | 470.5 | 461.1 | 451.9 | 2353.4 |
| Subsidies | 479.0 | 479.0 | 479.0 | 479.0 | 479.0 | 2395.0 |
| Variable costs | 517.3 | 517.3 | 517.3 | 517.3 | 517.3 | 2586.6 |
| Gross margin A | 451.6 | 441.8 | 432.2 | 422.8 | 413.5 | **2161.8** |
| Labour costs | 194.4 | 194.4 | 194.4 | 194.4 | 194.4 | 972.0 |
| Gross margin B | 257.2 | 247.4 | 237.8 | 228.4 | 219.1 | 1189.8 |
| Machinery costs etc | 668.0 | 668.0 | 668.0 | 668.0 | 668.0 | 3340.0 |
| Gross margin C | -410.8 | -420.6 | -430.2 | -439.6 | -448.9 | -2150.2 |

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*Table 11.7.b. Gross margin calculations assuming crop yield loss hypothesis 2 – conventional tillage and breaking barley monoculture with oilseed rape at year 3.*

CONVENTIONAL

| | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|
| Rotation | Barley | Barley | Oilseed rape | Barley | Barley | TOTAL |
| Crop yield | 3814.0 | 3737.7 | 2000.0 | 3814.0 | 3737.7 | 17103.4 |
| Market revenues | 489.9 | 480.1 | 595.1 | 489.9 | 480.1 | 2535.0 |
| Subsidies | 479.0 | 479.0 | 552.0 | 479.0 | 479.0 | 2468.0 |
| Variable costs | 517.3 | 517.3 | 606.0 | 517.3 | 517.3 | 2675.3 |
| Gross margin A | 451.6 | 441.8 | 541.1 | 451.6 | 441.8 | **2327.7** |
| Labour costs | 194.4 | 194.4 | 194.0 | 194.4 | 194.4 | 971.6 |
| Gross margin B | 257.2 | 247.4 | 347.1 | 257.2 | 247.4 | 1356.1 |
| Machinery costs etc | 668.0 | 668.0 | 684.0 | 668.0 | 668.0 | 3356.0 |
| Gross margin C | -410.8 | -420.6 | -336.9 | -410.8 | -420.6 | -1999.9 |

**Results concerning pre-crop value hypothesis**

Pre-crop values considered here are dependent on the last year's crop only, and land use earlier than that is not accounted for. For this reason, the analysis is rather simple and different from the crop yield loss hypothesis case shown above. However, one needs to be aware that the pre-crop values estimated from data over a certain time span may change even considerably if the pre-crop values are estimated from data from a different time span. Nevertheless, the same kind of uncertainty is inherent when assuming crop yield losses due to monoculture, or estimating such yield losses from empirical data material. Now introducing oilseeds in barley monocultures implies 9.5% higher GM A and 16.7% higher GM B, compared to barley monoculture. GM C improves by appr. 10% (Table 11.8.a-b). The same kind of results can be calculated in a case where wheat is grown as a main crop (Table 11.9) – GM A increases by 11% and GM B by 21%.

***Table 11.8.a.** Gross margin calculations assuming pre-crop value hypothesis. Conventional tillage and barley monoculture.*

CONVENTIONAL

| | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|
| Rotation | barley | barley | barley | barley | barley | TOTAL |
| Crop yield | 3814.0 | 3814.0 | 3814.0 | 3814.0 | 3814.0 | 19070.0 |
| Market revenues | 489.9 | 489.9 | 489.9 | 489.9 | 489.9 | 2449.4 |
| Subsidies | 479.0 | 479.0 | 479.0 | 479.0 | 479.0 | 2395.0 |
| Variable costs | 517.3 | 517.3 | 517.3 | 517.3 | 517.3 | 2586.6 |
| Gross margin A | 451.6 | 451.6 | 451.6 | 451.6 | 451.6 | **2257.8** |
| Labour costs | 194.4 | 194.4 | 194.4 | 194.4 | 194.4 | 972.0 |
| Gross margin B | 257.2 | 257.2 | 257.2 | 257.2 | 257.2 | 1285.8 |
| Machinery costs etc | 668.0 | 668.0 | 668.0 | 668.0 | 668.0 | 3340.0 |
| Gross margin C | -410.8 | -410.8 | -410.8 | -410.8 | -410.8 | -2054.2 |

*__Table 11.8.b__.Gross margin calculations assuming pre-crop value hypothesis. Conventional tillage and breaking barley monoculture with oilseed rape.*

CONVENTIONAL

| | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|
| Rotation | barley | barley | oilseed rape | barley | barley | TOTAL |
| Crop yield | 3814.0 | 3814.0 | 2098.0 | 4020.0 | 3814.0 | 17560.0 |
| Market revenues | 489.9 | 489.9 | 624.2 | 516.3 | 489.9 | 2610.2 |
| Subsidies | 479.0 | 479.0 | 552.0 | 479.0 | 479.0 | 2468.0 |
| Variable costs | 517.3 | 517.3 | 606.0 | 473.6 | 517.3 | 2631.5 |
| Gross margin A | 451.6 | 451.6 | 570.2 | 521.8 | 451.6 | **2446.7** |
| Labour costs | 194.4 | 194.4 | 194.0 | 194.4 | 194.4 | 971.6 |
| Gross margin B | 257.2 | 257.2 | 376.2 | 327.4 | 257.2 | 1475.1 |
| Machinery costs etc | 668.0 | 668.0 | 684.0 | 668.0 | 668.0 | 3356.0 |
| Gross margin C | -410.8 | -410.8 | -307.8 | -340.6 | -410.8 | -1880.9 |

*__Table 11.9.__ Results assuming pre-crop value hypothesis in the case of wheat monocultures (not studied in case study 12)*

| CONVENTIONAL | | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | |
| Rotation | Wheat | Wheat | Wheat | Wheat | Wheat | TOTAL |
| Crop yield | 3720.0 | 3720.0 | 3720.0 | 3720.0 | 3720.0 | 18600.0 |
| Market revenues | 549.3 | 549.3 | 549.3 | 549.3 | 549.3 | 2746.5 |
| Subsidies | 479.0 | 479.0 | 479.0 | 479.0 | 479.0 | 2395.0 |
| Variable costs | 616.7 | 616.7 | 616.7 | 616.7 | 616.7 | 3083.7 |
| Gross margin A | 411.6 | 411.6 | 411.6 | 411.6 | 411.6 | **2057.9** |
| Labour costs | 194.4 | 194.4 | 194.4 | 194.4 | 194.4 | 972.0 |
| Gross margin B | 217.2 | 217.2 | 217.2 | 217.2 | 217.2 | 1085.9 |
| Machinery costs | 659.0 | 659.0 | 659.0 | 659.0 | 659.0 | 3295.0 |
| Gross margin C | -441.8 | -441.8 | -441.8 | -441.8 | -441.8 | -2209.1 |
| CONVENTIONAL | | | | | | |
| | 1 | 2 | 3 | 4 | 5 | |
| Rotation | Wheat | Wheat | Oilseed rape | Wheat | Wheat | TOTAL |
| Crop yield | 3720.0 | 3720.0 | 2068.0 | 4203.6 | 3720.0 | 17431.6 |
| Market revenues | 549.3 | 549.3 | 615.3 | 620.7 | 549.3 | 2883.9 |
| Subsidies | 479.0 | 479.0 | 552.0 | 479.0 | 479.0 | 2468.0 |
| Variable costs | 616.7 | 616.7 | 606.0 | 616.7 | 616.7 | 3072.9 |
| Gross margin A | 411.6 | 411.6 | 561.3 | 483.0 | 411.6 | **2279.0** |
| Labour costs | 194.0 | 194.0 | 194.0 | 194.0 | 194.0 | 970.0 |
| Gross margin B | 217.6 | 217.6 | 367.3 | 289.0 | 217.6 | 1309.0 |
| Machinery costs | 659.0 | 659.0 | 684.0 | 659.0 | 659.0 | 3320.0 |
| Gross margin C | -441.4 | -441.4 | -316.7 | -370.0 | -441.4 | -2011.0 |

## 11.4.Discussion

The results suggest that breaking barley or wheat monocultures by introducing oilseed rape once in 5 years may increase farm gross margin by appr. 10% in a 5 year period. In reality, some, even significant, increase in oilseed production could be easily sold to domestic markets where supply has been decreasing due to pests and diseases and decreasing land allocation for oilseeds. However, a large increase in oilseed production (e.g. > 100%) may not be realistic because of imports of oilseeds and crushed oilseeds for feed, often at relatively low prices. Thus, limited domestic demand and low prices compared to the cost of production restricts oilseed production even if it seems clearly more profitable at the farm level, at least when compared to wheat and barley production.

Average 2000-2014 crop prices were used in the gross margin calculations. Gross margins and difference in GMs between crops are sensitive on market prices of crops but relatively less sensitive on the prices of production inputs since almost the same inputs such as fertilisers, fuel, labour and machines, are used for all crops, though with some differences.

Limitation of this gross margin -based analysis is the 5 –year time span used. Diversification benefits and costs may have longer term implications and incentives for change for a farmer. Changes in gross margins due to diversification (and implied changes in inputs and crop yields) may lead to significant changes in land use at the farm level. Results from a dynamic optimization model over a 30-year time span assuming all crop yield losses (e.g. Purola 2018, Liu et al. 2016) or pre-crop values (under analysis) shows a more comprehensive picture on farm level land use and input use implications of diversification. Optimisation based analysis assumes full utilization of diversification benefits, up to the land and other constraints of a farm. For this reason, the gross margin changes based on 5 –year gross margin analysis at given land use pattern may not show the whole farm level impact of diversification but it may show the direction of the economic gains or losses for a farmer who may find it rational to change to land use and input use patterns even very significantly. For this reason, it is necessary to analyse how economically rational farmers could utilize benefits of diversification by changing land use and other farm management simultaneously in a dynamic optimization framework.

In some other case studies, where diversification is based on e.g. catch crops, cover crops or mixed / intercropping and where the whole farm management changes relatively little (e.g. the production of main crop is unchanged) this kind of gross margin based gross margin calculation may be fully sufficient to show the essential farm level consequences of diversification. This kind of analysis is much needed and relevant from farm level point of view.

Results on nitrogen leaching and greenhouse gas emissions, as well as biodiversity implications of diversification can be weighed against farm level economic results when parameters and other more detailed results become available from the case studies, such as case study 12.

## 11.5. Conclusions

The results from farm level gross margin calculations suggest that diversification is more likely to have significant effects on farm economy and management – land use and the use of inputs – if diversified cropping implies changes in crop yields, and not only changes in the use of some individual inputs. For example, it was found that some 20-25% changes in needed nitrogen fertilization of barley, when cultivated after oilseeds, or some seed costs due to catch/ cover crops, have relatively small impacts on field parcel or farm level gross margins over a 5-year period, if no change in crop yields. On the other hand, if losses in crop yields due to monocultural cultivation could be decreased or fully eliminated, then total accumulated gross margin over a 5 -year period can increase more than 10%. This can be considered a significant gain. However, a large part of this gain may result from introduction of new /recently uncultivated crops at the farm, with higher gross margin even without any additional benefits from diversification. If there are such crops with good gross margins and still positive diversification effects on crop yields of other crops, or on the use of inputs, they can be easily recommended for farmers. Then it depends on the demand of the individual crops if certain diversified cropping patterns and crop rotations may become more common at larger scales.

Since pre-crop values, or crop yield losses due to monoculture, are very little reported in the literature, it is likely that the benefits of diversification are not fully utilized or even understood. The farm level analysis based on gross margins presented shows the first steps in evaluating the little utilized diversification benefits. Such results are in a pivotal role when recommending diversification for farmers and value chain firms.

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# 12. CS 13 Organic cheese – Diversified grass forage production in Finland

## 12.1. Introduction

The main environmental problems of agriculture in southern Finland, nutrient leaching to watercourses and biodiversity loss, are related to cereal monocultures (Manninen et al. 2018, Salonen et al. 2007). Monocultures of cereals and intensive tillage often leads to decreasing soil organic matter content. This increases risk of soil erosion and nutrient leaching (N and P) (Manninen et al. 2018). Soil organic matter is gradually and slowly, but continuously decreasing in Finland. The change in management practices towards increasing cultivation of annual crops during the last decades has contributed to soil carbon losses (Heikkinen et al., 2013). Poor soil structure and low water conductivity may also lead to reduced crop yields and economic profitability of agriculture. Another, related motivation for soil improvements is linked to climate change since more frequent extreme weather conditions such as droughts or floods, pose adaptation challenges for farmers in Northern Europe where increased precipitation is a likely outcome of climate change (Ruosteenoja et al., 2011). Improved soil structure could alleviate the effects of more frequent extreme weather conditions (Peltonen-Sainio et al., 2016, Wiesmaier et al. 2019).

The main driver behind the relative increase in the area under annual crops in Southern Finland (OFS 2019a) is rapid structural change in dairy and beef sectors in Finland (OFS 2019b), a trend since several decades and forecasted to continue (Lehtonen et al. 2017). Milk production is concentrating on certain areas through farm size growth and decreasing in most other regions, such as south-east Finland (ibid, OFS 2019b) where Diverfarming case study 13 is located. Nevertheless, such developments are common in Europe (Zimmermann et al. 2012). This decreases demand for grass forage feed locally. Since forage feeds such grass forage silage are not usually traded or transported long distances due to low nutrient density, decreasing dairy and beef production implies reducing grasslands and thus cropping diversity. This is because arable farms have most often relatively simple crop rotations and monocultures are common in Finland (Peltonen-Sainio et al. 2017).

Cereal and even cereal species monocultures dominate in large parts of southern Finland despite some alternative crops available for diversification of monocultures (ibid). Areas under protein crops, oilseeds, potatoes, sugar beets and other crops are relatively small in south-east part of Finland (OFS 2019a) due to limited local and domestic demand and agglomeration of the production of these crops closer to specialised networks of farms and industrial operators who plan production and cultivation on contract-basis. Relatively small areas under protein crops (OFS 2019a) are also linked to high yield risk, i.e. high inter-annual variability of protein crop yields, as well as to excessive low-priced imports of protein feed for livestock (OFS 2018; food balance sheets).

Perennial grasses or other deep-rooted species build up organic matter and store carbon in the soil as they grow over the entire growing season (Dohleman and Long 2009) and have high root biomass (DuPont et al. 2010). The root-derived carbon compounds decompose at a slower rate than those from the above-ground biomass (Kätterer et al. 2011). Furthermore, the erosion risk and nutrient run-off are lower compared to annual crops (Saarijärvi et al. 2004).

In regional scale, dairy production is an effective way to maintain rotational grasslands and thus diverse crop rotations in a northern country with limited possibilities for extending the vegetated period of fields with other means than forage production (Peltonen-Sainio et al. 2017). Local farm-scale cheese production with differentiated special products is one way to create value added, maintain dairy production and local food traditions. Legume-hay grass mixtures, with N fixation in the soil and reduced need for (manure or inorganic) fertilisers, are used especially in organic dairy production and can be used in conventional dairy production as well. As a deep-rooted crop red clover (*Trifolium Pratens*) is very suitable for soil improvement.

The most important Finnish forage production species are timothy (*Phleum pratense*) and meadow fescue (Festuca pratensis Huds.). These are preferred because of their combination of good winter tolerance, reasonably high yield capacity and high nutritive value, under Finnish conditions and management practices (Virkajärvi et al. 2015). The most important forage legume is Red clover (*Trifolium pratens*), which, along with other legumes, is commonly cultivated in Northern Europe as well as in the United States and Canada (Kuoppala et al. 2009). As a legume, red clover offers biological nitrogen (N) fixation, which reduces the need for N fertilization. These benefits are realized, in the context of Finland, if sufficiently low (N) fertilization, e.g., 50 kg of soluble N per ha, is applied. This would maintain a clover biomass comparable to the hay biomass in the vegetation, while higher N fertilization leads to deterioration of clover and intensive growth of hay grass species (Mela 2003; Nykänen 2008).

Soil improvement is a relevant aspect as well since it is known that some cereals farms, and even some conventional dairy farms, experienced soil compaction, despite extensive cereals-grasslands rotation, during past decades in the case study region (Anon. 2019). Such problems may be attributable to e.g. high axle loads of farm machinery, intensive tillage, and wet conditions during the harvesting period of high axle loads (Hoefer & Hartge 2010).

This farm level economic analysis specific to case study 13 evaluates two main farm economic issues: (1) profitability of adopting hay-clover grass mixtures at a typical conventional dairy farm; (2) profitability of organic dairy production compared to conventional dairy production. Even if the case study 13 includes also field experiments enabling comparison between conventional and organic cereals production we focus on the comparison between the cereals-grass forage rotations in conventional and organic dairy production. This is because the farm level economic analysis of the case study 12 (presented in this volume) already focuses on diversifying cereals monocropping.

## 12.2.Case study description

The objective of the Diverfarming case study 13 is to quantify the long-term effects of organic grass forage based milk production - with more diversified crop rotations and lower nutrient intensity - on soil properties, runoff quality and crop yield as compared with conventional farming, and modified by proportion of legumes and grass in the crop rotations. Case study 13 is also a long-term research experiment in Diverfarming. Hence there is some data from earlier years against which new data gathered 2017-2020 can be compared and evaluated.

In Finnish livestock systems, grass leys are grown in rotation with other crops, mostly cereals such as barley (*Hordeum vulgare* L.) or oats (*Avena sativa* L.). The leys are renovated by ploughing every 3–4 years, mainly with barley as the cover crop (Virkajärvi et al., 2015). This is needed due to weed management and feed quality reasons, and also because of winter-time damages on grass vegetation due to frost and snow. Hence renewal of forage grass every 3-4 years provides good quality silage feed for dairy cows with relatively high milk yields per cow, e.g. 8-10 tons of milk per cow per year (Pro Agria 2019). High production costs, e.g. the need of winter-proof buildings and high seasonality costs, do not allow low quality feed for dairy cows with high genetic production potential. Most grassland is harvested for silage and direct grazing of grass represents only 6 % of the annual energy intake of dairy cattle (Virkajärvi et al. 2015).

Case study 13 experiment was organised as 4-year crop rotations (Figure 12.1). Similar crop rotations were practiced since 2001. Since diversifying cereals production was already analysed in Case study 12 (farm economic analysis presented in this deliverable) we focus on grass-cereals rotations in organic and conventional milk production. In this experimental arrangement only two harvests of forage grass is obtained in each four-year rotation. However, the barley or oats harvests are also needed at a typical dairy farm since the high average milk yielding dairy cows requires also cereals-based feed to ensure easily metabolised energy, especially in early intensive parts of the lactating period. Feed intake typically include also protein feed supplements, often crushed oilseed rapeseed purchased outside farm. Soya based protein feed is not used for dairy and beef animals in Finland.

| Year | Organic Cereal (A)<br><br>0,5 lu/ha manure + biological nitrogen fixation | Organic Milk (B)<br><br>0,9 lu/ha manure +biological nitrogen fixation | Conventional Cereal (C)<br><br>Mineral fertilisers | Conventional Milk (D)<br><br>1,1 lu/ha manure + mineral fertilisers |
|---|---|---|---|---|
| 1st year | Barley with undersown grass (timothy and clover) | Barley with undersown grass (timothy and clover) | Barley | Barley with undersown grass (timothy and meadow fescue) |
| 2nd year | Grass ley (1 or 2 yields) Rye sown in the autumn | Grass ley (2 yields) | Barley Rye sown in the autumn | Grass ley (2 or 3 yields) |
| 3rd year | Rye | Grass ley (2 yields) | Rye | Grass ley (2 yields) |
| 4th year | Oats | Oats and vetch for fodder | Oats | Barley for fodder silage |

***Figure 12.1.*** *Experimental design and crop rotations in case study 13.*

**Basic core information of the case study 13 experiment in nutshell:**

- **Current crop**: Feed for milk production
- **Current cropping system**: rain-fed conventional feed production
- **Crop final use**: feed for milk production
- **Harvest time**: June-August for ley, August-September for cereals
- **Product**: cheese
- **Current value chain**: Milk producer, farm-scale cheese producer, quality and certification, distribution, supermarket
- **Current management practices**: Intensive tillage, mineral fertilizer, pesticides, herbicides,
- **Simple rotations**: Barley-ley-ley-barley and barley-barley-rye-oats
- **Diversification 1**: Legume in feed rotation (Barley-clovergrass-ley-vetch+oat)
- **Diversification 2**: Legume in cereal rotation (Barley-clovergrass-rye-oats)

Overall, more than 50% of metabolised energy of dairy cows comes from forage silage, hence its quality and protein content are decisive for the economy of a dairy farm (Pro Agria 2019). This is because some protein supplements and feed grain, despite some own production at a farm at relatively low yield levels, can be purchased outside the farm while forage grass silage most often cannot. Hence good quality and quantity of forage grass for silage is the key for profitability.

# 12.3. Data

Crop yields in the experiments were measured 2017-2019 (2020 yields not available under time of writing) (Figure 12.2). Grass yields were exceptionally low in 2018 due to severe drought (rainfed production, no irrigation). Grass yields of organic grass forage was as much as 40% less than the yield of conventional grass forage. Most often forage grass yields were 20-30% lower in organic production than in conventional production. While hay-grass was fertilised appr. 190 kg N/ha (soluble N) using both manure and inorganic fertiliser, clover-grass was fertilised appr. 50-60 kg N/ha (soluble N) using only manure fertiliser.

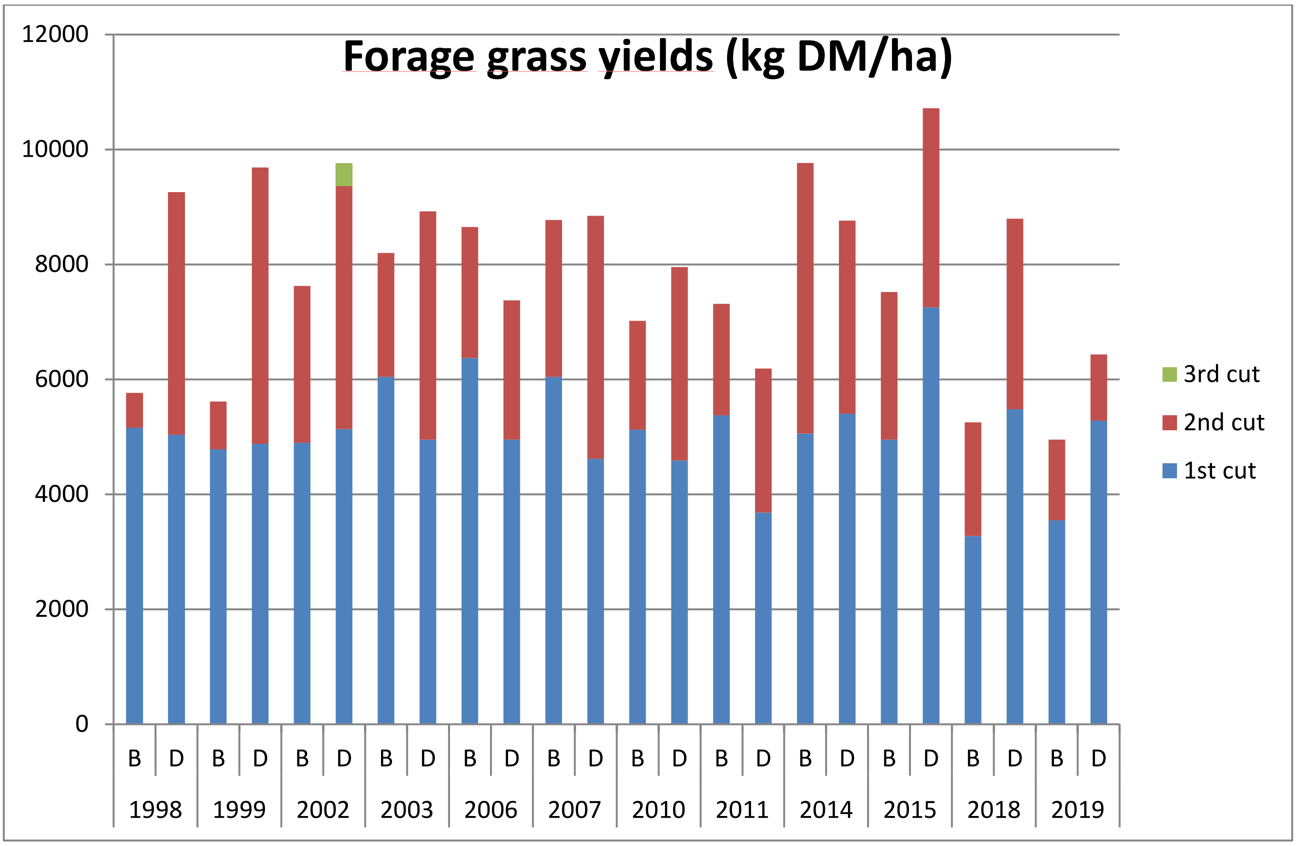


***Figure 12.2.*** *Forage grass yields (kg DM/ha) at consecutive years of forage grass in rotation. Source: Luke Toholampi experimental field trial data. B = plot B organic management. D = plot D conventional management*

We use FADN farm level cost and revenue data (Luke 2020) in the gross margin calculations, as well as the input use consistent to the case study experiments. FADN data is widely used in Finland and the data sample of dairy farms is well representative even at regional level.

# 12.4. Methods

**Assumptions / hypotheses**

Summary of the main assumptions concerning clover-grass cultivation and feed use:

i. Assuming a 15% higher protein content in clover-grass than in hay grass silage, a maximum of 50 kg soluble N per ha is required for N fertilization from manure (Luke 2015b; Nykänen 2008). High N fertilization decreases clover-grass yields in other countries, as well (Helming et al. 2014).

ii. Clover-grass DM yield is estimated to be 70% of the yield of intensive grass silage yield (Laine et al., 2015). This is a conservative estimate, based on the data shown in Figure 1 which suggests slightly higher, close to 80% yields of clover-grass, compared to hay grasses. This conservative estimate is however warranted since there are individual years of significantly larger differences between the yields. Such years may be particularly troublesome for a farmer since forage grass silage is most often not a traded commodity. If available at the local market, the quality differences and problems imply additional costs.

iii. The cost of clover-grass cultivation per ha is 14% lower than the cost per ha of intensive hay grasses. This estimate is calculated by Lehtonen & Niskanen (2016). This relatively small difference in cost per ha is due to high machinery costs per hectare, partly incurred by increased overall manure spreading costs on a farm (due to amounts of manure spread per ha for clover-grass) and seed costs of clover-grass. There are less fertilizer and harvesting costs for clover-grass per ha, but a higher cost per kg DM, compared to the case of pure hay silage.

**Calculations based on gross margins**

When calculating the cost implications when shifting from conventional hay-grass -based dairy production to clover-grass dominated dairy production we must consider the following issues:

(a) Land area is probably not sufficient to replace all intensively fertilised hay-grass areas with clover-grass forages. Since livestock densities are relatively low in Finnish dairy production (0.92 livestock units (LU)/ha in conventional production and 0.71 LU/ha in organic production; Niskanen 2020) there is some flexibility land use and manure spreading, in most cases. Increasing clover-grass area with low manure N input (e.g. 70 kg total N/ha, equivalent to 50 kg soluble N/ ha) implies higher amounts of manure N on the rest of the land area, e.g. hay grasses or cereals. Based on our calculations, maximum 30% of land can be allocated to clover-grass mixtures on conventional dairy farms

(b) This would increase manure spreading costs only slightly since more expensive manure spreading on clover-grass fields increases costs, but at the same time larger amounts of manure spread on other crops decreases the manure logistics and spreading costs. Hence, we assume the change in manure logistics costs is small

(c) It is nevertheless important to consider the cost estimate calculated earlier by Lehtonen & Niskanen (2016) that the cost of clover-grass cultivation per ha is 14% lower than the cost per ha of intensive hay grasses. Since the expected DM yield of clover-grass is 30% lower compared to hay-grass silage, the cost per ton produced increases significantly

(d) 15% higher crude protein content of clover-grass, compared to conventional grass, decreases purchased protein supplements.

These issues are accounted for in the following gross margin calculations.

Whole-farm modelling, including comprehensive land use and nutrient-use descriptions, has been considered important when analysing improvements in sustainability of farming systems (Vogeler et al. 2013). We do not have any comprehensive dairy farm model available for the purposes of this study. Hence it is reasonable to consider whole farm data from organic and conventional dairy farms in evaluating the profitability of shifting from a conventional dairy farm to an organic farm, and the profitability of adopting (more) clover-grass mixtures in cultivation of feed at a conventional dairy farm. Different causal linkages and interactions between grass forage cultivation system and dairy cows producing milk, to be used for cheese, eventually, are complex and not easy to be quantified in detail. For these reasons we adopted data from Farm Accountancy Data Network (FADN) from Taloustohtori database of Luke (Luke 2020) since this data from specialised dairy farms represents the core linkages and processes.

## 12.5.Results

Summarising the gross margin calculation results suggests that organic dairy is relatively profitable (Table 12.1). Relatively good profitability of organic dairy production (case 1), especially when comparing gross margins A and B to the conventional cases, is primarily linked to 10-15% higher milk price compared to conventional dairy production. However, the costs of production are also higher, not least because of the excessive utilisation of clover-grass forages and higher prices of purchased feeds. Machinery costs per cow are significantly higher on organic farms than on conventional farms. This is probably linked to the fact that 1.45 ha/LU is required on organic farms, on the average, and only 1.11 ha/LU at conventional farms. The livestock units include also young cattle.

While almost all forage grasslands on organic farms are some sort of clover-grass forages, or other grasslands under rotations with leguminous crops, the share of grasslands in clover-grass type management has been estimated as 15% only on conventional farms in Finland (Lehtonen & Niskanen 2016). When calculating gross margin in case 3: for an average conventional dairy farm shifting to increased clover-grass share of 30%, various calculations were made. First, it was assumed that milk yield per cow will not change, i.e. the change in the overall feeding is not that big that it could imply losses in milk quantity or quality. In fact, one may expect the opposite since Kuoppala et al. (2009) have reported increased feed intake of cows if clover based feeds have been increased. This means that eating motivation of cows increases if clovers, with appr. 15% higher crude protein content compared to hay grasses, are made available. Still protein supplements are needed in case 3, but in reduced volume. On the other hand, more cereals based feeds must be purchased because the smaller quantity of forage grass, even though improved quality, implies decreased overall energy content of the feeds produced at the farm. Since prices of purchased feeds are considered the same in cases 2 and 3, the overall value of purchased feeds decreases only little. Small decrease in the value of purchased feeds is explained by the fact that protein supplements are more expensive per energy unit than feed grains.

Liming activity should be increased, at least slightly, if increased area under clover-grasses. This is because clovers are less tolerant for low pH of soil compared to hay grasses. Fertiliser costs decrease clearly if shifting from case 2 to case 3 since clover-grasses are fertilised by manure in this example. Since the manure fertilisation is also limited to 50 kg soluble N/ha then more manure is spread on other crops in case 3 than in case 2. Hence the N fixation of clover-grasses really make a difference in inorganic fertiliser costs. This, however, is not any huge cost saving in money terms. Labour use is only slightly (appr. 2%) smaller in case 3 than in case 2. This is because the relatively small difference in labour hours needed in manure spreading and harvesting the grass forage. Since the total grass forage harvest is smaller from the same area in case 3 than in case 2, a relatively small gain is achieved in labour costs.

DIVERFARMING

**Table 12.1.** *Gross margin calculations for cases 1-3, based on FADN data from conventional and organic dairy farms in southern Finland, per dairy cow. Organic farms: 61.8 LU, 89.6 ha; Conv. farms: 70.2 LU, 78.2 ha.*

| EUR PER COW | Case 1: Organic | Case 2: Conventional | Case 3: Conv., clover-grass 15% => 30% |
|---|---|---|---|
| Market revenues from livestock products | 2932 | 2553 | 2553 |
| Market revenues from crop products | 93 | 51 | 51 |
| Other market revenues | 23 | 56 | 56 |
| Market revenues, total | 3049 | 2659 | 2659 |
| Farm subsidies | 1657 | 1179 | 1179 |
| TOTAL REVENUES | 4706 | 3839 | 3839 |
| Liming | 26 | 22 | 25 |
| Fertilisers | 0 | 125 | 106 |
| Other crop production costs | 246 | 110 | 108 |
| Crop protection | 0 | 16 | 16 |
| Fuels | 117 | 137 | 130 |
| Electricity | 126 | 104 | 104 |
| Purchased feeds | 628 | 632 | 614 |
| Purchased animals | 13 | 24 | 24 |
| Other animal costs | 312 | 272 | 272 |
| Veterinary costs | 62 | 47 | 47 |
| Other machinery costs | 778 | 434 | 434 |
| Other building costs | 73 | 48 | 48 |
| Purchased labour | 123 | 187 | 183 |
| ALL VARIABLE COSTS | 2505 | 2159 | 2099 |
| **GROSS MARGIN A** | **2200** | **1680** | **1728** |
| Family labour | 1002 | 1007 | 987 |
| **GROSS MARGIN B** | **1199** | **673** | **741** |
| Machinery depreciations | 309 | 368 | 368 |
| Buildings, depreciations | 358 | 306 | 306 |
| Various other fixed costs | 997 | 591 | 591 |
| Interests | 80 | 85 | 85 |
| **GROSS MARGIN C** | **-545** | **-677** | **-609** |

## 12.6.Discussion and conclusions

Organic dairy production shows relatively best gross margins, especially gross margins after variable factors of production, A and B. However, the high various kinds of fixed costs in organi7c dairy farms decrease the difference in gross margin C (calculating also fixed costs) relative to conventional dairy production. Farm level gross margins increase relatively little because of the shift from low utilisation of clover grasses (case 2. 15% under clover grasses) to higher utilisation (case 3, 30% under clover-grasses). The gain per cow per year is appr. 70 eur. However, considering farms with 50 or 100 cows, respectively, the annual gains would be 3500 – 7000 eur per year. This is not negligible since the average incomes of farmers show a decreasing trend in Finland, as evidenced by FADN data over several years (Luke 2020).

Adopting low-input legume-based grassland in dairy production may lead to significant environmental benefits (Lüscher et al., 2014; Soussana et al., 2010) and offer farmers an option for increasing resilience to market changes, by reducing production costs. Low-input dairy systems are primarily understood to differ from high-input dairying in terms of feed ration composition and feed production. However, decreasing input use in Northern European forage production has not been considered a very attractive option, as high capital production costs require high animal productivity (Virkajärvi et al., 2015). Reduced feed quantity and quality, harvested from larger forage areas, due to decreased use of inputs, could jeopardize productivity and economic viability of dairy production.

Over the last 10 years, increasing dairy production in Europe due to e.g. milk quota abolition in the EU is often coupled with larger farm size, more intensive land use and feed production, and increased use of feed protein purchased outside the farm. Nevertheless, legume-based grasslands are considered promising since they reduce the need for nitrogen(N) fertilization, production costs and increase protein content of feed (Lüscher et al., 2014).

Our results suggest that the case 3, shifting towards higher share of clover-grasses, is an intermediate case in terms of gross margins comparted to case 1 and 2, organic (high utilisation of clovers) and conventional (little utilisation of clovers) farms. This means that relatively small but still significant and robust gains could be achieved through shifting to clover-grasses, if that is possible in terms of animal density of a farm. If low animal density, e.g. LU/ha, then even larger gains could be attained if shifting to clover-grasses in a greater extent than assumed in this example, based on average animal density farms.

High N fertilization is often the only possibility at farms with high livestock density. There is often too little or too expensive additional land available for more extensive production. It is difficult to significantly increase clover-grass area under such circumstances. According to Finnish FADN (Farm Accountancy Data Network) results, the average livestock density is still relatively low (0.80 livestock units (LU)per ha 2006, 0.82 LU/ha 2014, and close to 0.9 LU/ha 2018) on Finnish dairy farms (Luke 2020). Such livestock densities typically imply 50–100 kg manure N per ha, on average, depending on the productivity levels of a farm (Kokkonen et al., 2014). If soluble N in manure is less than 50 kg N/ha, or slightly more than that, then there is a possibility of increasing clover-grasses with N fixation and soil improvement properties. Increasing clover-grass, overall, is possible in Finland, if properly incentivized (Lehtonen & Niskanen 2016).

Market based solutions are often prioritised by economists. Increased demand for organically produced milk and dairy products could indeed increase also clovers in grass forage production. The share of organic milk production is as little as about 3%. Some organically produced milk has been sold as conventional milk, as well, due to weak demand (Pro Luomu 2013). Organic dairy is not only about organic fertilization, it is also about crop rotations, animal welfare and grazing obligations. Grazing is obligatory and cows are indeed grazing during the feasible grazing period, late-May-early September, annually. Therefore, organic dairy production offers a bundle of agroecosystem services.

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# 13. CS 15 Biodynamic arable farm – Diversified agriculture in the Netherlands

## 13.1. Case study description

This case study differs from other cases in the Diverfarming project. It does not have agronomic experimental plots. Instead it functions as an example of a highly diversified arable farming system, run based on *biodynamic principles* (Biodynamic Association 2020a). Thus, this case study will not present comparisons of farm level gross margins between monocropping and diversified options based on experimental data but will present gross margin calculations of different exemplary more and less diversified rotations.

The farm is organic and Demeter certified (Biodynamic Association 2020b), as well as Global GAP and GRASP, social standards of GlobalGAP (GlobalGAP 2020). The farm is located in the central region of Gelderland in the northern Netherlands. It comprises 100 ha of land in long-term lease and an extra 30 ha which is rented. The current rotation focuses of soil health and is guided by biodynamic principles. The farm's rotations are typically 6 years long and include two consecutive years of grass clover. Further, these rotations draw from a variety of crops, namely onions, potatoes, red beets, pumpkins, red cabbage, peas, quinoa, sweet lupins, spelt, an old wheat variety, hemp, triticale seed production intercropped with winter peas, flax, and calendula flowers. The current rotation starts with the farm's cash crops such as onions, potatoes and red beets. It also always includes at least one legume and at least one cereal. The last two years of the rotation are always grass clover to let the soil fully recover before the next round of cash crops. The farm is managed and run with a total working input of 2.5 full-time equivalents (FTE) of which approximately 1,5 FTE go to the farm managers. The remaining 1 FTE is a hired employee. Additionally, 25 seasonal employees are hired for two months in the summer for, mostly for manual weeding (approximately 10 FTE total).

The main source of revenue of the farm is crop sales. About 70% of revenues, on average, come from onions, potatoes, red beets and pumpkins, with some yearly fluctuations. These cash crops cover roughly 50% of land at a time. The marketing channels of this farm are diverse. They sell to national and international wholesalers, as well as directly to close-by processors. They have different contract farming arrangements with industrial processors (e.g. for peas and red cabbage), pooling structures where a dedicated sales person is hired to sell the product of several farmers jointly, as well as simpler, reoccurring oral agreements.

The farm's cost structure has four main components: seeds, manure, machinery and labour. Seeds or seedlings for all considered crops are purchased and so is the manure used. Manure is the only fertilizing external input used and is composted on-farm. Machines used on the farm are owned by the farm, with few exceptions (e.g. harvesting of peas is part of the industry contract and is executed by the buyer). Labour cost on this farm come mostly from manual weeding operations. The labour cost considered in the analysis here includes all hired labour but not the farm managers. Thus since only purchased labour is considered, the margins reported in the following correspond to "Gross Margin A", defined in the introduction of this deliverable.

## 13.2.Materials and methods

The analysis of this case study focuses on estimating the overall margins of different 6-year rotations. Three different scenarios are presented:

(1) **One that promotes soil health akin to the currently practiced rotations on the farm,**
(2) **a cash crop-oriented scenario, and**
(3) **an intermediate scenario.**

All scenarios are evaluated based on prices and costs within the organic/biodynamic system. For each scenario, rotations' values are presented in nominal terms, and discounted with 1%, 3% and 5% yearly. Each rotation is calculated in terms of gross margin per hectare.

The scenarios are based on discussions with the farmers and their categorisation of alternative rotations according to soil health effects. They illustrate the strong incentives present for cash-crop intensive rotations if long-term soil health effects are not taken into account. The reasoning behind these scenarios is practical. For the case study farmers, the possibility to estimate different trade-offs between healthy soils and revenues of different rotations was deemed the most useful outcome of WP8 for this case study. The approach has been decided in consultation with the farmers of this case study and is based on their needs.

The data collection for this case study was performed using the same data collection tool as was used for the Diverfarming case studies 5-6-7, DIFARMA. In brief, it takes into account costs for seeds, pesticides and fertilizer, labour cost, machineries and services, subsidies and crop revenues. This means that overall farm level costs such as land rent, buildings, taxes, etc. are not taken into account. For this analysis data for 6 different crops on 6 different plots was considered. Data was collected for the year 2019. Crops considered are onions (red and yellow), potatoes, red beets, spelt, peas and grass clover.

## 13.3. Results

Table 13.1 shows an overview of product prices, production, revenues, costs and resulting margins as calculated using the DIFARMA data collection tool. The gross margin (GM) for each crop is used in calculating its financial value in a six-year rotation. For reference, Table 13.2 shows under which certification each crop was sold. This implies that the prices given are likely unattainable in conventional production due to price premiums attached to products sold under certification.

*Table 13.1*: *Overview of prices, cost, revenues and margins. All prices in €.*

| Plot | Crop | Price per kg | Production in kg | Total revenue | ha | Revenue per ha | Subsidy per ha | Cost per ha | GM per ha |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Red beets | 0.18 | 487,500 | 87,750 | 7.5 | 11,700.00 | 262.00 | 426.67 | 11,535.33 |
| 2 | Grass clover | 0.125 | 88,000 | 11,000 | 8.8 | 1,250.00 | 262.00 | 785.91 | 726.09 |
| 3 | Potatoes | 0.4 | 103,800 | 41,520 | 3.46 | 12,000.00 | 262.00 | 4,700.87 | 7,561.13 |
| 4 | Peas | 0.99[1] | 36,331 | 35,968 | 6.02 | 5,974.70 | 262.00 | 102.99 | 6,133.71 |
| 5 | Onions red[2] | 1.15 | 150,000 | 286,250 | 11.06 | 25,881.56 | 262.00 | 4,843.54 | 21,300.02 |
| 5 | Onions yellow[3] | 0.65 | 175,000 | | | | | | |
| 6 | Spelt | 0.65 | 28,000 | 18,200 | 7.17 | 2,538.35 | 2280.00 | 300.00 | 4,518.35 |

**Table 13.2:** Certification of each crop under which it was sold in 2019

| Plot | Crop | Certification |
|---|---|---|
| 1 | Red beets | Demeter |
| 2 | Grass clover | Organic EU |
| 3 | Potatoes | Organic EU |
| 4 | Peas | Demeter |
| 5 | Onions red | Demeter |
| 5 | Onions yellow | Demeter |
| 6 | Spelt | Organic EU |

[1] Peas were sold under Demeter certification directly to a processor for conserved peas sold to supermarkets in Germany.
[2] Red onions grown on 60% of the plot.
[3] Yellow onions grown on 40% of the plot.

**Scenario 1: Promoting soil health**

These rotations are examples of rotations currently used on the case study farm. There are two main guidelines used by the farmers in their crop choice: Firstly, heavy root crops that are financially valuable but damaging to the soil are grown no more than once every three years. Secondly, there are always two consecutive years of grass clover in which the plot is not ploughed. According to the farmers, the full root system of grass clover only develops in the second year. That is meant to restore the soil organic matter and soil structure. The two rotations presented here focus either on onions or on red beets, as these are the two crops with the highest gross margins. Table 13.3 shows the 6-year pay-offs for the onion rotation, table 13.4 shows the 6-year red beet rotation.

***Table 13.3:*** *Soil health promoting rotation with focus on onions in €*

| | Crop | GM per hectare | GM per ha discounting (1%) | GM per ha discounting (3%) | GM per ha discounting (5%) |
|---|---|---|---|---|---|
| Year 1 | Onions | 21,300.02 | 21,300.02 | 21,300.02 | 21,300.02 |
| Year 2 | Peas | 6,133.71 | 6,072.98 | 5,955.06 | 5,841.63 |
| Year 3 | Spelt | 4,518.35 | 4,429.32 | 4,258.98 | 4,098.28 |
| Year 4 | Potatoes | 7,561.13 | 7,338.76 | 6,919.51 | 6,531.59 |
| Year 5 | Grass clover | 726.09 | 697.76 | 645.12 | 597.36 |
| Year 6 | Grass clover | 726.09 | 690.85 | 626.33 | 568.91 |
| **Total** | | **40,965.39** | **40,529.69** | **39,705.01** | **38,937.78** |

***Table 13.4:*** *Soil heath promoting rotation with focus on red beets in €*

| | Crop | GM per hectare | GM per ha discounting (1%) | GM per ha discounting (3%) | GM per ha discounting (5%) |
|---|---|---|---|---|---|
| Year 1 | red beets | 11,535.33 | 11,535.33 | 11,535.33 | 11,535.33 |
| Year 2 | peas | 6,133.71 | 6,072.98 | 5,955.06 | 5,841.63 |
| Year 3 | spelt | 4,518.35 | 4,429.32 | 4,258.98 | 4,098.28 |
| Year 4 | potatoes | 7,561.13 | 7,338.76 | 6,919.51 | 6,531.59 |
| Year 5 | grass clover | 726.09 | 697.76 | 645.12 | 597.36 |
| Year 6 | grass clover | 726.09 | 690.85 | 626.33 | 568.91 |
| **Total** | | **31,200.70** | **30,765.00** | **29,940.33** | **29,173.09** |

### Intermediate soil health rotation

In this intermediate rotation, root crops are grown every second year with always one root crop followed by a rest crop (from soil perspective). This means that each root crop is followed by either a legume, a grain or grass clover. According to the farmers, a rotation like this does not fully restore the soil but rather slows down degradation.

***Table 13.5:*** *Intermediate rotation in €*

| | Crop | GM per hectare | GM per ha discounting (1%) | GM per ha discounting (3%) | GM per ha discounting (5%) |
|---|---|---|---|---|---|
| Year 1 | onions | 21,300.02 | 21,300.02 | 21,300.02 | 21,300.02 |
| Year 2 | peas | 6,133.71 | 6,072.98 | 5,955.06 | 5,841.63 |
| Year 3 | potatoes | 7,561.13 | 7,412.15 | 7,127.09 | 6,858.17 |
| Year 4 | spelt | 4,518.35 | 4,385.47 | 4,134.93 | 3,903.12 |
| Year 5 | red beets | 11,535.33 | 11,085.23 | 10,248.99 | 9,490.14 |
| Year 6 | grass clover | 726.09 | 690.85 | 626.33 | 568.91 |
| **Total** | | **51,774.63** | **50,946.69** | **49,392.42** | **47,961.99** |

### Cash crop focus

According to the farmers, this section shows a rotation focussed on root crops. Two years of root crops are followed by just one year of rest with the focus crop returning every three years. The calculations are presented with onions and red beets as the focus crops. While this type of rotation may be more similar to rotations used by conventional farmers, these calculations are still based on prices and costs obtained in an organic and biodynamic farming system. They are thus not comparable to margins in a conventional farming system. The pay-offs for these rotations are much higher than the above. However, it is likely that such pay-offs may not be possible to be sustained in the long-term. The calculations cannot take into account the long-term effects of soil health changes. According to the farmers, rotations such as presented here are more susceptible to pests and diseases and can harm soil structure. They may thus be more likely to degrade soil health over time, and decrease crop yield. In conventional farming systems, farmers may use chemicals for crop protection and fertilizer to increase soil fertility to manage some of the drawbacks of such a rotation. However, this is not possible within the certification schemes currently used on the farm and would thus not be possible in the current business model.

These rotations, thus, are not realistic and rather illustrate the short-term argument for such rotations and the lock-in they create. Because such rotations are so profitable under ideal conditions in the short-term, they look tempting for farmers to pursue. These high ideal-case gross margins are illustrated here. This shows that in order to motivate farmers to diversify, long-term effects on the soil need to be shown and taken into account. Hence alternative incentives, e.g. policy measures accounting for negative environmental effects, need to be specified and implemented to make such rotations less attractive than those offering long-term soil health and productivity.

*Table 13.6: Cash crop rotation with focus on onions in €*

| | Crop | GM per hectare | GM per ha discounting (1%) | GM per ha discounting (3%) | GM per ha discounting (5%) |
|---|---|---|---|---|---|
| Year 1 | onions | 21,300.02 | 21,300.02 | 21,300.02 | 21,300.02 |
| Year 2 | red beets | 11,535.33 | 11,421.12 | 11,199.35 | 10,986.03 |
| Year 3 | peas | 6,133.71 | 6,012.85 | 5,781.61 | 5,563.46 |
| Year 4 | onions | 21,300.02 | 20,673.58 | 19,492.53 | 18,399.75 |
| Year 5 | potatoes | 7,561.13 | 7,266.10 | 6,717.97 | 6,220.56 |
| Year 6 | spelt | 4,518.35 | 4,299.06 | 3,897.57 | 3,540.25 |
| **Total** | | **72,348.55** | **70,972.73** | **68,389.04** | **66,010.06** |

*Table 13.7: Cash crop rotation with focus on red beets in €*

| | Crop | GM per hectare | GM per ha discounting (1%) | GM per ha discounting (3%) | GM per ha discounting (5%) |
|---|---|---|---|---|---|
| Year 1 | red beets | 11,535.33 | 11,535.33 | 11,535.33 | 11,535.33 |
| Year 2 | onions | 21,300.02 | 21,089.12 | 20,679.63 | 20,285.73 |
| Year 3 | peas | 6,133.71 | 6,012.85 | 5,781.61 | 5,563.46 |
| Year 4 | red beets | 11,535.33 | 11,196.08 | 10,556.46 | 9,964.65 |
| Year 5 | potatoes | 7,561.13 | 7,266.10 | 6,717.97 | 6,220.56 |
| Year 6 | spelt | 4,518.35 | 4,299.06 | 3,897.57 | 3,540.25 |
| **Total** | | **62,583.87** | **61,398.54** | **59,168.56** | **57,109.97** |

**Comparison**

The comparison (Table 13.8) suggests that the margins would be significantly higher if this biodynamic farm would follow less diversified rotations similar to those in conventional agricultural systems. However, the long run consequences would not be accounted for when making the shift to such less diversified rotations. Negative consequences for soil and crop yields might not materialise immediately but over some years, and thus shifting to these rotations or even conventional production may look tempting. Nevertheless, the negative costs of local environment and climate are not priced at the markets. The long run sustainability and land and soil stewardship principles motivate the farmers in keeping biodynamic principles. Sufficient scale of biodynamic production may provide sufficient farm income even though shorter rotations could provide higher income per hectare in the short run. The experienced evidence of good soil health, soil organic carbon, sufficiently high crop yields and income level considered sufficient by the farmer support the decision to stay in the current biodynamic farming system. This may be a better solution in the long run since increasing levels of fertilisers and crop protection are avoided, as well as crop yield and income decline due to deteriorating soil health. Negative effects on local environment and climate are also avoided. The exact price of these benefits of the current biodynamic farming, however, is hard to be calculated exactly, as this example shows.

***Table 13.8:*** *Comparison of the gross margins in the different rotations over 6 years in €*

| | GM per hectare | GM per ha discounting (1%) | GM per ha discounting (3%) | GM per ha discounting (5%) |
|---|---|---|---|---|
| Soil health promoting rotation with focus on onions | **40,965** | **40,530** | **39,705** | **38,948** |
| Soil heath promoting rotation with focus on red beets | **31,201** | **30,765** | **29,940** | **29,173** |
| Intermediate rotation with one-year break between root crops | **51,775** | **50,947** | **49,392** | **47,962** |
| Cash crop rotation with focus on onions | **72,349** | **70,973** | **68,389** | **66,010** |
| Cash crop rotation with focus on red beets | **62,584** | **61,399** | **59,169** | **57,110** |

## 13.4. Conclusions

The results shown here illustrate high short-term gross margins from cash crop intensive rotations compared to soil health promoting, less intensive rotations. However, unless long-term effects of decreasing soil health and soil organic carbon with decreasing crop yield and increasing input cost implications are taken into account, these short-term calculations most likely do not show the full picture. Still, the diversified rotations may require a rather entrepreneurial approach: To achieve good market access for all crops involved, marketing and relationship management can be time- and skill-intensive. This may not suit every farmer's business model. Yet, the calculations show that at a farm size of approximately 100 ha, the diversified rotations are a profitable approach that is likely to be more sustainable in the long-term, environmentally and economically.

Speaking about limitations, we need to indicate that, over all, the data collected cannot take into account the time-investment for knowledge gathering and relationship management that the different crops entail. Yet each additional crop implies the need for initial gathering of technical knowledge, as well as continuous management of an additional value chain and its relationships. This is a hidden cost that the models are not be able to quantify.

Further, the data is limited to one farm and one year of data collection. Results should thus be seen more as illustrative than as definitive as we cannot take into account the variability of all prices and yields over time. Additionally, it should be noted that the results obtained for this case study come from a farm that has been operated as an organic and diversified farm for many years and the models thus do not include any issues around soil health recovery of a farm in transition from non-diversified to diversified agriculture.

## 13.5.References

Biodynamic Association 2020b. Biodynamic Principles and Practices. Referenced July 8 2020 https://www.biodynamics.com/biodynamic-principles-and-practices

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