Olive farmers’ compliance to soil-erosion-control policies in the Protected Designation of Origin Estepa.

Iris Flamand
MSc thesis in Environmental Sciences

November 2020

Picture taken by a proud farmer in PDO Estepa on the morning of July 27, 2020, showing his olive grove with spontaneous vegetation growth.

Supervised by: Dr Lenny van Bussel & Dr Jantiene Baartman.
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Environmental Systems Analysis

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Supervisors:
1) Dr Lenny van Bussel (ESA)
lenny.vanbussel@wur.nl
2) Dr Jantiene Baartman (SLM)
jantiene.baartman@wur.nl
3) Dr Gema Guzmán & Dr José Gomez (IAS, Host Institute)
gemaguzmandiaz@ias.csic.es
joseagomez@ias.csic.es

Examiners:
1st: Dr Lenny van Bussel
2d: Prof. dr Rik Leemans

Preface

This Master thesis has been performed from February until November 2020. A collaboration was made between Wageningen University, the Research Institute for Sustainable Agriculture (IAS) in Córdoba, Spain, and the Protected Designation of Origin (PDO) Estepa and its olive farmers. The report is aimed at researchers in the (policy) field of sustainable agriculture in Europe and dedicated to the PDO Estepa and its olive farmers and the researchers of the IAS in Córdoba.

My interest of doing the research in collaboration with IAS started during the orientation phase in which I searched a research topic within the Sustainable Land Management (SLM) chair group at Wageningen University. After a brainstorm session with Jantiene Baartman (from SLM) she initiated to contact the research institute CSIC in Spain. I was specifically interested in Córdoba, because I got inspired by the beautiful place and surroundings when I visited my boyfriend who was at that time studying there. Jantiene also had contacts with researchers at IAS (one branch of the CSIC) in Córdoba and from that point I decided to match my personal interests with sustainable agriculture for the research topic.

I thank all the people that have made this research into a success, even though I had to continue the work largely online because of the COVID-19 pandemic restrictions. I am glad that I had the opportunity to start my thesis abroad with the Erasmus+ programme and to study Spanish for a month. I am thankful for everyone's flexibility in continuing the research solely online. I thank the 21 farmers of PDO Estepa for participating in this research and the five pre-testers within the Netherlands for improving the survey's quality. In special, many thanks to Gema Guzmán and José Gomez from the IAS for reviewing the research proposal and closely staying in contact with me and the PDO Estepa. They significantly improved the research design and contributed to the data input. I greatly want to thank my main supervisors Lenny van Bussel and Jantiene Baartman, who reviewed the report during all phases, for the brainstorm sessions, for keeping me on the right track during writing and for motivating me. Also, I thank Rik Leemans for reviewing the thesis report and the many peer students from the ESA chair group for giving me tips on specific chapters. In addition, I thank my boyfriend Cheyenne for supporting me in all times, my friends from Wageningen (in special Esmé, Lotte, Marisa and Aniek) for closely following my progress and enjoying together the free time, my housemates (in special Varsha, Thibault and Vera) in Wageningen for giving me fresh insights and writing tips, my sister and mother for motivating me, and lastly, my team members in Nijmegen from Starters4Communities for supporting me during the final stage and for being compassionate.

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Summary

Poor management of agricultural systems and climatic factors cause soil erosion in Europe. This environmental problem is large in mediterranean countries, like Spain and especially olive groves are highly vulnerable to soil erosion. Most olive oil in Spain is produced in Andalusia. The Andalusian landscape is typified by bare soils and these are at risk due to total weed removal and irrigation systems combined with high tree densities. These soil-erosion problems should be controlled by agri-environmental measures (AEMs) of European Commission's Common Agricultural Policy, which aim to control and reduce the soil erosion effects. My study contributes to the Commission's initiative to map the current environmental policies' adoption in each member state.

In Andalusia, olive farmers already voluntarily adopted organic and integrated farming practices aimed at the soil erosion control in return for subsidies. These two sustainable-farming systems could be an example for other Spanish olive farmers, since AEMs are not always prioritized by conventional olive farmers.

I analyzed the compliance of soil-erosion-control measures within organic and integrated olive farming in Andalusia. Specifically, adoption rates of environmental measures were quantified and external factors that affect the adoption of those measures by olive farmers in the Protected Designation of Origin (PDO) Estepa, were identified. The adoption rates were analyzed to determine compliance of AEMs and an Exploratory Factor Analysis was combined with a Principal Component Analysis (PCA) to identify the farmers' socio-economic and institutional factors that explain differences in adoption rates. I considered different agricultural practices to determine compliance rates which were measured with a survey among 21 organic and integrated olive farmers. The results show that from the 21 farmers, 20 were integrated farmers. Almost three-quarters of the integrated farmers complied with the contractual regulations and all applied at least one soil-erosion-control measure. Relatively high adoption rates were found for cover crop use. The PCA results show that neighboring farmers' practices and insufficient erosion-control information negatively affect compliance rates. Besides, attention should be paid to farmers with off-farm activities as their major income source because they tend to not apply soil-erosion-control measures.

The recent COVID-19 restrictions limited the number of survey respondents and future research should focus on the factors that I considered in my study, and also perform in-depth interviews with the olive farmers to gain a more complete perspective. Regardless of the statistical significance of my results and having few survey respondents, I found strong and realistic correlations between considered external factors and adoption rates of cover crops and tillage directions.

AEMs are designed to be a precision tool to achieve environmental goals. This is necessary to ensure food safety for future generations. PDO Estepa, where most farmers use integrated practices, is a promising example for other Spanish olive-oil farmers to control soil-erosion problems. To increase adoption rates of soil-conservation practices, more information should be provided on the mandatory requirements on integrated-farming practices and on the cross-compliance regulations. The future CAP reforms, which likely consider the objectives of the European Green Deal, probably provide opportunities for effective soil-conservation policies. Besides the importance of the new AEMs, the monitoring of compliance and considering external factors are crucial to boost sustainable-farming practices across the whole agricultural sector in Europe.

Keywords: olive groves, soil erosion, soil conservation practices, integrated farming, organic farming, Common Agricultural Policy.

Chapter 1
Introduction

1.1 Soil degradation and soil erosion in Europe

In Europe almost half of the land use is dominated by agriculture (Randall & James, 2012). Since the 1940s, agricultural practices became increasingly intensive to fulfill food demands (Grigg, 1987). One of the impacts of this intensification and of poor land use is the decline in soil conditions. This environmental problem is referred to as soil degradation. One of the main processes resulting in soil degradation is soil erosion. Worldwide current rates of soil erosion processes are beyond natural circumstances because of anthropogenic land use and soil management (van Leeuwen et al., 2019).This will eventually threatens agricultural production because of reduced soil fertility. Farmers experience an increase of production costs to compensate for the soil value loss. Therefore, soil erosion has in addition the potential to decline the market value of land (Franco & Calatrava-Leyva, 2006).

The European Union (EU) recognized erosion as one of the soil degradation processes linked to agriculture. In 2015, Member States of the EU committed to stop land degradation by 2030 and aim to balance losses in land-based natural capital and associated ecosystem functions and services (ECA, 2018). This goal is in line with Sustainable Development Goal 15.3, which states: “By 2030, combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world” (UN, 2015). Measures must urgently be taken, especially in the most vulnerable areas (Eurostat, 2020), like the Mediterranean area within Europe (Salvia et al., 2019). In a report about combating desertification in the EU, from the European Court of Auditors (ECA, 2018), an increase in Mediterranean vulnerable land area can be observed between 2008 and 2017. Besides direct anthropogenic processes that drive soil degradation, also changes in climatic factors contribute to this environmental problem (Louwagie et al., 2011). Increasing temperatures, decreased precipitation, and more extreme weather conditions like droughts and heavy precipitations are examples of climatic factors affecting environmental conditions in southern European countries (Iglesias et al., 2007).

1.2 Soil erosion in olive groves in southern Spain

Many arid areas in Spain are experiencing land degradation as a result of worsening environmental conditions (Salvia et al., 2019) and more than a third of Spain’s area has soil erosion problems (Rodríguez Sousa et al., 2019a). Olive groves are the dominant cropping system in Spain and are highly contributing to soil erosion problems (Gómez, 2017). Spain has a such a large olive-oil sector because the trees are one of the country’s oldest crops that have adapted to the Spanish climate. Three quarters of the olive oil in Spain is produced by farmers in the most southern autonomous community: Andalusia. The olive production has provided employment, wealth, ecosystem services and food to the region (Ropero et al., 2019). Traditionally, Spanish olive farmers maintained low tree plant densities, a limited canopy size by pruning and bare soils to reduce water consumption by eliminating ground cover. This strategy created bare soil landscapes with limited ground cover that are vulnerable for soil erosion (Gómez, 2017). Andalusian olive groves are typified by those bare soil landscapes (Gómez, 2017) and at risk due to soil erosion problem caused by increased tree densities, total weed removal and irrigation systems (Pienkowski & Beaufoy, 2002; Rodríguez Sousa et al., 2019c).

1.3 Spain and the Common Agricultural Policy history

Olive cropping has always been an important sector in Spain, however in the 1970s the price of olive oil decreased, which resulted in large extensions of abandoned land (Ropero et al., 2019). To prevent further abandonment of agricultural land in Europe, the EU started investing in agricultural production growth, simultaneously causing negative environmental effects, like soil erosion. In the 1980s, when the EU crisis years were passing, the Common Agricultural Policy (CAP) reform was planned, which aimed to deal with these negative environmental effects. In 1992 the reform was official andincluded a shift from product to producer support. Direct payments, which are (still) part of the first pillar of the CAP, serve as an income subsidy for farmers. To receive this income support farmers need to comply with basic rules known as cross-compliance (van Leeuwen et al., 2019). Agri-environmental measures (AEMs) were (and still are) the second instrument that result from the CAP reform and provide payments to farmers to voluntarily manage their agricultural land sustainably (Randall & James, 2012). These AEMs are part of the second pillar of the CAP and known as the Rural Development Policy (RDP;(van Leeuwen et al., 2019). Direct payments were one of the reasons for Spanish farmers to increase their olive groves' productivity (Ropero et al., 2019). In the latest CAP reform (2014-2020), more attention was paid to environmental protection and delivery of public goods. This resulted in formation of the 'new greening measures', which further integrate environmental objectives and orient towards achieving the climate action goals (Hart et al., 2017; van Leeuwen et al., 2019).

1.4 Spain's AEMs in practice

In Spain, organic and integrated farming practices are adopted by olive farmers to integrate voluntary environmental measures (like soil-conservation practices) and gain additional financial support (Pienkowski & Beaufoy, 2002). Conventional olive farming is the traditional way of farming and represents conventional tillage and (high) intensive olive farming systems. Organic farming is described by the EU (2005) as: "a clearly defined and controlled approach to farming which incorporates a wider range of measures e.g. input reduction, rotation, extensification of livestock. Expected impacts include: enhanced soil quality, preserving water quality, and biodiversity enhancement." The aims of organic farming are improving rural economic development and preserving the environment. However, organic farming does also have external environmental and economic disadvantages compared with conventional farming. Organic farming requires more land than conventional farming, which results in higher land costs for farmers. CAP's financial support is often inadequate for stimulating organic farming because the yield does not counterbalance the costs of organic land management practices (Pleguezuelo et al., 2018). Integrated farming systems minimize pesticide and fertilizer use (Randall & James, 2012) and are seen as semi-organic since the use of chemicals and machinery is regulated (Rodríguez Sousa et al., 2019a). The reduced input of chemicals ensures that the pollution of groundwater, surface water and adjacent biotopes is minimized. Therefore, it is assumed that this alternative farming system leads to minimal local environmental impact (Wijnands, 1997).

AEMs are aimed to be a precise tool for achieving environmental goals (EU, 2005) and specifically to control soil erosion problems (Louwagie et al., 2011). Previous studies found however low priorities given by Spanish olive farmers to adopt AEMS (Franco & Calatrava-Leyva, 2006; Rodríguez-Entrena et al., 2014; Sastre et al., 2017). These studies also present the socio-economic and institutional factors that determine such adoption.

Assuming that AEMs have desired effect to preserve soil conservation – appearing controversial in some studies (Finn et al., 2009; van Leeuwen et al., 2019) – the adoption rates of

AEMs by Spanish organic and integrated farmers needs to be studied to find out whether these promising olive grove management types can contribute to achieve the European environmental goals. So far, no study assessed the compliance of Spanish organic and integrated farming practices and the socio-economic and institutional factors behind the compliance.

1.5 Estepa as a research area in southern Spain

The Mediterranean climate has an average annual temperature of 17.5 degrees Celsius and an annual rainfall of 477 millimetres. The soils have a silty texture and mainly contain limestone substrate and are slightly alkaline with a pH ranging from 7.2-8.2 (Rodríguez Sousa et al., 2019b).

The Protected Designation of Origin (PDO)[1] Estepa is a large territory located in the autonomous community of Andalusia, Spain (see Figure 1), with 40,000 hectares (ha) that produce more than 25 million kilos of extra virgin olive oil per year, i.e. 50% of the total production of olive oil in the province of Seville (in the western part of Andalusia). The territory includes 19 olive oil mills, a bottling plant and a commercial trading company. More than 4500 families produce olive oils, which are sold under the brands *Oleoestepa, Estepa Virgin, Puricón, Las Valdesas and Hacienda Ípora* (Gutiérrez Vázquez & Rodríguez Aguilar, 2011). In 2003 a regulatory council was formed, that guarantees the quality of the extra virgin olive oil[2], and recognized by the Junta de Andalucía in 2004, later by the national Ministry of Agriculture, and since 2010 recognized as a PDO by the European Union (D.O.Estepa, n.d.). Estepa was recognized as a PDO by the European Union in 2010 (D.O.Estepa, n.d.).

Figure 1: Location of the territory of PDO Estepa adapted from Gutiérrez Vázquez and Rodríguez Aguilar (2011).

The olive tree density in PDO Estepa ranges from 100 to 500 trees per hectare (Rodríguez Sousa et al., 2019a) and is therefore classified as a traditional (<[3]200 trees per ha) to intensive (200-500 trees per ha) systems. Around 90% of the olive groves is rainfed, the remaining 10% is irrigated in times of water stress (c.f. Figure 2).

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[1] A PDO region means that the agricultural product originates from a specific place and is registered and certified with the PDO label (Hajdukiewicz, 2014).

[2] The regulatory council was established due to a petition for a Denomination of Origin for extra virgin olive oil from the region of Estepa and Puente Genil. The council's major aim is to ensure the quality of the regions' olive oil and to nationally and internationally promote the product (D.O.Estepa, n.d.). https://www.doestepa.es/do-estepa/regulatory-council/?lang=en

[3] i.e. 'less than'

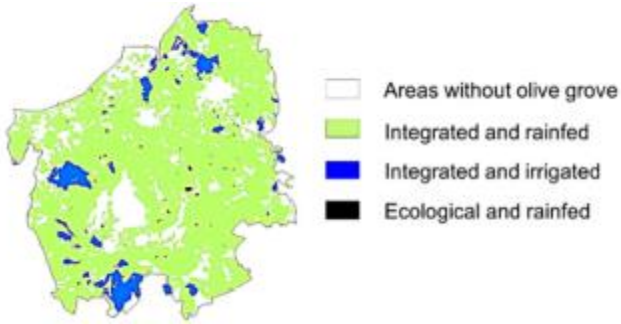

Figure 2: Management types in olive groves in Estepa, retrieved from the results of the research of Rodríguez Sousa et al. (2019b). Note that ecological is a synonym for organic.

PDO Estepa is of particular interest as a research area since the olive-oil producers are solely certified organic or integrated farmers (Figure 2) (JuntadeAndalucía, 2015). The farmers of PDO Estepa could therefore be a promising example for other Spanish farmers for minimizing or reducing the contribution of the olive-oil sector for causing soil erosion problems in Spain.

1.6 Objectives of the study

My study – valid for olive farmers in PDO Estepa – aims (a) to record the current CAP regulations related to soil-erosion-control measures, (b) to assess the current adoption rate of these soil-erosion-control measures and (c) to analyze the external factors that influence them.

The results of my study should give insights in the CAP's AEMs compliance by southern Spanish olive farmers. In addition, my study could contribute to the design of Spanish national and regional soil-conservation policies beyond 2020 and improve the implementation of the future CAP reform (2021-2027).

The research questions (RQs) that address Objective a, are:

RQ1 *What are the soil-erosion-control policies for Spanish olive farmers?*

RQ2 *Which soil-erosion-control requirements and measures are prescribed for southern Spanish olive farmers?*

The research question that addresses Objective b, is:

RQ3 *What are the adoption rates of the soil-erosion-control requirements and measures by olive farmers in PDO Estepa?*

The research questions that address Objective c, are:

RQ4 *Which external factors influence the adoption of soil-erosion-control requirements and measures by the olive farmers in PDO Estepa?*

RQ5 *Which external factors constrain the adoption of soil-erosion-control measures by southern Spanish olive farmers?*

1.7 Outline

The next chapter of this report defines the research design and the methods used which are linked to the RQs. Chapter 3, as the first results chapter, presents the soil-erosion-control requirements and measures for integrated and organic olive farmers in Spain and therefore answers RQs 1 and 2. The second result chapter (Chapter 4) explored the possible external factors and provides an answer to RQ4. Chapter 5 describes the characteristics of the olive farmers as a first result of the survey and relates to the representativeness of the sample which is required to extrapolate the results to the whole population of PDO Estepa. The sixth chapter presents the second survey results, revealing the compliance rates of soil-erosion-control measures and therefore answering RQ3. Consequently, the influence of the external factors and their strength and direction are described in Chapter 7 and provides an answer to RQ5. In the discussion (Chapter 8) the results of four types of data analysis are combined and interpreted. Within the first section, I discuss the strengths and weaknesses of the research design, followed by unforeseen obstacles or external factors that have affected the performance of the research. Within the second section, the sections present a summary of the result, followed by a draft conclusion, criticized and I lastly explain the effect of this criticism on the outcome. It will become clear if the found adoption rates are relatively high or low. Within the last section implications of my study and future research possibilities are given. Finally, the conclusion will reveal the compliance of the soil-erosion-control measures by the olive farmers in PDO Estepa and I explain what should be done to increase the adoption rates in future.

Chapter 2

Methodology

2.1 Research design

Figure 3 gives an overview of the research design of my study. The basis of the research lays in literature reviews, i.e. the secondary data, and the conduction of an online survey (i.e. the primary data). The survey contained questions about farm characteristics, the requirements regarding integrated or organic farming and regarding cross-compliance as well as questions regarding farmers' motivations for farming, their farming problems and social-economic related information. As can be seen in Figure 3, the secondary data was the input for the survey questions design. Three types of data analysis were performed and supported by statistics.

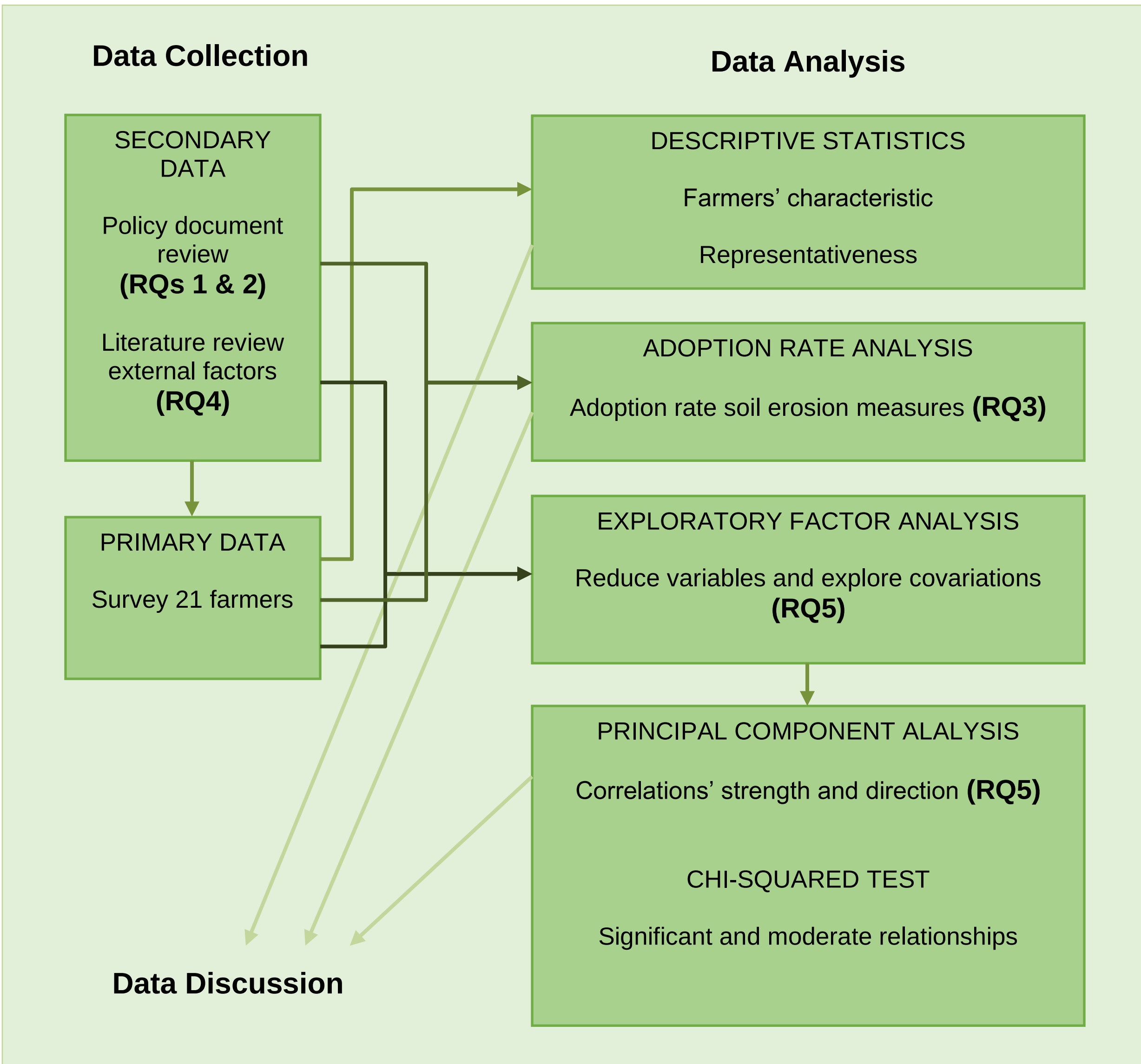

Figure 3: Research design in flow chart. The colours of the arrows are clarity of the arrow direction.

This research design was developed in collaboration with two researchers of the Institute for Sustainable Agriculture (IAS) in Córdoba. The institute is a research center within the CSIC (Spanish National Research Council) and focusses on the agricultural systems in Andalusia. It was established in 1992 and nowadays it is oriented towards the sustainability of agriculture, optimizing resource use and minimizing environmental degradation (IAS, n.d.). Dr. Gema Guzmán and Dr. José Gomez, researchers at IAS, were involved during the development of the research proposal and the survey. They were responsible for contacting the farmers of the PDO Estepa.

2.2 Data Collection

2.2.1 Policy documents and literature review

Spanish and EU policy document were reviewed to identify agricultural legislation at national and regional level for integrated and organic olive farmers. The policy documents were relevant because they are accessible for the farmer too, in contrast with research studies. The policy documents are open-access and identified and accessed by the search engine Google Scholar. Also, the IAS Córdoba recommended policy documents. The search terms (in combination) used were: *agri-environmental schemes (AES), soil erosion, land degradation, CAP, olivar ecologico, Andalucía, produción integrada, buenas practicas, BCAM,* and *conditionalidad.*

From the policy documents the contractual soil-erosion-control requirements were extracted to which the olive farmers in Spain must comply. The policy document review was oriented toward publications from the European CAP, like the RDP and the Commission and Council Regulations, regulation reports from the government of Andalusia, review studies, the FEGA (Spanish Agrarian Guarantee Fund) manual, and reports from the Spanish Ministry of Agriculture, Food and Environment.

Several studies about the economic, institutional, social and geographical factors that possibly determine low adoption of soil-erosion-control practices by olive farmers in southern Spain were reviewed. This literature was accessed by the search engine Google Scholar and the following search terms (in combination) were used: *soil erosion, cross compliance, olive groves, AES, adoption, soil-conservation practices, sustainable soil management,* and *Mediterranean.* From every identified paper all factors were extracted. Overlapping factors or non-desirable factors (those that are valid for topics outside the scope of the research) were eliminated and similar factors (e.g. major source of income vs. off-farm activities) were merged.

2.2.2 Farm surveys

The outcomes of the policy document and literature review were used to create a survey. The survey's first objective was to quantitively measure the compliance of soil-erosion-control requirements by the olive farmers from PDO Estepa. The second objective was oriented towards exploring the underlying socio-economic and institutional factors that determine the compliance. For this form of primary data collection an online survey was designed with Google Forms. This survey tool from Google is free to use and met my preconditions for the survey design. Those preconditions were to support the use of conditional questions (including sections), support pictures, easily distributable and deliver the outcomes in a downloadable .csv format. Google Forms was chosen in consultation with the IAS Research Institute and the PDO Estepa. A copy of the Spanish survey can be found in Appendix A. A translation of this survey into English can be found in Appendix B.

The drafting of the survey questions was coordinated with the supervisors at IAS Research Institute. The survey contained 42 questions in total, of which four were open-ended and 38 closed ended. The latter questions were categorical nominal and with multiple response options (e.g. type of cover crop with four response options) or categorical binary with single response option (e.g. integrated or organic), and few were categorical ordinal with multiple response options (e.g. surface area with ten response options). Forced choice questions made sure that the respondents answered a yes or no for every response option (e.g. elimination of cover crop per month) and to avoid the *response order effect.* Especially *primacy effects* (when the option is more likely to be chosen when it appears in the beginning of the list of response options) have been shown to be minimized when using forced choice questions (Dillman, 2011). Question 31 of the survey (Appendix B) is a good example in which the response order effect was tried to be minimized. In this question a list of motivations was presented, and the farmer had to indicate yes or no for every response option. If this "yes/no" was not done, but instead the farmer had to tick boxes (multiple choice), the first motivations were more likely to be chosen than the last motivations.

The first 23 questions were designed to measure the adoption rate (the primary objective) and the latter 19 questions to analyze the external factors (the second objective). Tree diagrams were made to determine the primary concepts to measure (see Appendixes C and D), which is called operationalization of abstract concepts. The first ramifications included the policies or the economic, institutional, social and geographical types. The subsequent ramifications, the domains, had to be homogeneous, mutually exclusive, exhaustive, no causes or effects, and neutral. This was all done to create data quality enhancement (Emonds, 2020). The survey was pre-tested and improved to, among other things, find out the completion time. The method for the pre-testing that was used was the 'think-aloud' and 'verbal probing' techniques described by Willis (1999). In this way improvement could be made related to navigation, instructions, clarity, assumptions, knowledge, sensitivity and bias and if all response categories are included. The five pre-testers were English-speaking people that had a background in (sustainable) agriculture, of which two are working as farmers. The survey started with a cover letter, introducing me, the research, the benefits for the respondent, what will happen with the results (confidentiality) and how much time the respondent needed to complete survey.

2.2.3 Survey participants

PDO Estepa decided to approach a restricted amount of 21 farmers in mid July 2020. I did not have any influence on the selection procedure, and due to COVID-19 no additional farmers could be approached. PDO Estepa selected the farmers based on their commitment to the cooperative, therefore convenience sampling is likely to be present. All 21 approached farmers responded in one week to the survey and no participants were excluded.

2.3 Analysis procedure

The survey versions presented in Appendices A and B are similar to the survey that was created in Google Forms; however within the *Word* version, the conditional questions (questions that are not automatically asked: you only have to answer them depending on your previous chosen response option) can be recognised with the italic text in square brackets (e.g. *[continue with question 3]*). Because of the conditional set-up not all questions were answered by the same number of respondents (i.e. the sample size *n* was variable).

The outcomes of the survey were downloaded in .csv format and imported and pre-processed in RStudio with *R version 4.0.2* and Microsoft Excel *version 2002*. The pre-processing included the responses translation from Spanish into English, the variable names and response options were shortened, and a version was made in which the data was coded.

Only one organic farmer responded. Therefore, the data of that farmer was only used for the analysis regarding the adoption of cross-compliance requirements.

2.4 Data analysis

2.4.1 Descriptive statistics of the olive farmers

The summary statistics of the sampled survey data are quantitively described and presented within a frequency table. The data in the frequency table were calculated in RStudio with the *count()* function and visualised within Excel.

2.4.2 Adoption rate analysis for measuring compliance by olive farmers

To calculate the number of farmers (i.e. # of farmers) that complied with each requirement that was included in the survey, RStudio and Microsoft Excel were used. A table was made to compare the response options that were allowed according to the policy document review, and the actual responses given by the farmers. The latter was done by creating frequency tables for every response option. The total adoption rate was calculated by taking the weighted average.

$$\text{Total adoption rate} = \frac{\sum_{i=1}^{n}(\text{sample size}_i \cdot \text{adoption rate}_i)}{\sum_{i=1}^{n}\text{sample size}_i} \qquad \text{Equation 1.}$$

Equation 1: The total adoption rate (# of farmers complied) of the requirements with n number of requirements.

2.4.3 Exploratory Factor Analysis for investigating covariations and their strength

The goal of Exploratory Factor Analysis (EFA) is to reduce the number of measured concepts (here the independent variables) that seems to cause the effect of the adoption rate of a requirement (here the dependent variable). Figure 4a visualises the investigated relation between the variables. For factor analysis it is assumed that for the previous selected dependent variables, there are a selection of underlying independent variables (called factors) that can explain the covariation among the two (Yong & Pearce, 2013). Covariation describes the variation between the dependent and independent variables. The relationship between one dependent and one independent variable was visualised to identify this possible covariation (see Figure 4b) (see for more details about this methodology Wickham and Grolemund (2016)).

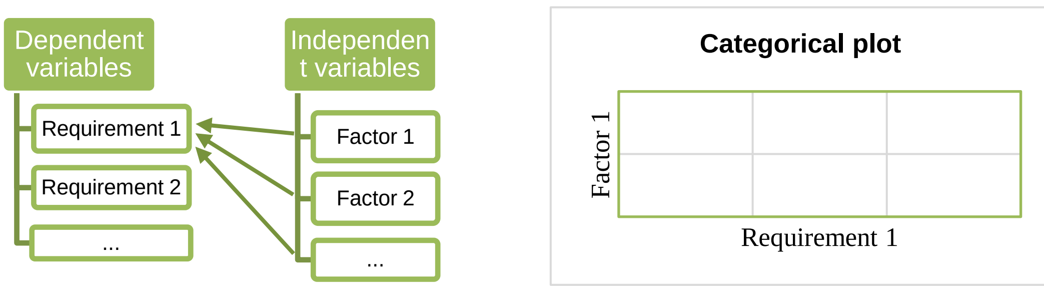

Figure 4a and 4b: a) the investigated effects of the independent variables on the dependent variables. b) Plot to identify covariation between two categorical variables, with the independent variable on the x-axis.

Visualising the covariation for two categorical variables was done by using the *geom_count()* function in RStudio, which resulted in more than 260 plots. These 2-dimensional plots, with the dependent variable on the x-axis and the independent variable on the y-axis (see appendix E for some examples), are made by counting the number of observations for each combination. The size of the circles in the *geom_count()* plot indicates how many observations occurred at each combination of the values. Covariation can be recognized by a strong correlation between specific x- and y-values. The number of independent variables was therefore extremely reduced. The EFA was performed for explaining the factors that cause low adoption of the requirements for integrated farming and the requirements for cross-compliance.

2.4.4 PCA for investigating correlations and their strength and direction

The reduced number of independent variables were used to do a Principal Component Analysis (PCA) in RStudio. I was mainly interested in the visualisation of the PCA, thus the PCA biplots because they easily show how the dependent and independent variables are correlated to one other. The biplots project the several independent variables (factors from the EFA) together with the dependent variable (from the adoption rate analysis) into a 2-dimensional plot with new variables. The two new dimensions of the biplot are the PC1 and PC2, which are the first two principal components (PC) that are uncorrelated with each other. These PCs are computed with the *prcomp()* function in R. The first few components retain most of the variation present in the original variables, indicated in % behind the label of the x- and y-dimension. Categorical variables can be used within PCA to colour observations (i.e. farmers) by groups. The appeared groups were expected to show clusters of sampled farmers based on their similarity. The visualisation of the different groups within the PCA biplot is the first outcome on which conclusions can be drawn. The second outcome, that can be retrieved from a PCA biplot, is related to the arrows and the angles between them. Since one dependent variable and all significant independent variables are visualised, the angle between the dependent variable and an independent variable is of interest to retrieve information about the correlations between the two. When the angle is close to 180 degrees, it means that the dependent and independent variables are negatively correlated. When the angle is close to 0 degrees, they are positively correlated. If the vectors meet at an angle of 90 degrees, they are not likely to be correlated with one other. Figure 5 shows a simplified PCA biplot in which a hypothetical distribution of the samples is displayed according one of the first survey questions related to the use of cover crops.

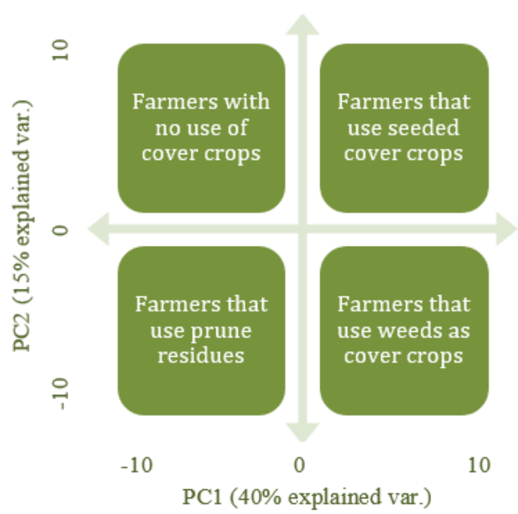

Figure 5: A simplified visualization of a PCA biplot with created groups based on the use of the type of cover crops by the olive farmers.

2.4.5 Chi-square test for investigating relationships and their strength

The Chi-squared test was performed to assess if the results of the sampled data represent the total population of PDO Estepa. The null hypothesis is that there is no relationship between the independent and dependent variables. The alternative hypothesis states that there exists a relationship between the variables. The Chi-squared test does not say anything about the direction of the relationship. The P-values (the probability) are set to 0.05 for significant relationships, which is the threshold for rejecting (<0.05) or accepting (>[4]0.05) the null hypothesis, and to 0.10 for moderate relationships. Hypothetically, when the P-value is lower than 0.05, the null hypothesis is rejected, and the alternative hypothesis is accepted.

In addition, data of the sampled farmers were compared with data from the total population that were requested by PDO Estepa. The data was analyzed and visualised within Excel and indicates where the sample represent the total population. This was done to gain a general idea of how divergent the farmers in the sample size are, compared to all farmers in the PDO Estepa.

[4] i.e. 'more than'

Chapter 3
Results: Soil-erosion-control requirements and measures

The requirements related to soil-erosion-control within olive farming encompasses the cross-compliance regulation (first pillar) and the agri-environmental measures (second pillar) of the CAP. The cross-compliance is defined as *La Conditionalidad* in Spanish and holds the legal management requirements. Organic and integrated farming are voluntarily contractual regulations which pertain to the agri-environmental measures or *buenas condiciones agrarias y medioambientales* (BCAM) in Spanish (Pienkowski & Beaufoy, 2002; van Leeuwen et al., 2019). These two separate regulations are explained in more detail within the following three sections. Each section ends with a summary about soil-erosion-control requirements for Spanish olive farmers, or specifically for Andalusian olive farmers, resulting from organic farming, integrated farming and the cross-compliance regulations (Textboxes 1, 2 and 3).

3.1 Organic olive farming regulations

The certification of organic products is in general defined by the EU. The following two EU norms are important for organic production and originate from the CAP: *Council Regulation (EC) No 834/2007 of 28 June 2007 on organic production and labelling of organic products and repealing Regulation (EEC) No 2092/91* and *Commission Regulation (EC) No 889/2008 of 5 September 2008 laying down detailed rules for the implementation of Council Regulation (EC) No 834/2007 on organic production and labelling of organic products with regard to organic production, labelling and control*.

These regulations can be retrieved from the EUR-Lex website (EuropeanUnion, 2020) or via the Spanish Official State Bulletin (BOE) website[5] for the Spanish version. The region specific requirements for organic olive farming are described within the Rural Development Programme of Andalusia 2014-2020 (JuntadeAndalucía, 2014): *Article 29 of the EU Regulation No 1305/2013 of the European Parliament and the Council of 17 December 2013 on support for rural development by the European Agricultural Fund for Rural Development (EAFRD) and repealing Council Regulation (EC) No 1698/2005.*

In Section 3.1.1. the contractual obligations for organic production will be discussed. Autonomous Communities in Spain are responsible for the organic products' control and certification. Public control authorities carry out the control and certification in most Autonomous Communities. However, Andalusia and Castilla La Mancha are an exception, where private bodies control and certificate the organic products. After registered as an organic farm, the farmer has three years to convert fully into organic farming. Converting to organic farming will be two years if the farm was abandoned in previous years (Leyva et al., 2017).

3.1.1 Contractual obligations of organic farming in Spain

To prevent soil compaction and soil erosion mechanical and biological methods, such as shallow tillage and compost use, are allowed for the cultivation of organic olive trees. These measures have as objective to maintain or increase organic material content of the soil and the biological activity in the soil. Besides, soil stability and soil biodiversity have to be reinforced. The use of cover crops is one of the main techniques that is mandatory to comply with these objectives. Either one of the following types of cover crops can be used: spontaneous vegetation (i.e. weeds) or seeded vegetation. Cover crops must be applied in the olive grove from autumn

[5] https://www.boe.es/buscar/

until the start of spring to minimize soil erosion. The cover crop can be controlled and therefore kept at an optimal height with mechanical methods (shallow tillage) or cattle grazing. Additionally, farmers must promote weeds in zones outside the cultivation area to reduce the formation of gullies. Farmers also have the option to save the prune residues of the olive trees, finely chop them and use them as a cover in between the olive trees to prevent soil erosion. This use of prune residues can be either combined with cover crops or used instead of cover crops. The use of prune residues increases water retention capacity and reduces weeds. Since the control of weeds can be challenging within organic olive farming due to the prohibition of chemical product use the use of prune residues is recommended (JuntadeAndalucía, 2015; Leyva et al., 2017).

Synthetic agrochemicals like herbicides are prohibited within organic farming. Fertilization method of organic agriculture is based on making efficient use of all the by-products that are generated by the farm itself. Examples are the earlier mentioned chopped prune residues, 'alperujo' compost (waste generated by the olive-oil extraction) and cattle manure (in case the olive farmer keeps cattle to control weeds) (JuntadeAndalucía, 2015; Leyva et al., 2017).

3.1.2 Summary of obligations for organic farming

Textbox 1: Checklist requirements for organic olive farming in Spain according to EU norms from CAP and the norms from the Plan Director de Andaluz by the Municipality of Sevilla (JuntadeAndalucía, 2015; Leyva et al., 2017).

Organic olive farmers in Spain comply with the following:

⇒ Only use biological and mechanical methods for cultivation.
⇒ Orient cultivation techniques towards preventing soil compaction and soil erosion.
⇒ Apply cover crops or chopped prune residues.
⇒ Use spontaneous or seeded cover crops.
⇒ Mandatory cover crop use from autumn until start of spring.
⇒ Control weeds mechanically or with animal grazing.
⇒ Use prune residues to minimize weeds.
⇒ Prohibited to use synthetic agrochemicals.
⇒ Use on-farm by-products efficiently for fertilization.
⇒ Promote weeds in zones outside cultivation area.

3.2 Integrated olive farming regulations

The certification of integrated farming in Spain is organised on regional level, thus within the according autonomous community (Leyva et al., 2017). Basic requirements of integrated production on national level are described by the Ministry of Agriculture, Fisheries and Food of Spain under the following legislation: *Real Decreto 1201/2002 (BOE núm. 287), de 20 de noviembre, por el que se regula la producción integrada de productos agrícolas*[6].

The requirements of integrated olive farming are designed and described for Andalusia under sub measure 10.1 which is part of the Rural Development Programme of Andalusia 2014-2020 (JuntadeAndalucía, 2014): *Article 28 of the EU Regulation No 1305/2013 of the European Parliament and the Council of 17 December 2013 on support for rural development by the*

[6] English: regulating integrated production of agricultural products.

European Agricultural Fund for Rural Development (EAFRD) and repealing Council Regulation (EC) No 1698/2005.

A corresponding regulation that describes the management of the operations of integrated agriculture in Andalusia and which is adapted from the basic rules of RD 1201/2002 is regulated under the following norm: *Decreto 245/2003 (BOE núm. 174), de 2 de septiembre, por el que se regula la producción integrada y su indicación en productos agrarios y sus transformados*[7].

The Ministry of Agriculture, Fisheries and Food has a registry of the farmers and entities who carry out integrated production practices. Two types of certification are available for integrated production: on individual level or a grouped certification (Integrated Production Group). The certification procedure goes via the Autonomous Community and several rounds of audits follow (Pérez & Berrocal, 2011).

3.2.1 *Contractual obligations of integrated farming in Andalusia*

When the slope of the olive grove is more than 10%, the interrow area of the olive trees must be covered with cover crops or shredded prune residues. The cover crop must be managed with mechanical methods, chemical methods or sheep cattle grazing. Tillage (either conventional or conservation tillage) is not allowed in the 10% or more slope groves. Tillage is exceptionally allowed when the soil is silty, has high tendency to form crust (heavily compacted), forms deep cracks, to incorporate organic matter, or if flora is resistant to herbicide or difficult to control (Pérez & Berrocal, 2011). Implements that deteriorate the soil structure, like disc harrows or moldboards, are prohibited. To avoid the formation of gullies, working in the direction of the slope[8] without taking additional measures against soil erosion is prohibited (Bilbao et al., 2005). It is advised to put barriers or obstacles in these gullies to limit their aggravation and to slow down the speed of the runoff water. Lastly, tillage is not allowed when the soil of the olive grove is watery, because these conditions can produce serious damage to the structure of the soil (Pérez & Berrocal, 2011).

An integrated farmer is compulsory to maintain cover crops (seeded or spontaneous) or apply prune residues in the interrow area of the olive trees in all part of the cultivation area (i.e. the non-slope area). The width of the cover must be at least 1.8 meters and has to be maintained from the first rains in the autumn until the end of winter. Tillage, either conventional or conservation tillage is allowed in case of preparing the land for planting cover crops, but other maintenance tasks are not allowed since they could destruct the soil structure and increase the risk of soil erosion. Tillage is exceptionally allowed to restore the farm zones which are affected by storms or heavy rainfall and therefore make the land vulnerable to soil erosion (JuntadeAndalucía, 2015). Pérez and Berrocal (2011) specifically indicate that the cover crop can be removed at the latest the last 10 days of March which is comparable with the legislation for organic farming described in Leyva et al. (2017).

For integrated farming organic agrochemicals are preferred to synthetic ones. This means that in general synthetic agrochemicals are not prohibited, although on bare soils during the cold months of the year (December and January) they are prohibited (Bilbao et al., 2005; Leyva et al., 2017). Herbicides may only be applied at most once annually, starting from 1st of October. On top of that, a maximum of two herbicide applications are allowed over a 5-year period. This is to avoid invasions of undesirable species or to implant and transplant the cover crops. Alternating the herbicide type every time is mandatory so that different active materials are applied, and the risk

[7] English: regulating integrated production and its recommendations for agricultural products and its changes.
[8] C.f. yellow arrows Image 5 in Appendix B.

of herbicide resistance is reduced. Also, for herbicides applying organic and natural products instead of the synthetic ones is recommended. An alternative for herbicides to manage weeds and control cover crops are mechanical methods (e.g. tillage). Both practices, herbicides and mechanical ones, are used to minimize water and nutrient competition between the olive tree and the crops and usually farmers begin using them at the end of winter or in spring (JuntadeAndalucía, 2015).

Textbox 2: Checklist requirements for integrated olive farming in Andalusia according to the Rural Development Programme of Andalusia (Bilbao et al., 2005; JuntadeAndalucía, 2014b; JuntadeAndalucía, 2015; Pérez & Berrocal, 2011).

Integrated olive farmers in Andalusia also comply with the following:

- ⇒ Maintain cover crops (seeded or spontaneous) or shredded prune residues in all part of the cultivation area.
- ⇒ Keep 1.8 meters as minimal width of the cover crop strips.
- ⇒ Maintain cover crop from autumn till spring.
- ⇒ Only apply (shallow) tillage for the planting and maintenance of cover crops or for restoring the soil after a storm or heavy rainfall.
- ⇒ Prohibited to apply fertilizers on bare soils in December and January.
- ⇒ Preferably use biological agrochemicals and mechanical methods.

Specific for groves with slopes of ≥10%:

- ⇒ Treat interrow areas with cover crops or shredded prune residues
- ⇒ Prohibited to perform tillage on steep slopes. Some exceptions exist, but in no case when the soil is watery.
- ⇒ Prohibited to use implements that destroy the soil structure.
- ⇒ Prohibited to work in the direction of the slope.

3.3 Cross-compliance regulations for olive farming

All farmers, whether conventional, organic or integrated, have to comply with legal cross-compliance regulation (Leyva et al., 2017). The soil-erosion-control requirements under this regulation are authorized by the FEGA and described in BCAM 4 and BCAM 5 (JuntadeAndalucía, 2019): *Norma 13-16 in BCAM 4: Cobertura mínima del suelo*[9] and *Norma 19 in BCAM 5: Gestión mínima de la tierra que refleje las condiciones específicas locales para limitar le erosión*[10].

These good agricultural practices are established in Annex II of the following EU regulation (EuropeanUnion, 2020): *Regulation (EU) No 1306/2013 of the Parliament and of the Council of 17 December 2013 on the financing, management and monitoring of the common agricultural policy and repealing* and *Council Regulations (EEC) No 352/78, (EC) No 165/94, (EC) No 2799/98, (EC) No 814/2000, (EC) No 1290/2005 and (EC) No 485/2008.*

3.3.1 Cross-compliance obligations of olive farming in Spain

Cover crops are only mandatory in olive groves with an average slope of 10% or more. Cover crops have to be maintained from the first rains in autumn till the end of winter. The minimal

[9] English: minimal soil cover.
[10] English: minimum land management considering specific local conditions to minimize erosion.

width of the cover crops should be one meter and has to be applied in the interrow area between the olive trees and transverse to the steep slope. Tillage is prohibited in the direction of the slope for very steep slopes (≥[11]15%). However, tillage is exceptionally allowed at very steep slopes when conservation tillage is applied, when total cover crop is maintained or when there are special structures (e.g. terraces) of cultivation applied (JuntadeAndalucía, 2019). In any case the formation of gullies should be avoided (FEGA, 2020).

Tillage is prohibited in rainfed olive groves between the harvesting date and the 1st of September. However, tillage in this period is exceptionally allowed for the management of cover crops, to control weeds, to apply fertilizers or to incorporate organic matter (JuntadeAndalucía, 2019).

Preparatory work (i.e. tillage) is prohibited in all groves (i.e. flat ones or with slopes) when the terrain is watery or covered with snow. Keeping structural elements on the grove in good condition and without altering them is mandatory. Structural elements are unique grove margins; retaining terraces, banks and ridges; island and enclave of spontaneous vegetation or rock; isolated trees and shrubs; water bodies (e.g. ponds, lagoons, holes); or small buildings (e.g. stone walls).

All operations that are executed on the farm have to be registered by the farmer, whether electronically or on paper. This farm-book should include the details of the following operations: labour; plantation; irrigation; prune residues treatment; application of phytosanitary and fertilizers. The farm-book additionally includes the performance of the olive grove, noting the location of the parcels and the dates of plantation, the dates of authorizations and delivery notes or invoices of operations that were required (FEGA, 2020).

Fertilizers are allowed according to the cross-compliance regulation, but applying them when the terrain is watery is prohibited (FEGA, 2020).

[11] i.e. 'equal or more than'

Textbox 3: Checklist requirements for conventional olive farming in Spain according to cross-compliance regulations described in BCAM 4 and 5 (FEGA, 2020; JuntadeAndalucía, 2019).

All olive farmers in Spain comply with the following:

⇒ Prohibited to carry out preparatory work on watery terrain.
⇒ Prevent the formation of gullies in the olive grove.
⇒ Keep structural elements in good condition.
⇒ Keep an updated farm-book.
⇒ Prohibited to fertilize on watery terrain.
⇒ Only carry out tillage work in rainfed groves - for cover crop management, weed control, fertilizer application or organic matter incorporation - between harvesting date and 1st of September.

Specific for groves with slopes of ≥10%:

⇒ Maintain cover crops (seeded or spontaneous) in between the olive trees and transversally to the slope from autumn till end of winter.
⇒ Prohibited to treat the cover crop strips with herbicides.
⇒ Keep 1 meter as minimal width of cover crop strips.

Specific for groves with slopes of ≥15%:

⇒ Prohibited to carry out tillage work in the direction of the slope, with exception of conservation tillage or with special forms of cultivation.

Chapter 4
Results: External factors infuencing compliance

Commonly found factors that influence the adoption of soil-conservation practices by olive farmers in southern Spain, in the scientific literature are described in this chapter. This literature review was carried out to explore the hindering factors for farmer's adoption of requirements and, subsequently, use the survey to collect data about the external factors. A tree diagram, which was used to formulate the corresponding survey questions is shown in Figure A in Appendix D.

4.1 Economic factors

Franco and Calatrava-Leyva (2006) describe the relationship between soil erosion reduction by conservation practices and the accompanied profitability as a factor for the adoption of soil-conservation practices by olive farmers. Farmers can choose to adopt such practices because it is expected that the profitability increases (Valetin et al. 2004 in Franco 2006). Calatrava Leyva et al. (2007) found that more profitably farms are able to cover the costs of additional requirements and therefore have a higher adoption rate of soil-conservation practices in comparission to non-profitable farms. Also Rodríguez-Entrena et al. (2014) found that profitability is a major factor influencing the adoption of soil-erosion-control measures by large olive farmers. In addition, farmers having their largest income source coming from on-farm activities is postively related to the adoption of soil-conservation practices by olive farmers in southern Spain (Calatrava Leyva et al., 2007). Lastly, the expansion of olive-oil producers in Mediterranean countries (Rodríguez-Entrena et al., 2014), enhancing stronger competition on the market, could be an incentive to adopt agri-environmental measures and comply with soil-conservation practices.

4.2 Institutional factors

Social cooperations (like a PDO) seem to positively affect the adoption of soil-conservation practices (Rodríguez-Entrena et al., 2014). By being part of a social cooperation farmers know that they can achieve a higher quality product, they are well-informed about requirements and farmers are more involved due to their larger network (Rodríguez-Entrena et al., 2014). Individual farmers could be motivated to join the cooperative when they notice that neighboring farmers have already joined. Farmers have the possibility of learning from each other when they are a member of the cooperatives, which is due to the earlier explained network capacity.

4.3 Social and farmers' awareness factors

The adoption of soil-conservation practices can be influenced by whether the farmer comes from a family of farmers and therefore has sufficient experience with farming practices. Experienced farmers are in general good managers, well-informed and aware of the appearance of technological innovations in future, which in return positively influences the adoption of conservation practices (Calatrava Leyva et al., 2007). Having a family farm (farms that rely on family labour and may have a relative as succesor) is also found to be positive for the adoption of soil-conservation practices (Calatrava Leyva et al. (2007). This is because the farmer is willing to invest in long terrm farming decisions. Franco and Calatrava-Leyva (2006) also found in their study that having a relative that will take over the farming activities influences the probability of the olive farmer to adopt soil-conservation practices.

Improvements of agricultural training, for example related to the benefits of adopting certain conservation practices and the information sources, were found to be an incentive for adopting soil-conservation practices. Furthermore, a low accesibility to the necessary technology can result in a low adoption rate (Aznar-Sánchez et al., 2020). Availability of the right machinery, for example, is related to higher adoption of soil-conservation practices by olive farmers in southern Spain (Rahm and Huffman (1984) in (Calatrava Leyva et al., 2007)). Calatrava Leyva et al. (2007) also describes that the adoption of certain soil-conservation practices decreases when the farmer is simply not aware of the requirements, and therefore lacks information about the contractual regulations of agri-environmental schemes

The environmental awareness of the farmer, like the impact of sustainable practices on the environment, is positively correlated to the adoption of sustainable agricultural practices (Aznar-Sánchez et al., 2020). Farmers' perception of soil erosion problems, as another aspect of farmers' environmental awareness, is key to a higher adoption of soil-conservation practices (Franco & Calatrava-Leyva, 2006).

4.4 Geographical and farm characteristics factors

A review by Rodríguez-Entrena et al. (2014) identified several geographical and farm characteristics that affect the adoption of soil-conservation practices. Besides the effect of farm size, the gradient of the land positively or negatively influences the adoption of those practices as well (Aznar-Sánchez et al., 2020). Also Franco and Calatrava-Leyva (2006) found that the slope of the farms influences (in both directions) the probability of the olive farmer adopting soil-conservation practices.

Chapter 5
Results: Surveyed farmers and the total population

5.1 Farmers' characteristics

The results of the survey revealed that 20 farmers are integrated farmers (Table 1). The other farmer is an organic farmer. Most of them apply spontaneous cover crops or prune residues. No farmers apply seeded cover crops. All farmers indicated that they encounter soil erosion problems in their olive groves. Six farmers encounter few problems (very few gullies, almost no crust forming and almost no soil compaction), 13 farmers encounter some problems (some gullies, some places of crust forming and soil compaction) and 2 encounter many problems (many gullies, largest part has crusts forming and soil compaction). Almost half of the farmers indicated that they have seen those soil erosion problems increasing during the last five years (2015-2020). According to the farmers the following events contribute to an increase in soil erosion problems: more intense rainfall (torrential or severe when it occurs), heavy storms, tillage, a disordered and more extreme climate and climate change.

The majority of the farmers indicated that they have joined PDO Estepa when it was established in 2004. The start year of cultivating with integrated or organic practices was not similar to the year of joining PDO Estepa. The most common reasons for farmers to start applying integrated or organic farming practices was to obtain a higher quality product, for personal prestige, for protection of the environment and for the social recognition that the brand PDO Estepa implies. The majority of the farmers (i.e. 17 farmers) indicated that olive farming is their major source of income. Two farmers indicated that their major source of income is dependent on other agricultural activities and two other farmers indicated that their major source of income comes from non-agricultural activities.

The farmers were asked what kind of information sources they already use to learn about the requirements for integrating or organic olive farming. Almost all indicated to receive information from the cooperatives belonging to the PDO. 15 farmers used other information sources such as farmer associations, research centers like CISC and public administrations like Junta Andalucía. The minority of the farmers (below 8 farmers) use information from neighboring or familiar farmers, information from internet (with RAIF, about phytosanitary product use, as specified webpage) or other information sources, like cooperative technicians, personal experience and the *Agropopular* Podcast (with César Lumbreras) of the Spanish radio channel COPE.

Table 1: The results of some qualitative descriptive data analysis, including the observations' frequency with n=21.

Variable	*Answer categories*	*Frequency*
Farmer type	Integrated	20
	Organic	1
Cover crop type	Spontaneous cover crops	9
	Prune residues	5
	None	7
Average slope (%)	0.1-5	6
	6-9	15
Irrigation system	Rainfed	14
	Irrigated	3
	Irrigated and rainfed	4
Area (ha)	4-9.9	4
	10-19.9	9
	20-29.9	1
	30-39.9	1
	40-49.9	2
	≥50	4
Age trees (years)	0-4	1
	10-19	3
	20-29	4
	30-39	6
	40-49	2
	≥50	5
Tree density (trees/ha)	<100	4
	100-199	11
	200-499	6
Erosion perception	Few problems	6
	Some problems	13
	Many problems	2
Erosion problems increased	Yes	10
	No	11
Successor	Yes, a family member	9
	Yes, a non-family member	1
	No	11

5.2 Surveyed olive farmers representative for PDO Estepa

In general, the sample of the survey represents the total population of PDO Estepa (Figure 6a, b, d). The sample population has however relatively more farmers with a large surface area (>4 ha), while the total population (N) has many farmers with a surface area smaller than 4 hectares (Figure 6c). Additionally, the sample population has many farmers with a tree density lower than 200 trees/ha, while the total population (N) has many farmers with a tree density bigger than 200 trees/ha (Figure 6e).

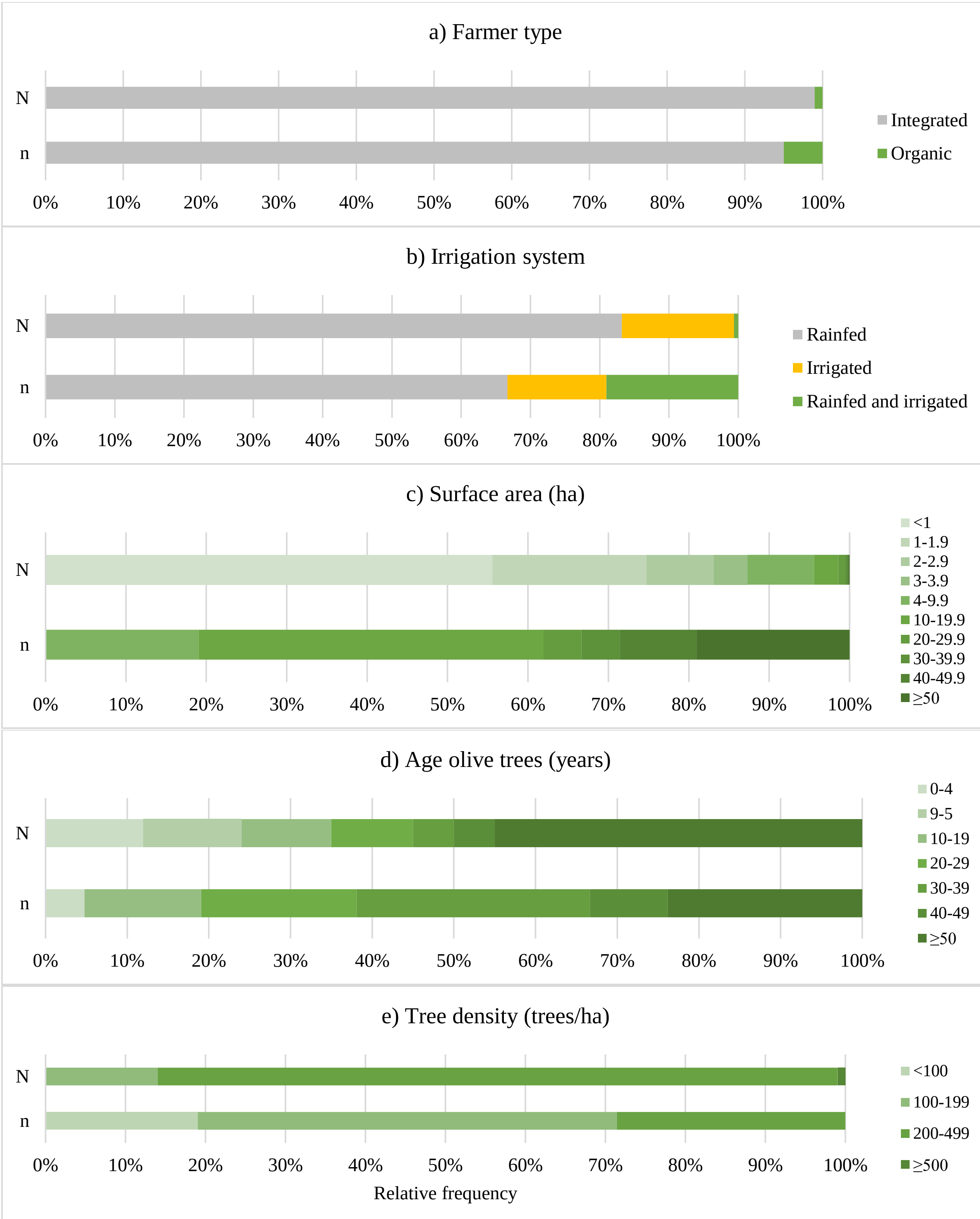

Figure 6: Representative sample (n=21) check with total population N = 4158 for a) type of olive farmers, b) olive farmers' irrigation system, c) olive farmers' the surface area, d) the age of the olive trees, and e) olive farmers' tree density.

Chapter 6
Results: Adoption rate analysis

The results of the adoption rate analysis for soil-erosion-control requirements under the agricultural regulations explored in Chapter 3 (the agri-environmental measures and the cross-compliance) are described and visualized in this chapter. The adoption rate equals the number of farmers (i.e. # of farmers) that complied with a requirement and is expressed in percentages (%). Note: the adoption rate analysis for organic farming has been excluded due to insufficient data (n = 1).

6.1 Integrated farming requirements' adoption rate

Integrated farmers in PDO Estepa indicated whether they did or did not apply the 12 agricultural practices that were measured with the survey. Table 2 shows the adoption rates per agricultural practice by the integrated olive farmers. Note that the sample size varies across the practices, which is due to the survey design that included conditional questions and therefore multiple sections (see Appendix B). For instance, a farmer who answered a 'Yes' in question a, would skip question b and go directly to question c. While a farmer who answered 'No' in question a would continue with question b. The agricultural practices with sample size 20 in Table 2 were therefore answered by all integrated farmers, while the lower sample sizes indicate that these were conditional questions. Four agricultural practices have adoption rates of 100%, while the lowest adoption rate equals 15%. The results of the practices that scored lower than an adoption rate of 95% are described in more detail in the next sections.

Table 2: Results of the 'adoption rate analysis' for integrated olive farming requirements and specified for soil-erosion-control.

Agricultural practice	*Sample size*	*Adoption rate (%)*
Cover crop	20	65
Removal method weeds	7	100
Cover crop min. width	13	85
Cover crop no removal winter	13	69
Cover crop control method	13	100
Prune residues	20	95
10% slope cover crop	6	67
10% slope exceptional tillage	6	100
Tillage direction	20	60
5-year herbicide use	20	15
Annual herbicide use	20	70
Reasons for tillage	20	100
Total		74

6.1.1 Cover crops

Integrated farmers have to apply one of the following cover crop types: spontaneous cover crop, seeded cover crop or prune residues. Figure 7 shows that no farmers use seeded cover crop, that most farmers use spontaneous cover crop and that seven farmers do not adhere this contractual requirement.

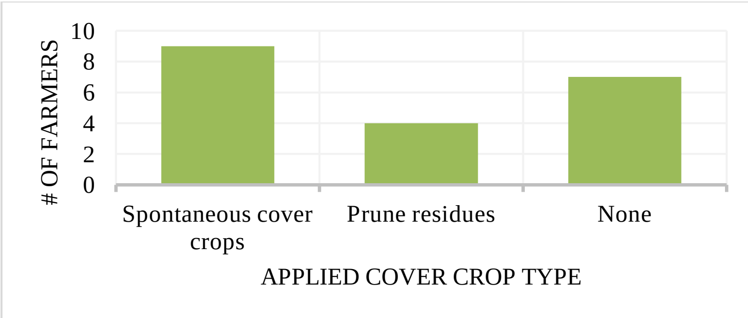

Figure 7: Frequencies of cover crop types by integrated farmers in PDO Estepa (n=20).

The farmers that do not apply cover crops indicated that they remove weeds on the olive grove with shallow tillage and synthetic herbicides, which are both legal practices.

The minimal width of cover crops in the interrow area has to be 1.8 meters (see Section 3.2.1). Two farmers do not adhere to this contractual requirement (Figure 8). Most farmers make sure the width is two meters, but some even apply entire homogeneous cover on their olive groves.

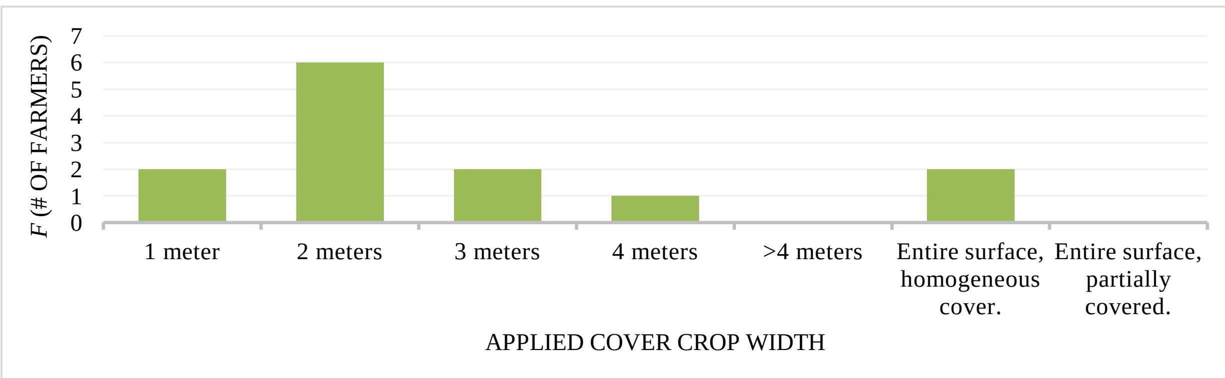

Figure 8: Frequencies (F) of applied cover crop width by integrated farmers in PDO Estepa (n=13).

During winter, the cover crops must be maintained (see Section 3.2.1). However, the results in Figure 9 show that some integrated farmers remove the cover crops also from October until February. Consequently, four farmers do not adhere to this requirement.

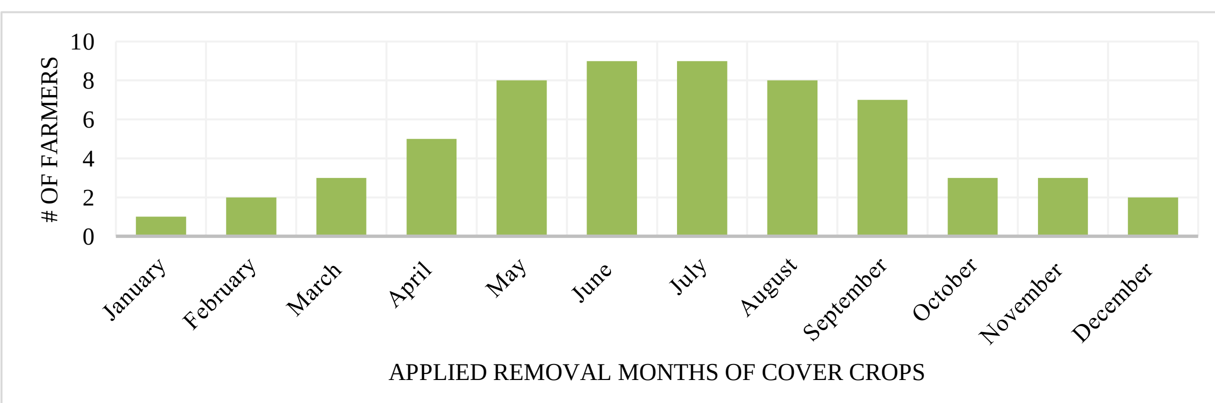

Figure 9: Frequencies of removal months of cover crop by integrated farmers in PDO Estepa (n=13).

The integrated farmers that did apply cover crops, indicated that the most common control methods for cover crops are mowing, shallow tillage and synthetical chemicals, which are all allowed according to the integrated farming contract (see Section 3.2.1).

Almost all integrated farmers indicated that they apply finely chopped prune residues in the interrow area of the olive trees. Only one farmer indicated no use of prune residues and this farmer neither indicated the use of cover crops. Most farmers (i.e. 16) apply every two years the prune residues, while three farmers indicated every year. This number of applications per year is not integrated in the legislation of integrated olive farming.

6.1.2 Tillage and herbicides

Table 2 indicates that 12 integrated farmers apply tillage in the direction of the slope, which is according to the regulation (see Section 3.2.1) only prohibited for groves with slopes of ≥10%. Having a closer look at the exact practices of tillage direction within Figure 10 shows that two farmers till in the direction of the slope, nine farmers till perpendicular to the slope[12] (i.e. that controls soil erosion problems) and six farmers apply both directions of tillage. Therefore, 11 farmers do not try to control soil erosion problems, but it is not certain whether they comply with the requirement of this integrated farming practice or not.

The twenty integrated farmers were asked for their reasons why they applied a certain tillage practice. The results show that most (i.e. 12 farmers) indicated to execute tillage for the removal of weeds. In addition, the restoration of soils (i.e. 11 farmers), the incorporation of organic matter and the application of phytosanitary products were common reasons as well (i.e. 8 farmers).

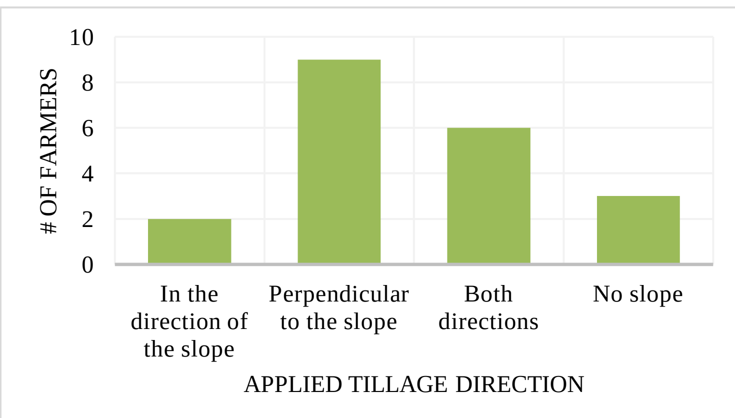

Figure 10: Frequencies of tillage direction on sloped groves by integrated farmers in PDO Estepa (n=20).

Chemical herbicide use is allowed within integrated farming, but there are restrictions for the number of applications per year. Figure 11 shows that 17 integrated farmers indicated that they apply more than two times herbicides over a five-year period, which is not allowed (see Section 3.2.1). 14 farmers indicated that they apply herbicides five or more than five times in a five-year period. Consequently, the contractual requirement of the annual herbicide application of maximum one-time application is by six farmers not complied with.

[12] c.f. whit arrows Image 5 in Appendix B.

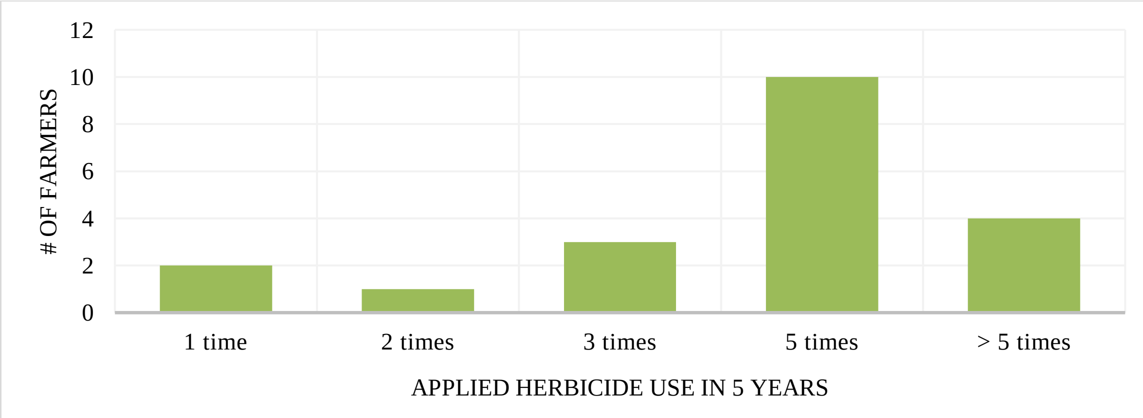

Figure 11: Frequencies of herbicide applications in a 5-year period from integrated farmers in PDO Estepa (n=20).

6.1.3 Special requirements for steep slopes

For steeper olive groves (i.e. having a slope of ≥10%) there are certain requirements prescribed in the contractual obligations of integrated olive farming (see Section 3.2.1). Six integrated farmers indicated that they have sloped groves of ≥10%. Three farmers keep cover crops in the interrow area perpendicular to the slope, and one farmer covers the entire surface with cover crops. Two farmers have ≥10% slopes do not adhere with the contractual obligation of applying cover crops in slope area.

All the six farmers with ≥10% slopes indicated that they apply chemical herbicides in those sloped groves, which is allowed for integrated olive farming. Three farmers indicated that they perform tillage in the ≥10% slope groves, which is only exceptionally allowed. Those three farmers have a legal exceptional reason for tillage: the soil has tendency to form crust, deep cracks or high soil compaction. Figure 12 indicates the problems that arise in the ≥10% olive groves according to 6 integrated farmers.

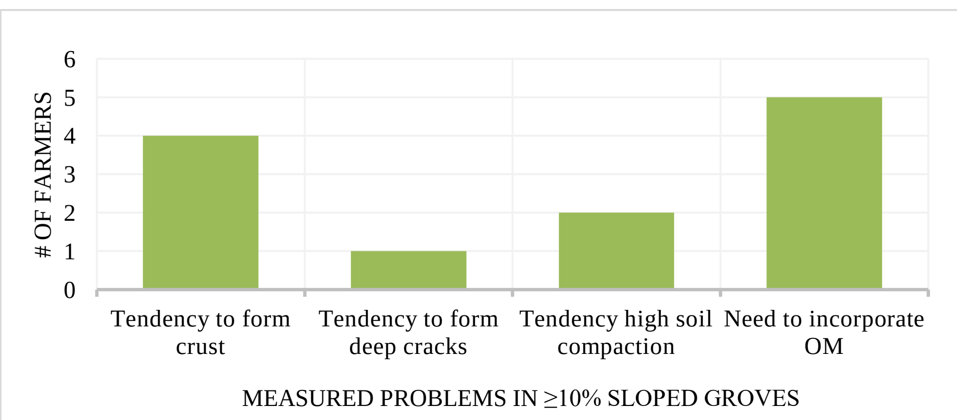

Figure 12: Frequencies of problems in ≥10% slope groves from integrated farmers in PDO Estepa (n=6).

6.2 Cross-compliance requirements' adoption

The adoption rate analysis has been applied for the cross-compliance requirements like was done in Paragraph 6.1 for integrating farming requirements. As explained within Chapter 3, data of integrated and organic olive farmers of PDO Estepa (n=21) are considered in the adoption rate analysis (Table 3). The lowest observed adoption rate is 50%, referring to keeping all compulsory information in a farm book. In other words, from the 16 farmers that keep a farm book, half of them record all obligatory information and therefore fully comply with this national requirement (see Section 3.3.1).

Table 3: Results of the adoption rate analysis for cross-compliance requirements and specified for soil-erosion-control.

Agricultural practice	*Sample size*	*Adoption rate (%)*
Farm book	21	76
Farm book information	16	50
Tillage and watery soil	21	86
Prevent gullies	21	100
Total		79

6.2.1 Farm book & information in farm book

All farmers must record a farm book with the information indicated on the x-axis of Figure 13. Four out of eight information criteria are complied with by all 16 farmers that keep a farm book. The information criteria that are not complied with are related to the planting dates (i.e. plantation), the irrigation dates (i.e. irrigation) and the dates of authorizations.

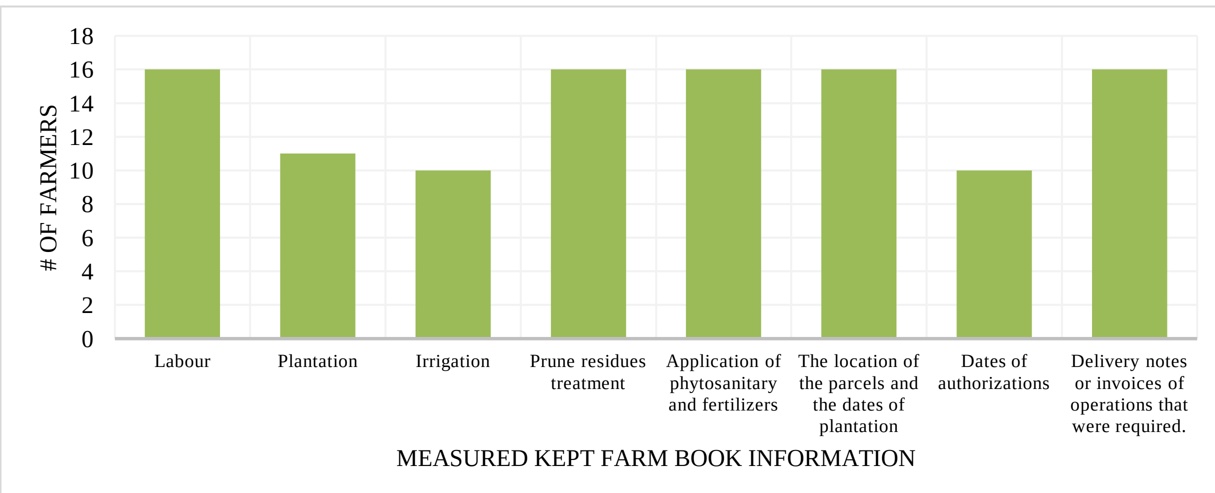

Figure 13: Frequencies of information taken up in the farm book by olive farmers in PDO Estepa (n=16).

6.2.2 Tillage and watery soil

All olive farmers indicated that they try to prevent gullies in their olive groves, which is a compulsory practice according to the cross-compliance regulation (Section 3.3.1). Simultaneously, the farmers were asked if they perform preparatory work (i.e. tillage) when the soil is watery. The agricultural practice of tilling on watery soil is enhancing the formation of gullies and is therefore not allowed in the framing of soil-erosion-control (Section 3.3.1). Figure 14 shows that three olive farmers do not comply with this requirement.

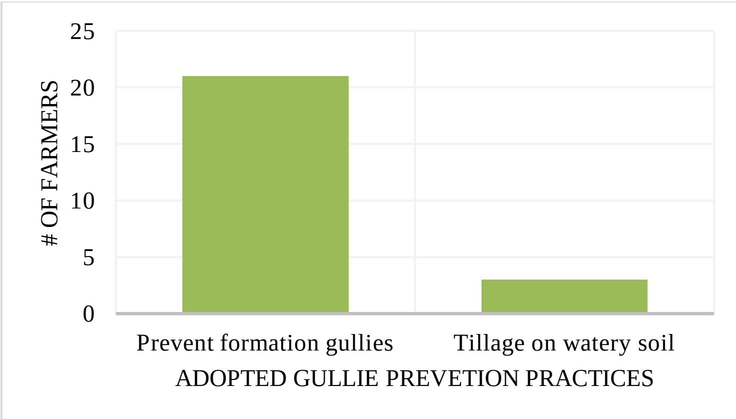

Figure 14: Frequencies of gullies prevention and tillage on watery soil olive farmers in PDO Estepa (n=21).

Chapter 7
Results: Constraining external factors for adoption requirements

Section 7.1 describes the results of the survey in which farmers were asked if they lack specific needs. Those can be the type of information related to the soil-erosion-control measures and what is needed to reduce soil erosion problems in terms of money, knowledge or experience.

7.1 What farmers lack and require

Twenty farmers would like to gain more information on soil-conservation practices, 17 farmers on soil management restrictions, and 16 on aids and subsidies available (see Figure 15).

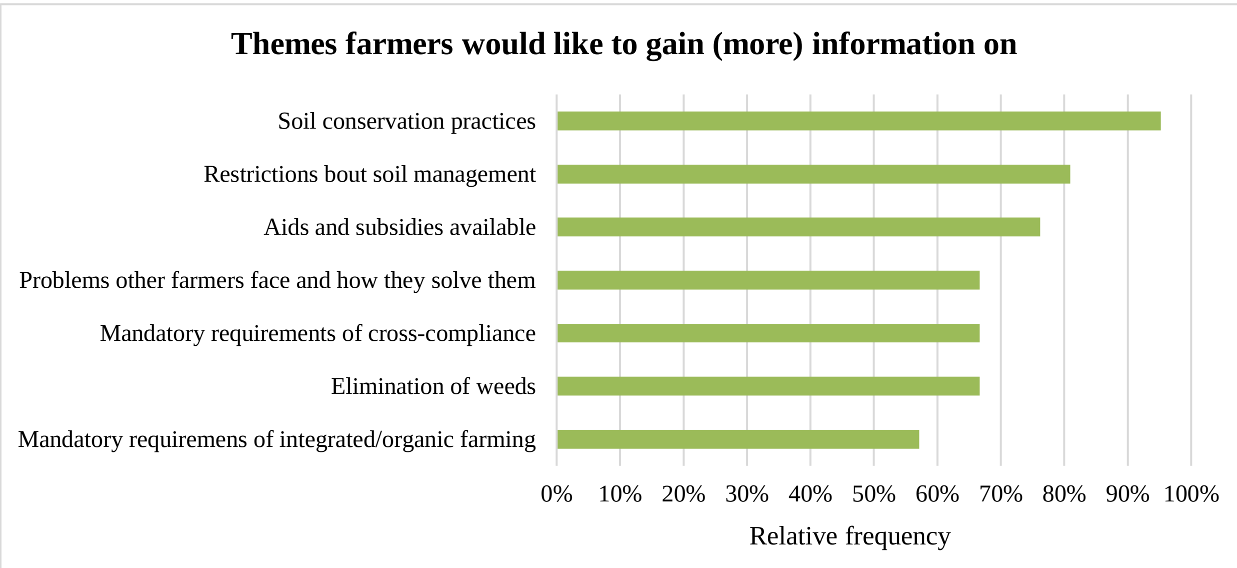

Figure 15: Results of the survey about themes that farmers would like to gain more information on (n=21).

Twenty farmers encounter a stronger competition on the market since they started cultivating with integrating and organic farming practices. Besides, the establishment and the management of cover crops is encountered to be difficult for 14 farmers. The farmers were asked why cover crop management is difficult. They answered that 1) spontaneous cover crops grow irregular over the years, and some species are undesired in the groves; 2) unwanted species invade the desirable spontaneous cover crops; 3) lack of rainfall in dry years makes the planting of cover crops difficult; 4) occurrence of rabbits destroying the cover crops; 5) difficulties to maintain the cover crops when planted some years ago; 6) the planting of cover crop is dependent on rainfall; lastly, 7) the technique of cover crop management is not an exact one, so that there is no universal recipe for all olive plots.

Figure 16 displays other problems encountered since the cultivation with integrated or organic farming practices. The additional cost for integrating or organic cultivation comes from – according to the farmers – the elimination of weeds at the foot of the olive trees by mechanical means, and the purchase of special authorized active substances (i.e. herbicides).

One integrated farmer indicated low consumer's appreciation for the olive oil as the biggest problem of integrated farming. Consumers do not value the accompanied health benefits of the olive oil, nor the respect for the environmental and sustainability by the integrated farmers. The farmer explained that for organically produced olive oil, those benefits have been achieved better, or at least the consumers seem more loyal to the producers (i.e. organic olive farmers).

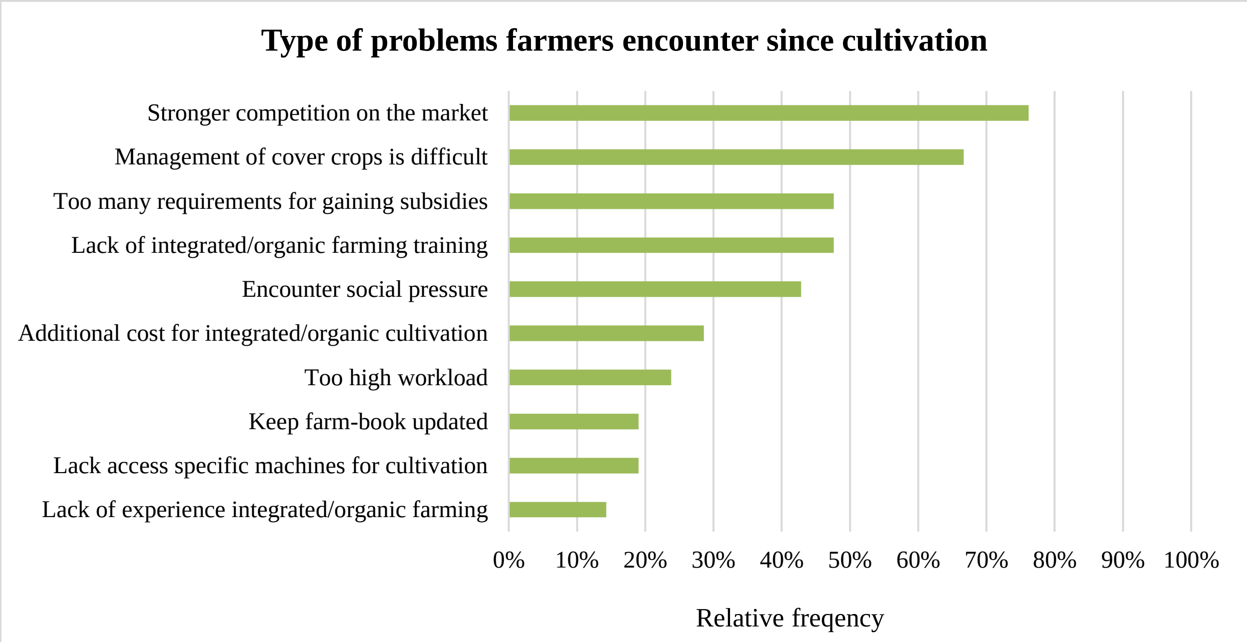

Figure 16: Results of the survey about problems that farmers encounter since the cultivation with integrated or organic farming practices (n=21).

The farmers were asked if they need more financial support, access to technology or more related training to reduce the erosion problems in their olive groves. Figure 17 visualizes that for all three needs slightly more than half of the farmers agrees. The farmers who do not make use of cover crops answered to be interested in cover crops if they reduce soil erosion problems.

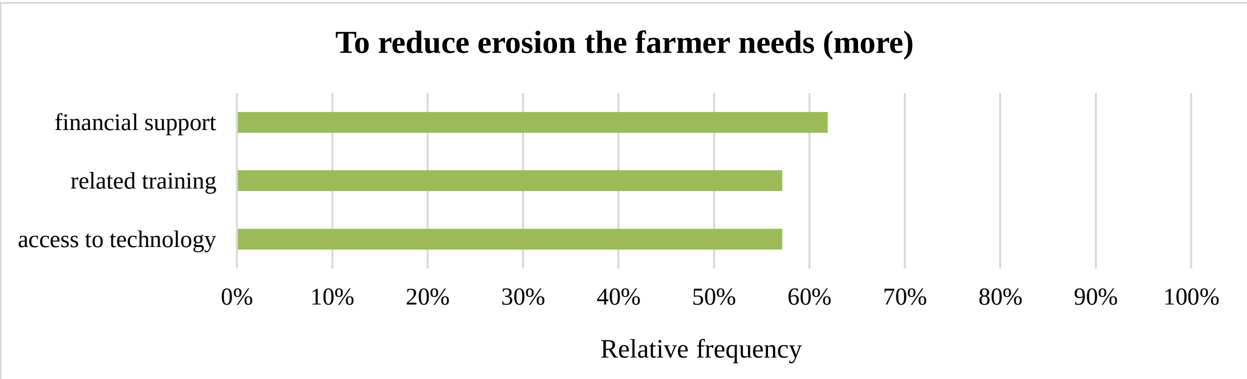

Figure 17: Results of the survey about farmers' needs to reduce the soil erosion problems (n=21).

7.2 Exploring external factors influencing integrated farmers' adoption

The adoption rate analysis (Table 2) shows that four soil erosion measures in olive groves (with n=20) have a low adoption rate (lower than 95%) by the integrated farmers in PDO Estepa. These four measures are: (1) the type of cover crop implemented, (2) the tillage direction, (3) the amount of herbicide application over a 5-years period and (4) the amount of annual herbicide.

Within this section, the external factors that seem to affect the adoption rates are described. All external factors (independent variables) and the corresponding soil erosion measure (dependent variable), are summed up in Table A in Appendix F.

7.2.1 External factors influencing adoption of cover crops

The EFA for the implementation of cover crops by the olive farmers in PDO Estepa resulted in 10 possible independent variables that influence adoption of cover crops. This number of 10 variables has been reduced from the original number of 44 variables by excluding the variables that did not show a possible covariation at all in the *geom_count()* plots (see appendix E). One example of such a plot is shown in Figure 18, where the variable 'whether the farmer wants to gain more information about the requirements of integrated farming' is plotted against cover crop use. The size of the circles shows the number of observations per combination of the response options of two variables. Covariation can be recognized by a strong correlation between the answering 'yes' on information gain (on y-axis) and no use of cover crops (on the x-axis). The EFA plots of the other 9 covariations can be found in Appendix E.

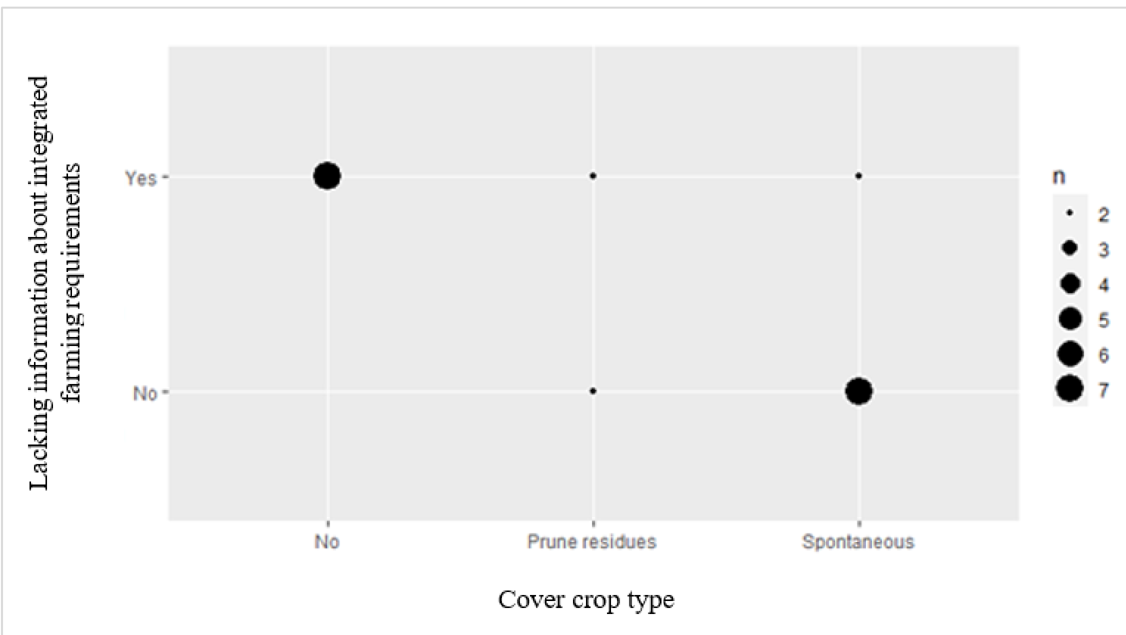

Figure 18: An EFA-plot in which the covariation of two categorical variables (lacking information about integrated farming requirements are visible.

The following external factors seem to affect the adoption of cover crops (whether prune or spontaneous cover): neighboring farmers' practices (no. 17), major income olive farming (no. 18), lacking information about elimination of weeds (no. 27), lacking information about cross-compliance requirements (no. 28), lacking information about integrated farming requirements (no. 29), neighboring farmers' problems and solutions of soil erosion (no. 30), stronger competition on the market (no. 32), soil erosion problems (no. 43), lacking integrated farming training (no. 33), and lacking technological access (no. 45).

7.2.2 External factors influencing tillage direction

The EFA for the tillage direction by the olive farmers in PDO Estepa resulted in five possible independent variables that influence adoption of the tillage perpendicular to the slope.

The following external factors seem to affect the adoption of the tillage perpendicular to the slope: major income olive farming (no. 18), neighboring farmers ‘information exchange (no. 19), lacking integrated farming training (no. 33), soil erosion problems (no. 43), tree density (no. 10).

7.2.3 External factors influencing 5-yearly herbicide application

The EFA for the herbicide application over a 5-year period by the olive farmers in PDO Estepa resulted in five possible independent variables influencing adoption of maximum two herbicide applications over a 5-year period. The following external factors seem to affect the adoption of maximum two herbicide applications over a 5-year period: profitability (no. 12), additional subsidies (no. 13), neighboring farmers’ practices (no. 17), lacking information about elimination of weeds (no. 27), and lacking information about cross-compliance requirements (no. 28).

7.2.4 External factors influencing annual herbicide application

The EFA for the annual herbicide application by the olive farmers in PDO Estepa resulted in four possible independent variables that influence adoption of maximum one herbicide application annually, i.e. at most once per year. The following external factors seem to affect the adoption of the maximum one herbicide application annually: age olive trees (no. 9), surface area (no. 8), public administrations (no. 20), and number of requirements to gain subsidy (no. 35).

7.3 Goodness of fit of relationships total population integrated farmers PDO Estepa

The Chi-squared test is used to see how likely it is that the relationship between each soil erosion measure and the external factor is valid for the whole population of integrated farmers within PDO Estepa. The outcome of the Chi-squared test is represented by a p-value (Table 4), which does not indicate the direction, but only about the strength of the relationship (i.e. significance level).

Three out of 10 possible relationships between external factors and cover crop adoption are found to be significant for the total population and four out of 10 possible relationships are found to be moderately significant for the total population. One out of five possible relationships between external factors and tillage direction adoption is found to be moderately significant for the total population. I did not found significant or moderate relationship between external factors and 5-yearly herbicide use adoption. One out of four relationships between external factors and annual herbicide use adoption is found to be significantly for the total population.

7.4 Strength and direction of factors influencing integrated farmers’ adoption

The PCA visualisations are used to explore the strengths and the directions of the correlations between the soil erosion measures and the external factors. Additionally, a PCA biplot distinguishes two groups of farmers among integrated farmers in PDO Estepa: the ones who comply to the measure or requirement and the ones who do not. The full variable names corresponding to the numbers of the PCA vectors are summed up in Table A in Appendix F.

Table 4: Results of the Chi-squared test (significant relationships with 95% confidence interval are in bold black letters, moderate relationships with 90% confidence intervals are in black letters).

Requirement/ measure	*Variable*	*n*	*Df*	X^2	*P-value*
Cover crop	Neighboring farmers' practices	20	2	6.5	**.038**
	Major income olive farming	20	4	9.3	.054
	Lacking information about elimination of weeds	20	2	4.7	.097
	Lacking information about cross-compliance requirement	20	2	5.8	.054
	Lacking information about integrated farming requirements	20	2	9.7	**.008**
	Neighboring farmers' problems and solutions of soil erosion	20	2	5.8	.054
	Stronger competition on the market	20	2	4.1	.126
	Soil erosion problems	20	2	6.3	**.042**
	Lacking integrated farming training	20	2	2.3	.319
	Lacking technological access	20	2	1.2	.546
Tillage direction	Major income olive farming	20	6	10.8	.094
	Neighboring farmers 'information exchange	20	3	5.1	.164
	Soil erosion problems	20	3	6.8	.123
	Tree density	20	6	7.0	.323
	Profitability	20	3	3.8	.280
5-yearly herbicide use	Additional subsidies	20	4	2.8	.595
	Neighboring farmers' practices	20	4	4.5	.338
	Lacking information about elimination of weeds	20	4	6.2	.185
	Lacking information about cross-compliance requirement	20	4	5.4	.249
Annual herbicide use	Age olive trees	20	5	4.5	.477
	Surface area	20	5	5.8	.321
	Public administrations	20	1	4.4	**.036**
	Number of requirements to gain subsidy	20	1	0.0	.845

7.4.1 Cover crop adoption and 10 constraining factors

The 10 external factors, together with the dependent variable (i.e. no cover crop use) are plotted in a PCA biplot (Figure 19) and two outcomes can be retrieved from this PCA plot. Firstly, a dense clustered group of non-cover crop users (in red) can be observed on the left side of the PCA plot. On the opposite side, a more scattered clustered group of farmers that apply cover crop (in green) is observed. Consequently, two groups of farmers can be recognized who tend to behave and think in similar ways; the first group does not comply with the measure and the second group does comply with the measure.

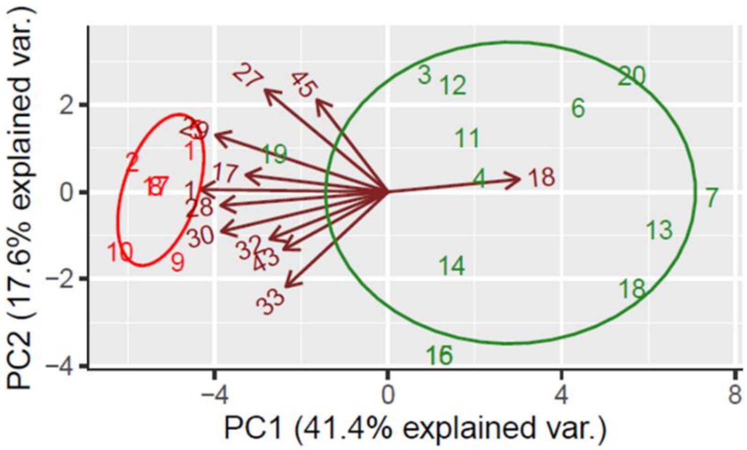

Figure 19: PCA biplot with 20 individuals, showing the 10 independent variables and the cover crop use dependent variable. (The colors show the different types of cover crop adoption groups: red are the farmers who do not apply cover crops, green are the farmers who do apply cover crops.)

Secondly, the directions of the vectors reveal a positive or negative and a strong, moderate or weak correlation with the dependent variable (i.e. the measure). One variable (vector 18) is pointing in the opposite direction of the dependent ‘no use of cover crops’ variable (vector 1). They almost make an angle of 180° which means that major income olive farming is strongly negatively related with no use of cover crops. Thus, olive farmers whose major income is not olive farming tend to not apply cover crops. The other nine independent variables point in the same direction as vector 1 and are therefore positive related with no use of cover crops. However, some positive correlations are weaker than others; vectors 17 and 28 are strongly positive correlated since they both almost make a 0° angle with vector 1. Consequently, both neighboring farmers’ practices and lacking information about cross-compliance requirement are strongly positive correlated with no use of cover crops. Thus, olive farmers who started cultivating olive farmers because of switching neighboring farmers tend to not apply cover crops. Additionally, olive farmers who are lacking information about the mandatory requirements related to cross-compliance tend to not apply cover crops. Moderate positive correlated variables are vectors 29, 27, 30, and 32. Consequently, farmers who are lacking information about the elimination of weeds, who are lacking information about integrated farming requirements, who want more information about neighboring farmers’ problems and solutions of soil erosion, and who compete stronger on the market since the cultivation of integrated farming are moderately positively correlated with no use of cover crops. Lastly, the vectors 43, 33 and 45 are weakly positively correlated with vector 1 because they almost make an angle of 90°. Consequently, soil erosion problems, lacking integrated farming training and lacking technological access are weakly positive correlated with no use of cover crops.

7.4.2 Tillage direction adoption and five constraining factors

The five external factors, together with the dependent variable (i.e tillage work direction), are plotted in a PCA biplot (Figure 20). The farmers who adopted the tillage direction that controls soil erosion problems are more clustered on the right side of the plot (in green), while the farmers who do apply tillage in the direction of the slope are scattered on the left side of the plot (in red).

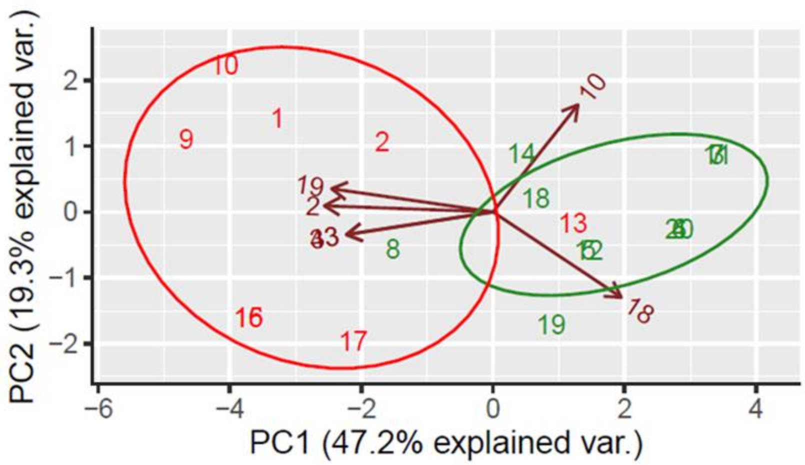

Figure 20: PCA biplot with 20 individuals, showing the five independent variables and the tillage direction as dependent variable. The colors show the different types of tillage direction adoption groups: red = farmers who till in the direction of the slope, green = farmers who till perpendicular to the slope.

Secondly, vector 19 is pointing in the same direction as vector 2 and thus are strongly positively correlated. Consequently, neighboring farmers' information exchange is strongly positively related to ploughing in the direction of the slope. Thus, olive farmers who gain information from their neighboring or familiar farmers about the requirements of integrated farming tend to apply tillage in the direction of the slope, which enhances soil erosion. Vectors 33 and 43 are moderately positively correlated with vector 2. Consequently, lacking integrated farming training and soil erosion problems are moderately positively correlated with applying tillage in the direction of the slope. Negatively correlated variables are vectors 10 and 18. Vector 18 is strongly negatively related with vector 2 which means that major income olive farming is strongly negatively related with applying tillage in the direction of the slope. Consequently, olive farmers whose major income is not olive farming tend to apply the tillage in the direction of the slope, which enhances soil erosion. Lastly, vector 10 is weakly negatively correlated with vector 2 which means that low tree density is weakly negative correlated with applying tillage in the direction of the slope.

7.4.3 5-yearly herbicide application and five constraining factors

The five external factors, together with the dependent variable (i.e. herbicide application in five years), are plotted in a PCA biplot (Figure 21). The farmers who adopted this measure are more visible on the left side of the plot (in green), while the farmers who did not comply with this requirement are scattered on the right side of the plot (in red).

Secondly, all vectors point in the same direction of the dependent variable (i.e. vector 3). The external factors therefore are all moderately positively correlated with the requirement. Consequently, profitability, gaining additional subsidies, neighboring farmers' practices, lacking information about elimination of weeds, and lacking information about cross-compliance requirements all moderately positively correlate with applying herbicides at most two times in a 5-year period.

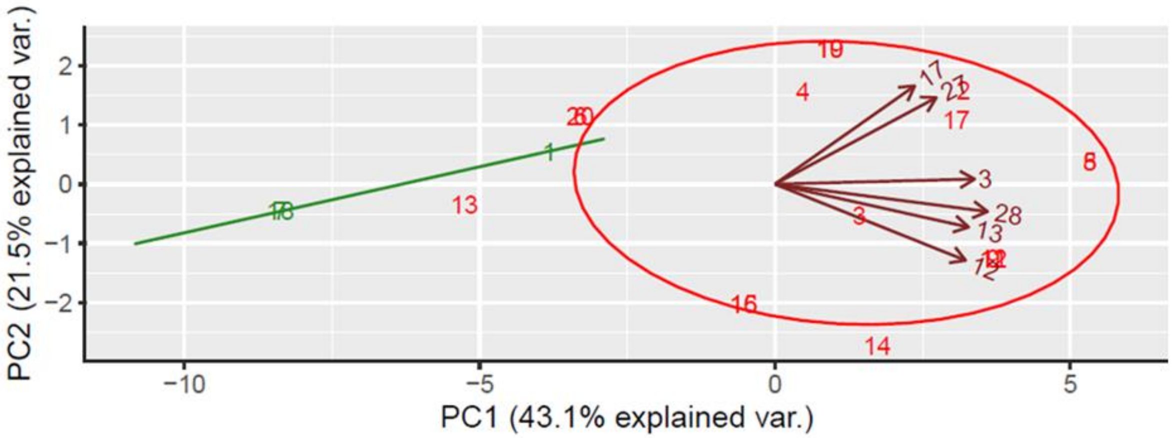

Figure 21: PCA biplot with 20 individuals, showing the five independent variables and the herbicide use in a 5-year period as dependent variable. The colors show the different types of 5-yearly herbicide application groups: red = farmers who apply more than twice herbicide in a 5-year period, green = farmers who at maximum apply twice herbicides in a 5-year period. The data points in green do not show a circle because the three observations are oriented in a straight line.

7.4.4 Annual herbicide application and four constraining factors

The four external factors, together with the dependent variable (i.e. annual herbicide application), are plotted in a PCA biplot (Figure 22). The farmers who adopted this requirement are more visible on the right side of Figure 22 (in green), while the farmers who did not comply with this requirement are scattered on the left side of the plot (in red).

Secondly, vector 8, 2 and 35 point into the same direction as the dependent variable (i.e. vector 4) and are therefore moderately positively correlated with the requirement. Consequently, surface area bigger than 20 ha, public administrations information exchange and an overload of requirements to gain subsidy are moderately positive correlated with applying herbicides at most two times annually.

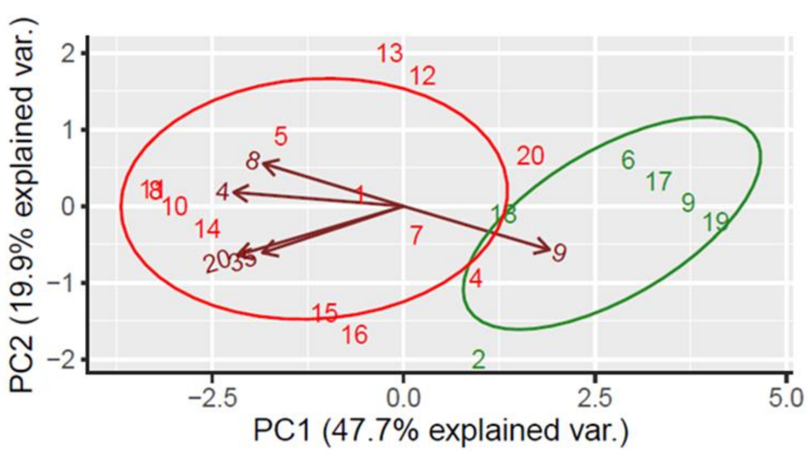

Figure 22: PCA biplot with 20 individuals, showing the four independent variables and the annual herbicide use as dependent variable. The colors show the different types of annual herbicide application groups: red = farmers who do apply herbicides more than ones a year, green = farmers who apply herbicide at maximum once a year.

7.5 Exploring external factors influencing olive farmers' cross-compliance adoption

The adoption rate analysis (Table 3) shows that two cross-compliance measures in olive groves (with n=21) are having a low adoption rate (<95%) by olive farmers in PDO Estepa. The two measures that are meet those two conditions (<95% and n=21) are: (1) Keep a farm-book and (2) tillage on watery soil.

7.5.1 External factors influencing keeping a farm book

The EFA for keeping a farm-book by the olive farmers in PDO Estepa resulted in two possible independent variables influencing the farm-book adoption, namely cooperatives and soil erosion problems. This number of two variables has been reduced from the original number of 44 variables.

Table 5: Results of the Chi-squared test (moderate relationships with 90% confidence intervals are in black letters).

Requirement/ measure	*Variable*	*n*	*Df*	X^2	*P-value*
Farm-book	Cooperatives	21	1	0.4	.529
	Soil erosion problems	21	1	3.7	.054

The outcome of the Chi-squared test is represented by a p-value (see Table 5), saying nothing about the direction of the relationship, but only about the strength (i.e. significance level). One out of two relationships between external factors and farm-book adoption is found to moderately significant for the total population.

Creating a PCA visualization was impossible since the correlations were extremely weak. Therefore, the two found variables resulting from the EFA do not influence the adoption of keeping a farm-book.

7.5.2 External factors influencing tillage on watery soil

The EFA for tillage on watery soil by the olive farmers in PDO Estepa resulted in zero possible independent variables influencing tillage on watery soil. This was because no possible relationships between the measured external factors and this practice were observed in the EFA-plots.

Chapter 8
Discussion

8.1 Weaknesses in the research approach

8.1.1 Survey use instead of semi-structured interviews

Initially I planned to execute semi-structured interviews among olive farmers in PDO Estepa. However, due to COVID-19 pandemic restrictions I had to switch to an online survey. I preferred doing semi-structured interviews over survey construction due to its rich in-depth data quality outcomes. However, the survey was constructed in such a way that additional comments could be included by the respondent, which have been reported in my study too. The pitfall of surveys is that self-reported behavior is not objectively measured and could result in exaggeration by the respondent (Northrup, 1997). As an example within my study, three farmers indicated that they performed tillage in the ≥10% slope groves which is according to legislation sometimes allowed. These farmers self-reported that they have a legal exceptional reason (i.e. avoid soil's crust formation, crack formation or soil compaction formation). Regardless of these limitations, the unplanned use of a survey resulted in the best alternative (considering the COVID-19 restrictions) to collect suitable data to answer my RQs. My surveys namely has a high reliability, high external validity and limited the interviewer effect (i.e. bias; (Emonds, 2020). Interviews could be a better alternative for unexplored research fields, while the present study is based on already existing knowledge (e.g.(Aznar-Sánchez et al., 2020; Calatrava Leyva et al., 2007; Franco & Calatrava-Leyva, 2006; Rodríguez-Entrena et al., 2014) related to adoption of soil-conservation measures.

8.1.2 Working from the Netherlands and sample procedure

A second limitation was the necessity of working from home due to the restrictions of the COVID-19 pandemic. I had no influence on the selection procedure of the farmers that participated in the survey. Although I asked to increase the sample size when the research method was changed to survey use, PDO Estepa indicated not to be willing to approach more farmers due to the external effects of COVID-19. I only had indirect mail contact with the representatives of PDO Estepa, via IAS research institute in Córdoba, and therefore the request of increasing the sample size had no effect. A larger sample size would enhance PCA outcomes, which possibly would determine more (strong) correlations between the measures and the external factors. Besides, for the given population size (around 4000) and investigating categorical data, statistical significance would be enhanced with a minimum sample size of 250 to 570 (Kotrlik & Higgins, 2001). Studies with survey method in the field of soil conservation also show higher sample sizes (e.g. around 200; (Franco & Calatrava-Leyva, 2006; Leyva et al., 2017).

8.1.3 A complete literature review

A limitation related to the secondary data collection is the lack of a complete review of the environmental policy documents and of the external factors. This means that I might missed some external factors or requirements that could have been included in the survey. However, the survey measured a limited number of requirements and external factors anyway to make it user friendly for the farmers. At least two external factors per factor type (see Appendix D) were addressed in the survey and therefore I made sure that not one of them got the upper hand.

8.1.4 *Language gap*

The language gap was an additional limitation that limited communication means to email, and therefore I could not have direct telephonic contact with either PDO Estepa or the olive farmers. The language gap also played a role when reviewing policy documents. Some vocabulary could have been interpreted differently (e.g. the use of 'control' or 'manage'). Hiring a translator that would have done part of the data collection and translation could have been an alternative approach. Besides the high costs of this alternative, it would not be a realistic to do since I wanted to enhance my Spanish vocabulary and gain experience with doing the data collection myself.

8.1.5 *Small sample size as heaviest effect*

These four limitations impact the validity of the research in different ways. The conclusions of my study are most effected by the sample size limitation because major results are related to the correlations of the external factors. My study could be interpreted as a pilot study and future research should execute the method on larger scale (i.e. all organic and integrated olive farmers in Spain). Nevertheless, considering the persistence of the pandemic restrictions, continuing the collaboration with PDO Estepa and agreeing to a small sample size was most appropriate and fortunate for me.

8.2 Farmers' characteristics and opinions

The reason for my study was an increase of soil erosion problems in southern Spain. The results of my study support this statement. All farmers indicated that they encounter soil erosion problems in their olive groves and half of the farmers indicated that they have seen those soil erosion problems increase during the last five years.

The qualitative descriptive data analysis showed that most surveyed farmers are integrated farmers, one is organic. 14 farmers have rainfed olive groves, three irrigated and the remaining four have both irrigation systems. This was found by the results of the survey (n=21).

A comparable research done in the same study area (Rodríguez Sousa et al., 2020) found a different distribution of farmer type and irrigation system that seems wrong; 65% of the farmers applied integrated farming and 35% organic farming, 90% of the olive groves were rainfed and the remaining 10% were irrigated. I namely compared my results with the total population of PDO Estepa (see Chapter 3) in which similar distributions of farmer type and irrigation system were found. I also compared the results of some descriptive data with the requested data from PDO Estepa representing the whole population of olive farmers joining the cooperative (N=4158). This comparison showed that the sample of the survey generally represents the total population according to farmer type, irrigation system and age of the olive trees. Some contrasting results were found when comparing the surface area and the tree density of the sample and the total population. The sample represent mostly bigger farms while the population represents more smaller farms. This result can be explained because PDO Estepa selected the farmers for the survey based on commitment. Farmers having olive farming not as major income, have smaller farms according to the results and are therefore likely to be less committed to the PDO. Additionally, the sample represents more low tree density farms, while the population represents more high tree density farms. This result can be explained because less intensified olive farms (i.e. with lower tree densities) usually are more environmentally friendly (i.e. intensified olive cultivation accelerates soil erosion processes (Gómez et al., 2014)) and therefore the less intensified farms are more committed to the PDO (i.e. proud and willing to share their experiences). Commitment of the farmers was an important aspect for PDO Estepa to select the survey participants and research indicates that this convenience type of sampling is most useful for pilot testing (Hibberts et al., 2012). All in all, The results in Section 3.2 of my study show that my data represents the whole population of PDO Estepa which hold more than 4000 integrated and organic farmers.

8.3 Soil-erosion-control measures' adoption rates

The results of the adoption rate analysis for integrated farmers, considering 12 variables, for soil-erosion-control measures shows that overall, three quarters of the farmers complied with the contractual regulation. All 21 farmers have adopted at least one soil-erosion-control measure. This agrees with results found by Franco and Calatrava-Leyva (2006) in which 147 olive farmers in the Alto Genil Basin (one of the main producing areas in Spain) were surveyed; all farmers adopted at least one measure to conserve the soil. The main soil-conservation practice found by Franco and Calatrava-Leyva (2006) was related to tillage practices, while in my study the highest adoption is found for the control method of weeds and cover crops (100%). A more recent study, Leyva et al. (2017), surveyed 223 farmers in the areas of Granada and Jaén found that 99% of farmers have adopted some type of measure to conserve their soil, and again, that the main conservation practice is related to tillage. Leyva et al. (2017) found that only a minority of the farmers adopted vegetation covers as effective conservation practice.

The results of the adoption rate analysis for cover crops shows that 13 integrated olive farmers (i.e. 65%) in PDO Estepa comply with the contractual regulation. Most farmers apply spontaneous cover crops, no farmer indicated the use of seeded cover crops. The remaining seven farmers (i.e. 35%) keep the soil bare during the whole year. A national study (Ministerio de Agricultura, 2019) and my study support the fact that Spanish olive farmers mainly make use of natural occurring vegetation to control soil erosion. The use of natural vegetation can be explained for farmers of PDO Estepa because they might be unaware of the beneficial use of seeded cover crops. In addition, the use and maintenance of seeded cover crops are extensive and complex according to Gómez (2017), possibly hindering the application. The cover crop adoption rates are put into perspective with other crops and regions in Spain (see Appendix G) and I found that PDO Estepa has a relatively high spontaneous cover crop adoption rate. Only within the stone fruit sector (which is almost 20 times smaller than the olive oil sector) the adoption rate is slightly higher. Nevertheless, when farmers are certified for integrated farming they should comply 100% to the legislation to legally receive subsidy[13]. Therefore, there is room for improvement for the farmers, but they are so far one of the best examples in Spain to minimize the contribution to soil erosion problems. Remarkably, Rodríguez Sousa et al. (2020) found a contrasting distribution of the adoption of cover crop for integrated farmers in PDO Estepa; 30% applied cover crops and the remaining 70% kept bare soil all year round. This contrasting result can be explained because different definitions of cover crops are assumed by the researchers and by me. In other words, I considered the adoption of prune residues as a cover for the soil and therefore the farmers do not leave the soil bare. Whereas if this would have not been done, the amount of bare soils would have been sufficiently higher (55%). Another study (Franco & Calatrava-Leyva, 2006) however did include prune residues as conservation practice and showed that more than a third adopted this practice, which is in line with my results. A recent study about cereal farmers to adopt conservation practices in Italy found that 75% adopted the use of prune residues (De Salvo et al., 2020).

The adoption of tillage direction by integrated olive farmers in PDO Estepa shows that 12 farmers (i.e. 60%) till perpendicular to the slope, and therefore comply with the contractual

[13] According to legislation: *Real Decreto 1201/2002 (BOE núm. 287), de 20 de noviembre, por el que se regula la producción integrada de productos agrícolas.*

regulation. Most farmers till perpendicular to the slope, but the remaining 8 farmers till in the direction of the slope or in both directions, which enhances soil erosion. This contrasts with results found by Leyva et al. (2017), in which the tillage practice that minimizes soil erosion is described as tillage following contour lines and which was adopted by only five olive farmers. This divergent result might be due to the high number of farmers in the study of Leyva et al. (2017) that practiced non-tillage practice instead (51%) while in my study all farmers did practice tillage.

The adoption of the herbicide application by integrated olive farmers in PDO Estepa shows that only 3 farmers (i.e. 15%) comply with a maximum of two herbicide application over a 5-year period and 14 farmers comply with maximum one herbicide application per year. Most farmers indicated that they apply five times (or more) herbicides over a 5-year period. Herbicide application has not been mentioned often as a soil-erosion-control measure in previous research (Franco & Calatrava-Leyva, 2006; Leyva et al., 2017). This is probably because herbicides cause an off-site (i.e. indirect) effect of erosion; it contaminates water bodies and causes eutrophication (Gómez et al., 2014). However, the very low adoption rates of this requirement found in my study show that more future research is needed to requirements that have an off-site erosion effect. Especially with increasingly intense rainfall due to climate change – as indicated by the farmers – the off-site contamination effect will become a bigger problem in future. From my study, the high amount (85%) of farmers that did not comply with the maximum allowed herbicide applications can be explained by the results of the indicated problems that farmers experience for the management of cover crops. They namely experience more problems with undesired vegetation growth, which results in more herbicide applications. Besides, the farmers indicated that for integrated farming the purchase of special authorized active substances (i.e. herbicides) is compulsory, and the effect on vegetation control might be lower in comparison with conventional herbicides.

The adoption of keeping a farm-book, obligated by the cross-compliance regulation of olive farming, by olive farmers in PDO Estepa shows that 75% of the farmers keep a farm-book, and half of the ones who keep a record of farming practices also include all mandatory information. The planting and irrigation dates that are not written down by the farmers who keep a farm-book can be explained because more than three quarters of the farmers have rainfed olive groves, which means that irrigation is not applied. Additionally, most farmers have olive trees of 10 years and older, whereby farmers are not in the stage of planting new olive trees anymore. An exploratory study by Biçoku et al. (2018) that assessed dairy farmers' awareness about food safety standards, found that in Albania almost 54% and in Kosovo 25% of the farmers have a farm-book. Besides, the farmers in Albania were not aware of the institution that is in change for controlling the farm-book, while the farmers in Kosovo are aware of that. Therefore, the adoption rate of farm-book keepers in PDO Estepa is relatively high.

The adoption of no tillage on watery soil by olive farmers in PDO Estepa shows that three farmers do not comply with this cross-compliance measure. All olive farmers in my study indicated to try to prevent gullies in their olive groves and therefore minimize soil erosion. This result is in contrast with some farmers who indicated that they till on watery soil. The latter namely is a practice that enhances soil erosion. These opposite results could be explained because the soil remains wet for a long time after the rain due to specific soil characteristics like bad infiltration (Castillo & Gómez, 2016) and the farmers have to do the practice. A research by Lesschen et al. (2008) on erosion and agricultural land abandonment in Mediterranean countries found that no tillage (and slow vegetation recovery) cause the formation of soil crusts and increase runoff and gully erosion risk. Therefore, the requirement of no tillage on watery soil can be criticized and the above described contrary result about olive farmers in PDO Estepa might not be as contradicting as expected in the first place.

Not all adoption rates of the four soil-erosion-control practices could be explained by the external factors considered in my study. Nevertheless, from the perspective of multivariate statistics, applying exploratory factor analysis and principal components analysis for categorical data were useful tools for reducing the number of variables (e.g. from 44 to 10 variables) and revealing the strength and direction of several intercorrelations (see Table 6). The combined use of test- and multivariate statistics has proven to be an essential and useful tool in my study because on one hand the adoption rates of two practices could be explained with external factors considered in my research, and on the other hand some of those external factors were found to be statistically significant (see Table 6). This approach should therefore be encouraged among researchers investigating in the field of soil-conservation practices adoption rates by farmers.

8.4 External factors influencing soil-erosion-control measures' adoption

The external factors that influence the adoption of soil-erosion-control measures by the integrated olive farmers in PDO Estepa are shown in Table 6. These are the results of the EFA, PCA and adoption rate analysis for integrated farmers in which the strengths and directions of the external factor on four soil erosion measures were analysed. The table output can be read from left to right as follows: "Neighboring farmers' practices *are* strongly positive *correlated with* no cover crop use *by olive farmers in PDO Estepa* which enhances soil erosion problems". Note that the following paragraphs explain the influences of external factors by integrated farmers only.

8.4.1 Explaining strength and direction of correlated external factors

The PCA for cover crop adoption shows that integrated olive farmers who started integrated olive cultivation because of switching neighboring farmers, tend to not apply cover crops. This effect can be explained because the density of farmers farming in PDO Estepa is high and seeing neighbours changing practice leads to own change of practice too. The latter is supported by Dessart et al. (2019) saying: "…farmers' decisions to adopt sustainable practices seem to be influenced by their neighbours' behaviour" [p. 433]. Especially the practice of changing from bare soils to covered soils in winter is notable.

The PCA for cover crop adoption shows that integrated olive farmers whose major income is not olive farming tend to not apply cover crops. This effect can be explained because these farmers are less dependent on olive farming and they do not opt for soil-conservation investments like cover crops. Another study in a semi-arid area in Afrika also found the negative influence of farmers depending on off-farm income on soil control management (Karidjo et al., 2018). Lipper (2001) explains that erosion control may require more labor and therefore the farmer may be giving up the opportunity of doing off-farm activities. My study found that more than three quarters of the olive farmers experience stronger competition on the market since they started integrated farming practices, which could cause farmers to depend more on off-farm income activities.

The PCA for cover crop adoption shows that integrated olive farmers who are lacking information about the mandatory requirements related to cross-compliance tend to not apply cover crops. This effect is not straightforward to explain since information about integrated farming requirement would be more realistic to be lacking among integrated farmers. Nevertheless, the research by Rodríguez Sousa et al. (2019b) concluded that olive farmers in Estepa are ignorant or unaware of the compulsory use of cover crops. This knowledge gap is overarching the information lack of soil-conservation practices that are mandatory to adopt according to integrated farming as found in my study. In addition, my study found that almost all olive farmers in PDO Estepa would like to gain more information on soil-conservation practices, highlighting the apparent knowledge gap. A recent study (Belachew et al., 2020) concluded that strengthening the provision of formal and non-formal training positively influences the adoption of soil conservation practices.

Table 6: Summary of the adoption rate analysis, EFA, PCA and Chi-squared test with n=20 (strong correlations are in bold letters).

Output EFA: *Possible external factors*	**Output PCA:** *Correlation's strength and direction*	**Output adoption rate analysis:** *Low adoption rate soil-erosion-control measures*
Neighboring farmers' practices	**strongly positive****	No cover crop use which enhances soil erosion problems
Major income olive farming	**strongly negative***	
Lacking information about elimination of weeds	moderately positive*	
Lacking information about cross-compliance requirement	**strongly positive***	
Lacking information about integrated farming requirements	moderately positive**	
Neighboring farmers' problems and solutions of soil erosion	moderately positive*	
Stronger competition on the market	moderately positive	
Soil erosion problems	weakly positive**	
Lacking integrated farming training	weakly positive	
Lacking technological access	weakly positive	
Major income olive farming	**strongly negative***	Tillage in the direction of the slope which enhances soil erosion problems
Neighboring farmers 'information exchange	**strongly positive**	
Lacking integrated farming training	moderately positive	
Soil erosion problems	moderately positive	
Tree density	weakly negative	
Profitability	moderately positive	Too many 5-yearly herbicide applications which enhances off-site soil erosion problems
Additional subsidies	moderately positive	
Neighboring farmers' practices	moderately positive	
Lacking information about elimination of weeds	moderately positive	
Lacking information about cross-compliance requirement	moderately positive	
Age olive trees	moderately negative	Too many annual herbicide applications which enhances off-site soil erosion problems
Surface area	moderately positive	
Public administrations	moderately positive**	
Number of requirements to gain subsidy	moderately positive	

*** Significant relationships according to Chi-squared test ($p<0.05$).*
** Moderate significant relationships according to Chi-squared test ($p<0.10$).*

The PCA for tillage direction adoption shows that integrated olive farmers who gain information from their neighboring or familiar farmers about the requirements of integrated farming tend to apply tillage in the direction of the slope, which enhances soil erosion. This effect can be explained because exchange of information between the farmers leads to take over of agricultural practices, especially because the tillage practice is notable when the farmers are working in the field.

The PCA for tillage direction adoption shows that integrated olive farmers whose major income is not olive farming tend to apply the tillage in the direction of the slope, which enhances soil erosion. This effect cannot be explained with logical reasoning because one would not expect that low willingness to invest leads to till in the direction of the slope. An explanation for this strange correlation might be due to the farmer's easy-going of tilling in the direction of the slope or due to overall (very) gentle slopes within Estepa territory. In addition, my study found that 17 farmers would like to gain more information about soil management restrictions, which highlights that olive farmers in PDO Estepa do not know that tillage in the direction of the slope is a restricted soil practice.

The adoption of herbicide application requirements can hardly be explained by the variables considered in the PCA since they moderately influence the soil-erosion-control requirement. The PCA plots of these two requirements showed that the observations were scattered and that two groups of farmers (who apply more than the maximum amount allowed and who comply with the maximum amount) where hardly distinguishable. This could mean that there is not one particular external factor that explains the low adoption rates, but rather a combination of ignorance and necessity.

The variables considered in the EFA for cross-compliance requirements cannot explain the low adoption of neither keeping a farm-book nor avoid tillage on watery soil. However, my study found that on one hand one in five olive farmers find it difficult to update their farm-book, and on the other hand that 13 farmers would like to gain information on the mandatory requirement of cross-compliance requirement. Both solving their difficulties and overcome the knowledge gap could improve farmers behavior towards complying with cross-compliance.

8.4.2 External factors' validity for all farmers in PDO Estepa

The Chi-squared test results give insight in which external factors could significantly contribute to higher adoption of soil-erosion-control measures by olive farmers in PDO Estepa. Consequently, higher adoption rates will minimize soil erosion problems in olive groves in southern Spain. The first two significant external factors are neighboring farmers' practices and soil erosion problems over the last five years being related to cover crop adoption. The latter is supported by a study that proves that the use of cover crops reduce soil erosion rates (Gómez et al., 2014), thus farmers who do not apply cover crops tend to perceive increasing soil erosion problems. The third significant external factor is public administrations being related to the annual herbicide application requirement. This result seems to explain the role that public administrations play within informing the olive farmers about herbicide applications. The olive farmers of PDO Estepa indicated that *Junta Andalusia* is their information source related to integrated farming.

Regardless of the statistical significance of the results and for having a low number of survey respondents, my study has found strong and realistic correlation between considered external factors and the adoption rate of cover crops and tillage perpendicular to the slope. A study by Prager and Posthumus (2010) reviewed the influence of external factors on farmers in Europe. External factors not measured in my survey but found by Prager and Posthumus (2010) were personal motivation, age and consequences of non-compliance to adopt soil conservation practices. Factors measured in my survey and found by Prager and Posthumus (2010) were experience, successor availability and indirect costs influencing adoption.

8.5 Implications and future research

8.5.1 Implication of the results for generalization

My study aimed to investigate the adoption rates and exploring the constraining external factors for the olive farmers belonging to PDO Estepa and this expectation came true from the perspective of the Chi-squared test results. My results showed that three factors were statistically confirmed and four were moderately significant. Further research could focus on these three factors and perform in-depth interviews with the olive farmers to gain a more complete perspective (data triangulation). Other factors did not significantly influence the adoption of cover crops, tillage perpendicular to the slope or the maximum herbicide applications by olive farmers. These findings highlight that neighboring farmers' practices, farming requirements information lack, and soil erosion problems affect the adoption of soil-conservation practices by all integrated olive farmers in PDO Estepa.

8.5.2 Implication of results for future CAP reform (2021-2027)

The results of my study are important for the development and the implementation of the European Green Deal's 'Farm to Fork' strategy[14], which is an opportunity for effective new soil-conservation policies in Europe. The European Commission invites all citizens and stakeholders to engage in the formulation of new CAP's debate, so that the reform will drive the Green Deal forward. The new 'eco-schemes', as successor of the current CAP's AEMs, are still under negotiating process and the European Commission highlights that proposals and practical initiatives from academics and citizens can improve these eco-schemes. These schemes aim to boost sustainable-farming practices, such as organic farming (EuropeanCommission, 2020). Therefore, the outcome of the adoption rates of specific AEMs (i.e. integrated olive farming practices to control soil erosion in southern Spain) within my study contributes to the European Commission's initiative to map the current environmental policies' adoption in each member state (EuropeanCommission, 2019). To increase adoption rates of soil-conservation practices, more information about the mandatory requirements for integrated farming and about the cross-compliance regulations should be provided. Farmers whose major income is dependent on off-farm activities should be in special stimulated to implement soil-conservation practices. The dashboard to monitor progress of the EU green deal objectives, initiated within the Communication on the European Green Deal (EuropeanCommission, 2019), could be elaborated to national and local scale including the progress of national and local objectives concerning soil conservation, biodiversity loss an soil and water pollution. Only then environmental policies and legislations can be enforced and shown to be effective, including the divisions between areas with high and low compliance rates.

In the light of desired effectivity of soil-conservation measures, previous research indicates that effective soil-erosion-control by cover crops (Rodríguez Sousa et al., 2019c), pruning residues, tillage following contour lines and reduced tillage (Franco & Calatrava-Leyva, 2006; Milgroom et al., 2007) are not always reflected in policy measures' formulations. The complexity of those conservation practices is reported by Gómez (2017), who highlights the need for a specific use of cover crops to optimally minimize soil erosion; cover crops must be seeded (or not removed when spontaneous vegetation appears) in the lanes at the start of the rainfall season (autumn and winter), they need to be chemically or mechanically controlled in early spring to prevent water competition with the olive trees. In addition, the residues of the cover crops should be maintained at the surface of the lanes to allow regrowth of cover crops during autumn (Gómez, 2017). Therefore, for the formulation of the eco-schemes the outcomes of studies like this have to be integrated to effectively control soil erosion in Spain, to combat soil degradation in Europe and to ensure a robust and resilient food system that functions in all circumstances. Soil erosion is just one example that threatens food circuity for all citizens in Europe, but the increase in droughts, floods, forest fires and new viruses and pests are a reminder that the agricultural sector in Europe must become more sustainable and resilient. European policies are facing a challenge in formulating clear and effective environmental regulations. Meanwhile, Members States still have the flexibility of their own interpretation of those environmental regulations and the freedom of

[14] More information about the future CAP's reform can be found in Appendix H.

formulating the national requirements and measures. Therefore, the new Environmental Action Programmes, initiated within the Communication on the European Green Deal (EuropeanCommission, 2019), should be taken seriously by each Member State to reduce any form of environmental degradation that is threatening the country.

Chapter 9
Conclusions

Soil-erosion-control policies within the agricultural sector are determined on European level by the Common Agricultural Policy (CAP) and each Member State designs their own specific measures and regulations. The CAP includes the cross-compliance regulations and the agri-environmental measures (AEMs). For Spain, which I questioned in RQ1, the voluntary soil-erosion-control requirements and measures originate from two sustainable-farming practices. Organic farming requirements, questioned in RQ2, are designed on European level, like ‘orienting the cultivation techniques towards preventing soil compaction and soil erosion’ which can be interpreted differently by each farmer, or ‘mandatory cover crop use from autumn until start of spring’, which is a more defined measure. Integrated farming requirements questioned in RQ2 are designed on regional level (i.e. within the according autonomous community) and are clearly defined, like ‘keeping 1.8 meters as minimal width of the cover crop strips’. The compulsory soil-erosion-control requirements and measures originate from the cross-compliance regulations, questioned in RQ2, which are designed at European level. These are often vaguely formulated and therefore hard to monitor, like ‘preventing the formation of gullies in the olive grove’, which seems more an objective that lacks a clear measure.

The results of my study reveal the importance of analysing the adoption rates of soil-erosion-control requirements and measures by southern Spanish farmers. Three quarters of the olive farmers in PDO Estepa complied with the contractual regulations of integrated farming. This together with the almost 80% found compliance rate for cross-compliance measures answers RQ3. At least one soil-erosion-control measure was adopted by all farmers. Relatively high adoption rates were found for cover crop use but room for improvement is evident to reach full compliance.

My results, that answer RQs 3 and 4, highlight the negative influence of economic (major income from off-farm activities) and social external factors (neighboring farmers’ practices and lacking information about cross-compliance requirements) of integrated olive farmers on the adoption of cover crops that minimize soil erosion problems. The same factors seem to also result in unfavourable tillage direction which enhances soil erosion problems. Besides these factors that resulted to be strongly correlated with soil-erosion-control measures (as a result from the Principal Component Analysis), information lack about integrated farming requirements, soil erosion problems and public administrations as information source seem to significantly influence the adoption of soil-erosion-control measures. Moreover, information lack about eliminating weeds and neighboring farmer’s problems and solution related to soil erosion seem to moderately relate to the adoption of soil-erosion-control measures subject to integrated olive farming.

AEMs are designed to be a precise tool for achieving environmental goals within the EU which is necessary to ensure food safety for future generations. PDO Estepa, with most integrated farmers, showed to be a promising example for other Spanish farmers to control the contribution of the olive-oil sector for causing soil erosion problems in Spain. However, most of the farmers indicated the need for more information on soil-conservation practices, soil management restrictions, and aids and subsidies available. In addition, almost all farmers encounter a stronger competition on the market since they started cultivating with integrating and organic farming practices. These difficulties explain no full compliance (on average 75%) of contractual requirements that are aimed at controlling soil erosion by integrated olive farmers in PDO Estepa.

Finally, the promising measure of cover crops to control soil erosion has room for improvements within policy formulations. The implementation and management of them is already encountered to be difficult by the majority of the farmers in PDO Estepa, while the most effective type of cover crop (according to (Gómez, 2017)) is not yet in sight. In regard of the EU Green Deal, the European Commission's initiative to map the environmental policies' adoption in each member state, as part of the effective monitoring strategy, can adopt the research method applied by the current study. Thereby, sustainable-farming practices adoption can successfully be achieved in whole Europe.

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Appendix A
Survey in Spanish

La Encuesta de Olivar en Estepa

Estudio colaborativo del Instituto de Agricultura Sostenible (CSIC), D.O. Estepa y la Universidad de Wageningen (Holanda).

Investigadora: Iris Flamand (iris.flamand@wur.nl)

Estimado/a participante,
Usted está invitado/a participar voluntariamente en este estudio. Antes de comenzar, aquí puede leer información sobre este estudio y la investigadora. No dude en contactar conmigo si tiene alguna pregunta al respecto a través de la siguiente dirección de correo electrónico: iris.flamand@wur.nl
¿Quién es la investigadora? Mi nombre es Iris Flamand, soy una estudiante de máster en Ciencias Ambientales de la Universidad de Wageningen (Holanda) y me alegra que usted esté dispuesto/a participar. Esta investigación de tesis se organiza online porque la pandemia de Covid-19 prohíbe las visitas al campo. Espero que todos estén bien y es un placer para mí ejecutar esta encuesta en colaboración con la D.O. Estepa. La investigación está a medio camino y finalizará en noviembre 2020.
¿De qué trata la investigación? Usted me está ayudando a identificar las limitaciones de las prácticas de manejo integradas y ecológicas en olivar, en relación con los requisitos nacionales y de la UE. El objetivo final es entender mejor las limitaciones que se ven en las explotaciones y que escapan a nivel de las regulaciones de la PAC u organismos de certificación para seguir mejorando los aspectos ambientales del olivar.
¿Qué obtiene usted? En mi investigación, he descubierto cómo de complejos pueden ser los requisitos de certificación para la agricultura integrada y ecológica. Esta es su oportunidad para aclarar los desafíos de ser un agricultor integrado u ecológico y de compartir cómo de satisfecho está con ser parte de una denominación de origen protegida, que es referente en el sector. Compartir su experiencia es muy importante y útil para otros productores en España y para toda la industria del aceite de oliva en el Mediterráneo.
¿Qué va a pasar con los resultados? Esta encuesta será anónima, y los resultados solo se utilizarán de forma confidencial, para la investigación de tesis y posibles publicaciones derivadas.
Completar la encuesta le llevará un máximo de 15-20 minutos.
Muchas gracias por participar.

Explicación de los símbolos en este formulario:

- Puede indicar solo <u>una</u> opción con resaltador amarillo. Por ejemplo:
  - Integrado/a

sí/no Puede indicar sí o no con resaltador amarillo. Por ejemplo:
Enero: *sí/no*

≥ igual o más que
≤ igual o menos que
> más que
< menos que

[Dependiendo de sus respuestas, siga los pasos marcados por estos intervalos]

….. Cuando encuentre estos puntos, por favor añada algún motivo o explicación que apoye su respuesta.

Privacidad
La participación en esta encuesta es de carácter voluntario. Todas sus respuestas serán tratadas de forma confidencial. Pero debe estar de acuerdo con el siguiente apartado:

- Acepto participar en esta investigación y doy mi consentimiento a la investigadora Iris Flamand para que recoja, procese y analice mis respuestas.

Aclaración
Como es posible que disponga de más de una parcela, y para garantizar la calidad de la encuesta, se puede encontrar con las siguientes situaciones:
1- Que usa exactamente el mismo manejo en todas las parcelas. En ese caso responda una única encuesta.
2- Que tiene diferentes manejos en diferentes parcelas. Entonces tiene dos opciones:
Opción A: Escoja la de mayor superficie y responda la encuesta sobre esta.
Opción B: Si no es abusar de su paciencia, rellene cuantas encuestas quiera para cada una de sus parcelas.

Cuestión 1

Figura 1 (izquierda) y 2 (derecha): Logos de certificaciones producción integrada Andalucía y Agricultura ecológica Andalucía (D.O. Estepa, n.d.).
¿Está certificado/a como agricultor(a) integrado/a o ecológico/a?

- Integrado/a
- Ecológico/a

Cuestión 2

Imagen 1 (Guzmán 2020).

¿Mantiene cubiertas vegetales (imagen 1) en el olivar durante el año?

- Sí, uso una cubierta vegetal con especies sembradas (cebada, Bromus, Brachypodium, etc.) *[continúa con cuestión 4]*.
- Sí, uso una cubierta vegetal de especies que salen espontáneamente. *[continúa con cuestión 4]*.
- Sí, uso una cubierta de restos vegetales secos (por ejemplo, restos de poda) *[continúa con cuestión 4]*.
- No, ninguna de las anteriores *[continúa con cuestión 3]*.

Cuestión 3
¿Con qué técnica suele eliminar la vegetación espontánea en el olivar? Indique sí o no:
Con laboreo superficial (<15 centímetros): *sí/no*
Con laboreo profundo (≥15 centímetros): *sí/no*
Con herbicidas de síntesis: *sí/no*
Con sustancias certificadas en ecológico: *sí/no*

De otra manera, como por ejemplo …………………………….

[continúa con cuestión 8]

Cuestión 4

Imagen 2 (Guzmán, 2020). Imagen 3 (Gómez, 2010).

En las calles situadas entre las filas de olivos, ¿Cuál es la anchura mínima que ocupa la cubierta vegetal?

- Ancho bien definido (1 metro)
- Ancho bien definido (2 metros)
- Ancho bien definido (3 metros)
- Ancho bien definido (4 metros)
- Ancho bien definido (>4 metros)
- La cubierta ocupa toda la superficie del suelo de forma homogénea (imagen 2).
- La cubierta ocupa parcialmente la superficie del suelo en manchas distribuidas en la parcela (imagen 3).

Cuestión 5
¿Elimina las cubiertas vegetales en un periodo de tiempo particular?

- Sí, elimino la cubierta vegetal durante un periodo particular cada año *[continúa con cuestión 6]*.
- No, dejo la cubierta vegetal durante todo el año *[continúa con cuestión 7]*.

Cuestión 6
Normalmente, ¿durante qué meses elimina la cubierta vegetal y deja el suelo desnudo? Indique sí o no:
Enero: *sí/no*
Febrero: *sí/no*
Marzo: *sí/no*
Abril: *sí/no*
Mayo: *sí/no*
Junio: *sí/no*
Julio: *sí/no*
Agosto: *sí/no*
Septiembre: *sí/no*
Octubre: *sí/no*
Noviembre: *sí/no*
Diciembre: *sí/no*

[continúa con cuestión 7]

Cuestión 7
¿Cómo <u>controla el crecimiento</u> de las cubiertas vegetales? Indique sí o no:
Con desbrozadoras: *sí/no*
Con laboreo superficial (<15 centímetros): *sí/no*
Con laboreo profundo (≥15 centímetros): *sí/no*
Con químicos de síntesis: *sí/no*

Con químicos ecológicos: *sí/no*
Ninguna medida mantenimiento: *sí/no*

De otra manera, como por ejemplo …………………………….

Cuestión 8

Imagen 4 (Gómez, 2010).

¿Distribuye los restos de poda en las calles (imagen 4) entre los olivos?

- Sí, una cubierta de restos de poda triturados *[continúa con cuestión 9]*.
- Sí, una cubierta con las ramas (sin triturar) procedente de las podas *[continúa con cuestión 9]*.
- No *[continúa con cuestión 10]*.

Cuestión 9
¿Con que periodicidad poda y distribuye los restos de poda como cobertura?

- Cada año.
- Cada dos años.
- Cada 3 años.
- Otras situaciones (explique por favor) ………………………………………………..

[continúa con cuestión 10]

Cuestión 10
Todo o parte de mi olivar tiene pendientes medias o superiores al 10% (pendientes moderadas o fuertes):

- Sí *[continúa con cuestión 11]*
- No *[continúa con cuestión 15]*

Cuestión 11

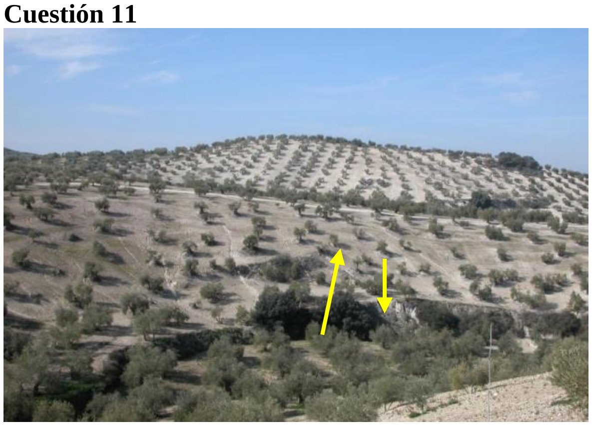


Imagen 5, adaptada de (Gómez, 2010).

¿Mantiene la cubierta vegetal entra las calles de olivos en un olivar de pendiente ≥10%?

- Sí, a favor de la pendiente (imagen 5, flechas amarillas).

- Sí, transversalmente a la pendiente (imagen 5, flechas blancas).
- Sí, ocupando toda la superficie del suelo.
- No

Cuestión 12
¿Aplica herbicidas en el olivar de pendiente ≥10%?
- Sí, químicos de síntesis.
- Sí, químicos ecológicos.
- No

Cuestión 13
¿Realiza labores de labranza en el olivar de pendiente ≥10%?
- Sí
- No

Cuestión 14
En el suelo del olivar de pendiente ≥10%, ¿presenta cualquiera de los siguientes problemas? Indique sí o no:
Tendencia a la formación de costra: *sí/no*
Tendencia a la formación de grietas profundas: *sí/no*
Tendencia a la alta compactación del suelo: *sí/no*
La necesidad de incorporar materia orgánica: *sí/no*

[continúa con cuestión 15]

Cuestión 15

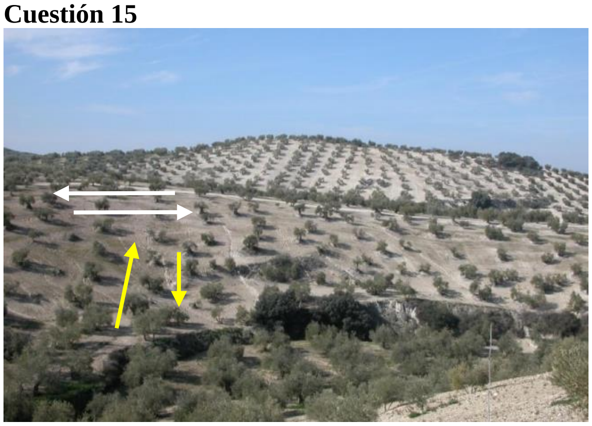



Imagen 5, adaptada de (Gómez, 2010).

¿Las labores de labranza las realiza a favor de la pendiente?
- Sí, a favor de la pendiente (imagen 5, flechas amarillas).
- Sí, transversalmente a la pendiente (imagen 5, flechas blancas).
- Sí, en ambos sentidos (imagen 5, flechas blancas y amarillas).
- No, todo el olivar es completamente llano.

Cuestión 16
Durante un período de 5 años, ¿cuántas veces suele aplicar herbicidas en el olivar?
- 0 veces
- 1 vez
- 2 veces
- 3 veces
- 4 veces
- 5 veces
- >5 veces

Cuestión 17
¿Hay años en los que haya necesitado aplicar herbicidas más de una vez bajo la copa del olivo o líneas de plantación?

- Sí
- No

Cuestión 18
¿Por qué motivo(s) labra (superficial o profundo) en el olivar? Indique sí o no:
Para incorporar materia orgánica al suelo: *sí/no*
Para la siembra de las cubiertas vegetales: *sí/no*
Para eliminar la vegetación espontánea: *sí/no*
Para eliminar la vegetación sembrada: *sí/no*
Para restaurar el suelo afectado por erosión, producida por tormentas o fuertes lluvias: *sí/no*
Para facilitar la aplicación de productos fitosanitarios y fertilizantes: *sí/no*

Otros motivos no mencionados anteriormente: ……………………………………………….

Cuestión 19
Por favor, indique si ejecuta trabajos preparatorios o de labranza en el olivar para cada caso:
Cuando el terreno se encuentra encharcado: *sí/no*
Cuando hay una formación de costra del suelo: *sí/no*
Cuando hay grietas profundas en el suelo: *sí/no*
Cuando ocurre una alta compactación del suelo: *sí/no*
Cuando llegan las primeras lluvias de otoño y hasta finales de invierno: *sí/no*

Cuestión 20
¿Mantiene un registro electrónico o en papel de las operaciones realizadas en el olivar?

- Sí *[continúa con cuestión 21]*
- No *[continúa con cuestión 22]*

Cuestión 21
Por favor, indique si incluye la siguiente información en este libro de registro:
Operaciones de laboreo: *sí/no*
Operaciones de plantación: *sí/no*
Operaciones de riego: *sí/no*
Tratamiento de poda: *sí/no*
Aplicaciones de productos fitosanitarios o fertilizantes: *sí/no*
La localización de las parcelas y las fechas en que se realizan: *sí/no*
Las autorizaciones: *sí/no*
Recibos o facturas de las operaciones que lo requieran: *sí/no*
Otros, por ejemplo: ……………………………………………….
[continúa con cuestión 22]

Cuestión 22
Como agricultor(a) de olivar, intento cuidar el suelo para evitar la formación de cárcavas:

- Sí
- No

Cuestión 23
¿Qué hace cuando aparecen zonas de vegetación (arbustos, matorrales, hierbas, etc.) espontánea **fuera del área de producción** de su olivar (pero parte de su territorio de olivos), como por ejemplo en márgenes o lindes de caminos?

- Controlo la vegetación espontánea.
- No controlo la vegetación espontánea, sigue su proceso natural.
- Elimino la vegetación espontánea.
- No tengo vegetación espontánea.

Cuestión 24
¿Cuál es la pendiente media de su olivar?
- 0% (llana, no pendiente)
- 0.1-5% (pendiente muy suave)
- 6-9% (pendiente suave)
- 10-15% (pendiente moderada)
- ≥15% (pendiente fuerte)

Cuestión 25
¿Qué régimen de riego tiene su olivar? Indique sí o no:
Secano: *sí/no*
Riego: *sí/no*

Cuestión 26
¿Cuál es la superficie de su olivar en hectáreas (ha)?
- <1 ha
- 1-1.9 ha
- 2-2.9 ha
- 3-3.9 ha
- 4-9.9 ha
- 10-19.9 ha
- 20-29.9 ha
- 30-39.9 ha
- 40-49.9 ha
- ≥50 ha

Cuestión 27
¿Cuál es la edad media de los olivos?
- 0-4 años
- 5-9 años
- 10-19 años
- 20-29 años
- 30-39 años
- 40-49 años
- ≥50 años

Cuestión 28
¿Cuál es la densidad media de plantación de su olivar (árboles/ha)?
- <100 árboles/ha
- 100-199 árboles/ha
- 200-499 árboles/ha
- ≥500 árboles/ha

Cuestión 29
¿En qué año empezó a implementar la agricultura integrada o ecológica en su olivar?
……………

Cuestión 30
¿En qué año se unió a la D.O. Estepa?
…………….

Cuestión 31
¿Qué motivaciones le han llevado a cultivar en ecológico o integrado? Indique sí o no:
El reconocimiento social que implica la marca Estepa: *sí/no*
La rentabilidad; el producto vende más caro: *sí/no*
Obtención de ayudas alternativas (de la UE): *sí/no*

Protegerla protección del medio ambiente: *sí/no*
Obtención de productos de mayor calidad: *sí/no*
Convicciones personales: *sí/no*
Los agricultores vecinos empezaron cambiar a agricultura integrada o ecológica: *sí/no*

Otras motivaciones, por ejemplo: ……………………………………………….

Cuestión 32
Mi mayor fuente de ingresos es el cultivo de olivos:
- Sí
- No; obtengo ingresos principalmente (≥50%) de otras actividades agrícolas.
- No; obtengo ingresos principalmente (≥50%) de actividades no agrícolas.

Cuestión 33
¿Qué fuentes de información <u>usa</u> normalmente para conocer los requisitos de agricultura integrada o ecológica? Indique sí o no:
Agricultores, vecinos o familiares: *sí/no*
Administraciones públicas (Junta de Andalucía, Ministerio de Agricultura, etc.): *sí/no*
Centros de Investigación (IFAPA, CSIC, Universidades, etc.): *sí/no*
Asociaciones de Agricultores: *sí/no*
Cooperativas pertenecientes a las D.O.: *sí/no*
Internet: *sí/no*; especificar las páginas webs: ………………………………………….
Otras fuentes de información (por ejemplo, revistas, radio etc.): *sí/no*; especificar…………………………………………

Cuestión 34
Si pudiera elegir, ¿sobre qué temas le gustaría tener más información? Indique sí o no:
Las prácticas conservación del suelo (p. ej. cubierta vegetal): *sí/no*
Restricciones relacionadas con el manejo del suelo: *sí/no*
Eliminación de la vegetación espontánea (malas hierbas): *sí/no*
Los requisitos obligatorios relacionados con la condicionalidad (cumplir normas básicas): *sí/no*
Los requisitos obligatorios relacionados con agricultura integrada o ecológica: *sí/no*
Cuáles son los problemas a los que se enfrentan otros olivareros y cómo los resuelven: *sí/no*
Ayudas y subvenciones disponibles: *sí/no*

Otra información, por ejemplo …………………………………………….

Cuestión 35
¿Qué problemas existen <u>en el cultivo</u> de olivar integrado o ecológico? Indique sí o no:
La competencia en los mercados es más fuerte ahora: *sí/no*
Me falta formación en algunos aspectos agrícolas, que sean más específicos para olivar integrado o ecológico: *sí/no*
Existe cierta presión social entre el olivar integrado o ecológico y los medios sostenibles: *sí/no*
Hay demasiados requisitos obligatorios que cumplir para obtener subsidios complementarios: *sí/no*
Me falta acceso a maquinaria específica (p. ej. trituradora de poda, segadora, etc.): *sí/no*
Me falta experiencia para trabajar como agricultor(a) integrado/a o ecológico/a de olivar: *sí/no*
Me resulta difícil de mantener actualizado el cuaderno de campo: *sí/no*
Tengo una carga de trabajo demasiado alta: *sí/no*
Tengo costes adicionales para el cultivo integrado o ecológico: *sí/no;* como por ejemplo ………………………………
El establecimiento y manejo de las cubiertas es complicado: *sí/no;* debido a, por ejemplo …………………………………

Me encuentro otros problemas, por ejemplo: ………………………………………………………………….

Cuestión 36

¿Con cuál de las siguientes afirmaciones se siente más identificado observando los problemas de erosión del suelo de su olivar?

- **sin problema**: no hay cárcavas y regueros, no hay formación de costra y no existe compactación del suelo.
- **pocos problemas**: hay muy pocas cárcavas y regueros, casi no hay formación de costra ni compactación del suelo.
- **algunos problemas**: hay algunas cárcavas y regueros, algunos lugares con formación de costra y con algunas zonas de compactación del suelo.
- **muchos problemas**: hay muchas cárcavas y regueros, en la mayor parte de la superficie hay formación de costra y compactación del suelo.

Cuestión 37

¿Han aumentado los problemas de erosión del suelo en los últimos 5 años?

- Sí, los problemas han aumentado en mi olivar *[continúa con cuestión 38]*.
- No, la problemática se mantiene constante a lo largo del tiempo *[continúa con cuestión 39]*.

Cuestión 38

¿Por qué cree que han aumentado los problemas de erosión en los últimos 5 años?

…………………………………………………………………………

[continúa con cuestión 39].

Cuestión 39
Responda sólo en caso de que no use cubierta vegetal.
¿Estaría interesado en utilizar cubierta vegetal en su olivar si resolviera los problemas de erosión?

- o Sí, estaría interesado.
- o No, no estaría interesado.
- o No tengo problemas de erosión.

Cuestión 40
¿Tiene todo lo necesario para reducir los problemas de erosión del suelo? Indique sí o no:
Necesito (más) soporte financiero: *sí/no*
Necesito (más) acceso a tecnología: *sí/no*
Necesito (más) entrenamiento agrícola: *sí/no*

Cuestión 41
Tengo un(a) sucesor(a) que se hará cargo de mi olivar en el futuro:

- o Sí, un(a) familiar.
- o Sí, pero no es un familiar.
- o No

Cuestión 42
Para ayudar a mejorar este estudio estoy dispuesto/a compartir el número de recinto SIGPAC de mi olivar, que serán tratados de forma confidencial:
Polígono………, Parcela …………………, Recinto…………………

¡Este es el final de la encuesta! Muchas gracias.
Por favor envíe este formulario completo a iris.flamand@wur.nl

Appendix B
Survey in English

Estepa olive grove survey

A study in collobaraion with the Sustainable Institute of Agriculture (CSIC), PDO Estepa and the University of Wageningen (the Netherlands).

Investigator: Iris Flamand (iris.flamand@wur.nl)

Dear participant,

You are invited to voluntarily participate in my study. Before starting, here you can read information about my study and me. Feel free to contact me if you have any questions in this regard via the following email address: iris.flamand@wur.nl

Who is the investigator? My name is Iris Flamand, I am an Environmental Sciences master student at Wageningen University (NL) and I am glad you are willing to participate in this research. This thesis research is organized online because the Covid-19 pandemic prohibits field visits. I hope you are all doing fine and it is a pleasure for me to execute this survey in collaboration with D.O. Estepa. The research is halfway and will be finalized in November 2020.
What is the research about? You help me identifying where problems occur within the integrated and organic olive farming practices in relation with corresponding national and EU requirements. The ultimate goal is to better understand the limitations of the farmers practices and the adoption rate of the CAP regulations, which aim at improving the environmental aspects of the olive grove.
What is in it for you? In my research journey I have discovered how complex the certification requirements can be for integrated and organic farming. This is your opportunity to clarify the challenges of being an integrated or organic farmer and to share how satisfied you are with being part of a protected designation of origin, which is a benchmark in the sector. Sharing your experience is very important and helpful for other olive farmers in Spain and the whole olive farming industry in the Mediterranean.
What will happen with the results? This survey will be anonymous, and the results will only be used confidentially, for thesis research and possible derivative publications.
Completing the survey will take a maximum of 15-20 minutes.
Thank you very much for participating.

Explanation of the symbols (only needed for Word version):

- You can only highlight one option with yellow marker, for example:
  - Integrated

Yes/no You can highlight yes or no with yellow marker. For example:
January: Yes/*/no*

≥ means “equal or more than”
≤ means “equal or less than”
> means “more than”
< means “less than”

[the text within these straight hooks tells you what to do next]

….. on the dots you need to indicate a number or explanation, related to the question.

Privacy
Participation in this survey is voluntary. All your answers will be treated confidentially. But you must agree with the following section:

- I agree to participate in this research, and I consent to researcher Iris Flamand to collect, process and analyze my responses.

Clarification
As you may have more than one plot, and to ensure the quality of the survey, you may encounter the following situations:
1- That it uses exactly the same management in all plots. In that case, answer a single survey.
2- That it has different management in different plots. Therefore, you have two options:
Option A: Choose the one with the largest surface area and answer the survey about it.
Option B: If it is not abusing your patience, fill out as many surveys as you want for each of your plots.

Question 1

Figure 1 (left) and 2 (right): Logos of the integrated production and organic production certifications in Andalusia (D.O. Estepa, n.d.).

Are you certified as integrated or organic olive farmer?

- Integrated
- Organic

Question 2

Image 1 (Guzmán 2020).

Do you keep a cover vegetation (image 1) in the olive grove?

- Yes, I seed a cover vegetation with seeded species (cebada, Bromus, Brachypodium, etc.) *[continue with question 4].*
- Yes, I allow spontaneous vegetation (weeds) to grow *[continue with question 4].*
- Yes, I apply the remains of dried crops (e.g. prune residues) *[continue with question 4].*
- No, none of the above *[continue with question 3].*

Question 3
How do you remove the spontaneous weeds in the olive grove? Indicate yes or no:
By shallow tillage (<15 centimetres): *Yes/no*
By vertical tillage (≥15 centimetres): *Yes/no*
With synthetic herbicides: *Yes/no*

With organic herbicides: *Yes/no*

Otherwise, namely ……………………

[continue with question 8]

Question 4

Image 2 (Guzmán, 2020). Image 3 (Gómez, 2010).

What is the width of the streets of the cover vegetation in your olive grove?

- 1 metre
- 2 metres
- 3 metres
- 4 metres
- >4 metres
- The cover vegetation occupies the entire surface of the soil (see as example image 2).
- The cover vegetation occupies partially the soil (see as example image 3).

Question 5

Do you remove the cover vegetation in a particular time period?

- Yes, I remove the vegetation in a particular time period *[continue with question 6].*
- No, I keep the cover vegetation all year round *[continue with question 7].*

Question 6

In which months do you normally remove the cover vegetation and keep the soil bare (to avoid water competition with the olive trees)?

January: *Yes/no*
February: *Yes/no*
March: *Yes/no*
April: *Yes/no*
May: *Yes/no*
June: *Yes/no*
July: *Yes/no*
August: *Yes/no*
September: *Yes/no*
October: *Yes/no*
November: *Yes/no*

[continue with question 7]

Question 7

How do you control the growth of cover crops? Please indicate yes or no:
By mowing: Yes/no
By shallow tillage (<15 centimetres): Yes/no
By vertical tillage (≥15 centimetres): Yes/no

With synthetic herbicides: Yes/no
With organic herbicides: Yes/no
No control measure: Yes/no

Otherwise, namely ……………………

Question 8

 Image 4 (Gómez, 2010).

Do you distribute the pruning remains in the streets (image 4) among the olive trees?

- Yes, a cover of shredded pruning remains [continue with question 9].
- Yes, a cover with the branches (without crushing) from the pruning [continue with question 9].
- No [continues with question 10].

Question 9
How often do you prune and distribute the pruning remains as cover?

- Every year
- Every two years
- Every 3 years.
- Other situations (please explain) ……………………………………………..

[continue with question 10]

Question 10
All or part of my olive grove has slopes that are medium or higher than 10% (moderate or strong slopes):

- Yes [continue with question 11]
- No [continue with question 15]

Question 11

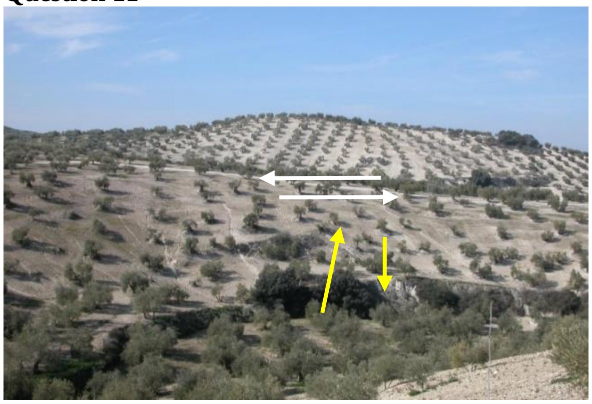


Image 5, adapted from (Gómez, 2010).

Does the vegetation cover between the streets of olive trees maintain an olive grove with a slope of ≥10%?

- Yes, in the direction of the slope (image 5, yellow arrows).

- Yes, across the slope (image 5, white arrows).
- Yes, occupying the entire surface of the floor.
- No

Question 12
Do you apply herbicides in the olive grove with a slope of ≥10%?

- Yes, synthetic chemicals.
- Yes, organic chemicals.
- No

Question 13
Do you carry out tillage work in the olive grove with a slope of ≥10%?

- Yes
- No

Question 14
In the soil of the olive grove with a slope of ≥10%, does it present any of the following problems? Please indicate yes or no:
Tendency to crust: yes / no
Tendency to deep crack formation: yes / no
Tendency to high soil compaction: yes / no
The need to incorporate organic matter: yes / no

[continue with question 15]

Question 15

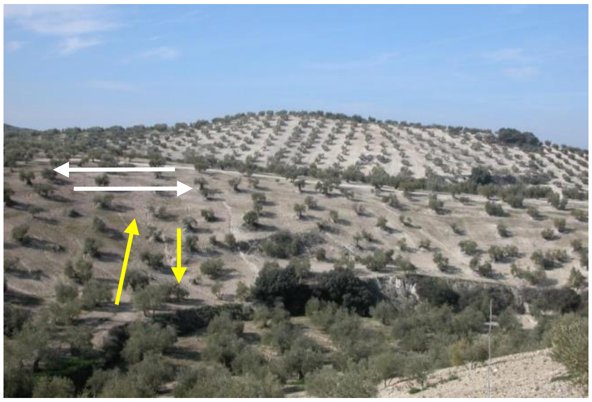


Image 5, adapted from (Gómez, 2010).

Is the tillage work done in the direction of the slope?

- Yes, in the direction of the slope (image 5, yellow arrows).
- Yes, across the slope (image 5, white arrows).
- Yes, in both directions (image 5, white and yellow arrows).
- No, the entire olive grove is completely flat.

Question 16
During a 5-year period, how many times do you usually apply herbicides to the olive grove?

- 0 times
- 1 time
- 2 times
- 3 times
- 4 times
- 5 times
- >5 times

Question 17
Are there years when you have needed to apply herbicides more than once under the olive tree canopy or planting lines?

- Yes
- No

Question 18
For what reason (s) do you work (superficial or deep) in the olive grove? Please indicate yes or no:
To incorporate organic matter into the soil: yes / no
For planting the ground covers: yes / no
To remove spontaneous vegetation: yes / no
To remove planted vegetation: yes / no
To restore the soil affected by erosion, produced by storms or heavy rains: yes / no
To facilitate the application of phytosanitary products and fertilizers: yes / no

Other reasons not mentioned above: ……………………………………………….

Question 19
Please indicate whether you carry out preparatory or tillage work in the olive grove for each case:
When the land is flooded: yes / no
When there is a crusting of the soil: yes / no
When there are deep cracks in the ground: yes / no
When high soil compaction occurs: yes / no
When the first autumn rains arrive and until the end of winter: yes / no

Question 20
Do you keep an electronic or paper record of the operations carried out in the olive grove?

- Yes [continue with question 21]
- No [continue with question 22]

Question 21
Please indicate whether you include the following information in this logbook:
Tillage operations: yes / no
Plantation operations: yes / no
Irrigation operations: yes / no
Pruning treatment: yes / no
Applications of phytosanitary products or fertilizers: yes / no
The location of the plots and the dates on which they are carried out: yes / no
Authorizations: yes / no
Receipts or invoices for operations that require it: yes / no
Others, for example: ……………………………………………….

[continue with question 22]

Question 22
As an olive grove farmer, I try to take care of the soil to avoid the formation of gullies:

- Yes
- No

Question 23
What do you do when areas of spontaneous vegetation (shrubs, bushes, herbs, etc.) appear outside the production area of your olive grove (but part of your olive grove territory), such as on margins or roadsides?

- I control spontaneous vegetation.
- I do not control spontaneous vegetation; it follows its natural process.
- I eliminate spontaneous vegetation.

- I do not have spontaneous vegetation.

Question 24
What is the average slope of your olive grove?
- 0% (flat, not sloping)
- 0.1-5% (very gentle slope)
- 6-9% (gentle slope)
- 10-15% (moderate slope)
- ≥15% (steep slope)

Question 25
What irrigation regime does your olive grove have? Please indicate yes or no:
Rainfed: yes / no
Irrigation: yes / no

Question 26
What is the area of your olive grove in hectares (ha)?
- <1 ha
- 1-1.9 ha
- 2-2.9 ha
- 3-3.9 ha
- 4-9.9 ha
- 10-19.9 ha
- 20-29.9 ha
- 30-39.9 ha
- 40-49.9 ha
- ≥50 ha

Question 27
What is the average age of the olive trees?
- 0-4 years
- 5-9 years
- 10-19 years
- 20-29 years
- 30-39 years
- 40-49 years
- ≥50 years

Question 28
What is the average planting density of your olive grove (trees / ha)?
- <100 trees / ha
- 100-199 trees / ha
- 200-499 trees / ha
- ≥500 trees / ha

Question 29
In what year did you start to implement integrated or organic agriculture in your olive grove?
……………

Question 30
In what year did you join the PDO Estepa?
…………….

Question 31
What motivations have led you to grow organic or integrated? Please indicate yes or no:
The social recognition that the Estepa brand implies: yes / no

Profitability; the product sells more expensive: yes / no
Obtaining alternative aid (from the EU): yes / no
Protect the environment protection: yes / no
Obtaining higher quality products: yes / no
Personal convictions: yes / no
Neighboring farmers started switching to integrated or organic farming: yes / no

Other motivations, for example: ……………………………………………….

Question 32
My biggest source of income is the cultivation of olive trees:

- Yes
- No; I earn income mainly (≥50%) from other agricultural activities.
- No; I earn income primarily (≥50%) from non-farm activities.

Question 33
What sources of information do you normally use to find out the requirements for integrated or organic farming? Please indicate yes or no:
Farmers, neighbors or relatives: yes / no
Public administrations (Junta de Andalucía, Ministry of Agriculture, etc.): yes / no
Research Centers (IFAPA, CSIC, Universities, etc.): yes / no
Farmers Associations: yes / no
Cooperatives belonging to the PDO: yes / no
Internet: yes / no; specify the web pages: ………………………………………….
Other sources of information (eg magazines, radio etc.): yes / no; specify…………………………………………

Question 34
If you had a choice, what topics would you like more information about? Please indicate yes or no:
Soil conservation practices (eg vegetation cover): yes / no
Restrictions related to soil management: yes / no
Elimination of spontaneous vegetation (weeds): yes / no
Mandatory requirements related to cross compliance (meet basic standards): yes / no
Mandatory requirements related to integrated or organic farming: yes / no
What are the problems other olive growers face and how do they solve them: yes / no
Aids and subsidies available: yes / no

Other information, for example …………………………………………….

Question 35
What problems exist in the cultivation of integrated or organic olive groves? Please indicate yes or no:
Competition in the markets is stronger now: yes / no
I lack training in some agricultural aspects, which are more specific to integrated or organic olive groves: yes / no
There is some social pressure between the integrated or organic olive grove and sustainable means: yes / no
There are too many mandatory requirements to meet to obtain supplemental grants: yes / no
I lack access to specific machinery (eg pruning mulcher, mower, etc.): yes / no
I lack experience to work as an integrated or organic olive grove farmer: yes / no
I find it difficult to keep the field notebook updated: yes / no
I have too high a workload: yes / no
I have additional costs for integrated or organic farming: yes / no; for example ………………………………
The establishment and management of the covers is complicated: yes / no; due to, for example …………………………………

I encounter other problems, for example: ………………………………………………………………….

Question 36
With which of the following statements do you feel most identified by observing the problems of soil erosion in your olive grove?

- no problem: there are no gullies and gullies, there is no scab formation and there is no compaction of the soil.
- few problems: there are very few gullies and gullies, almost no scab formation or soil compaction.
- some problems: there are some gullies and gullies, some places with scab formation and some areas of soil compaction.
- many problems: there are many gullies and gullies, in most of the surface there is crust formation and soil compaction.

Question 37
Have soil erosion problems increased in the last 5 years?
- Yes, problems have increased in my olive grove [continues with Question 38].
- No, the problem remains constant over time [continues with Question 39].

Question 38
Why do you think erosion problems have increased in the last 5 years?
…………………………………………………………………………

[Continue with question 39].

Question 39
Answer only if you do not use vegetative cover.
Would you be interested in using vegetation cover in your olive grove if it solved the erosion problems?
- Yes, I would be interested.
- No, I would not be interested.
- I have no erosion problems.

Question 40
Do you have what it takes to reduce soil erosion problems? Please indicate yes or no:
I need (more) financial support: yes / no
Do I need (more) access to technology: yes / no
Do I need (more) agricultural training: yes / no

Question 41
I have a successor who will take over my olive grove in the future:
- Yes, a relative.
- Yes, but it is not a relative.
- No

Question 42
To help improve my study, I am willing to share the SIGPAC site number of my olive grove, which will be treated confidentially:
Polygon ………, Plot …………………, Enclosure …………………

This is the end of the survey! Many thanks.
Please send this completed form to iris.flamand@wur.nl

Appendix C
Tree diagram: adoption of measures

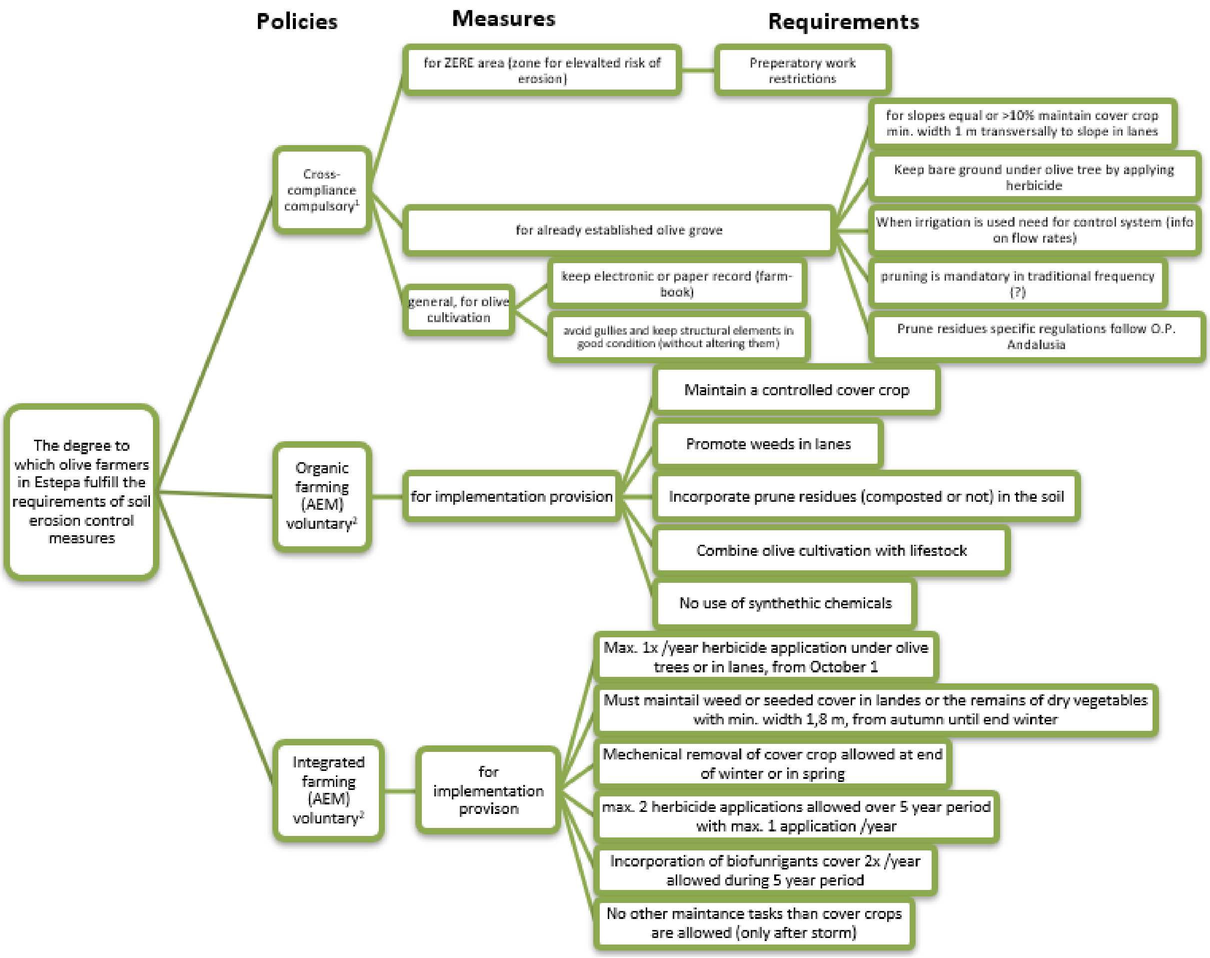


Figure A: tree diagram indicating what to measure in the survey to answer RQ 3, with [1](FEGA, 2020) [2](JuntadeAndalucía, 2015).

Appendix D
Tree diagram: external factors

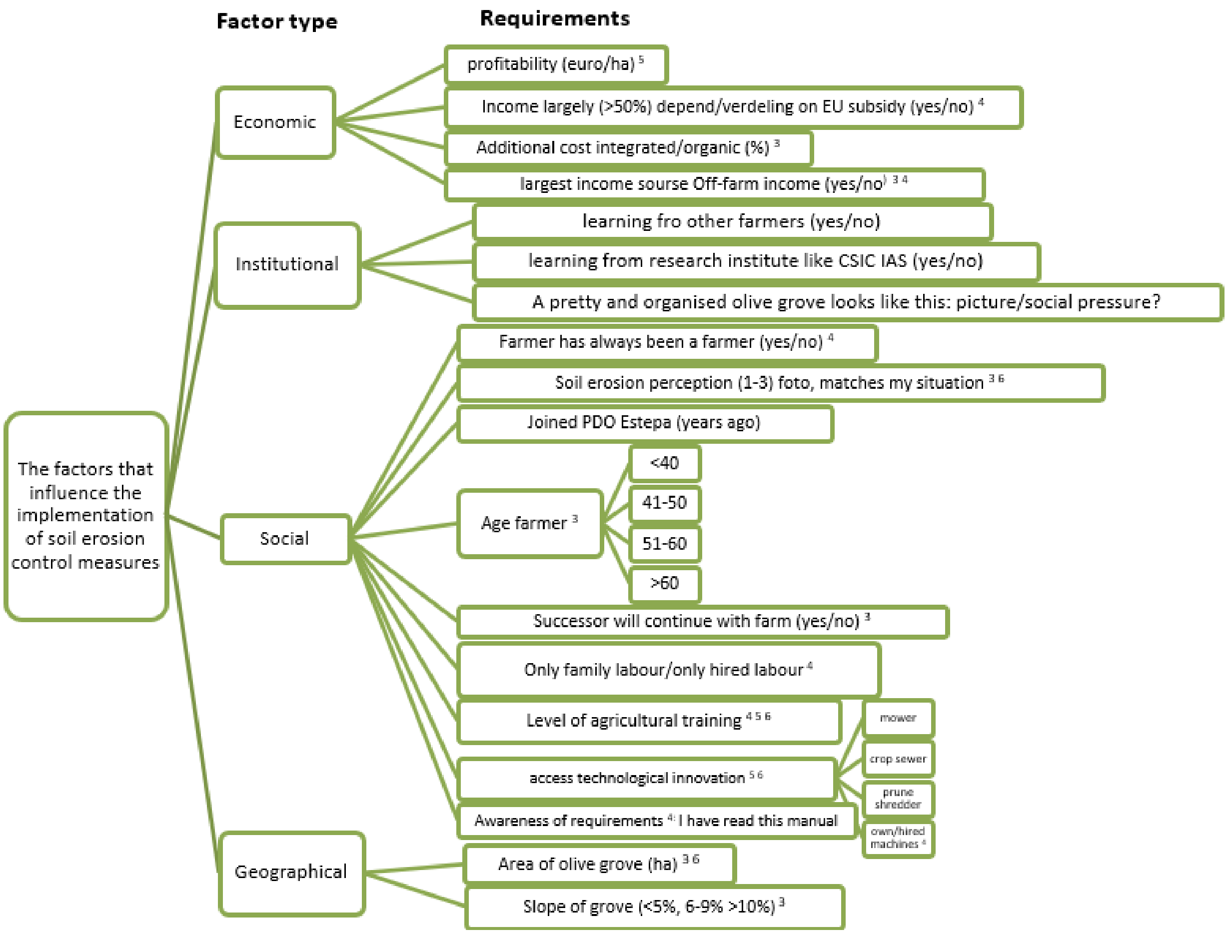
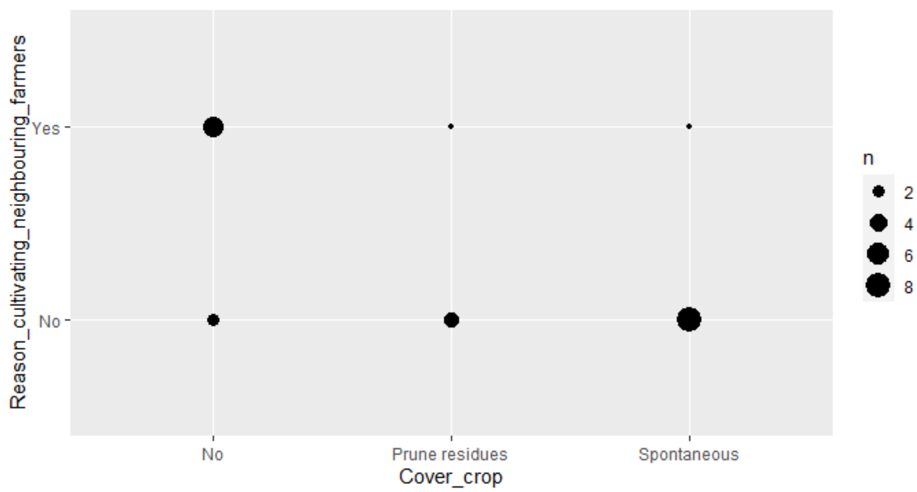
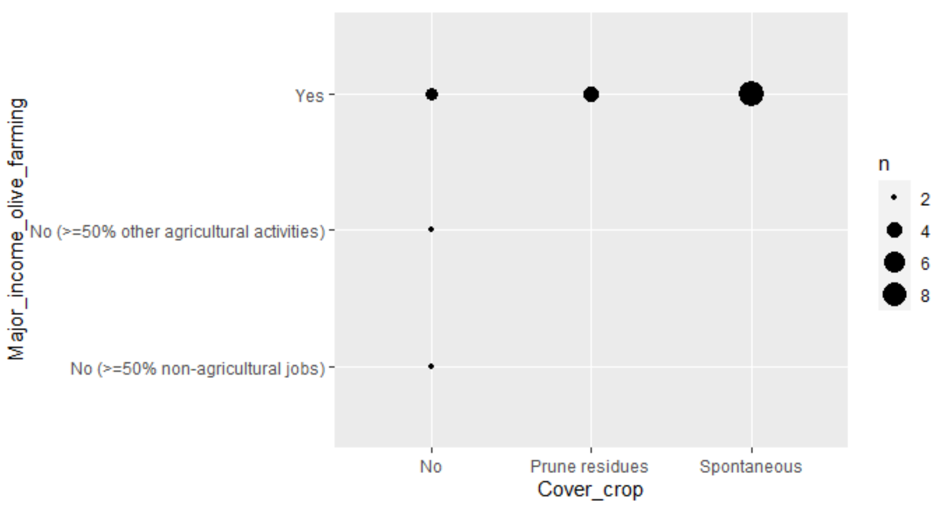


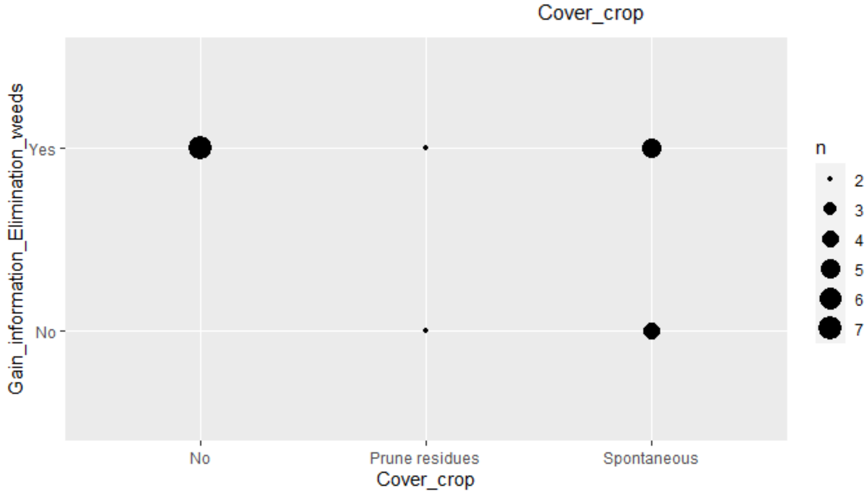
Figure B: tree diagram indicating what to measure in the survey to answer RQ 4, with 3(Franco & Calatrava-Leyva, 2006) 4(Calatrava Leyva et al., 2007) 5(Rodríguez-Entrena et al., 2014) 6(Aznar-Sánchez et al., 2020).

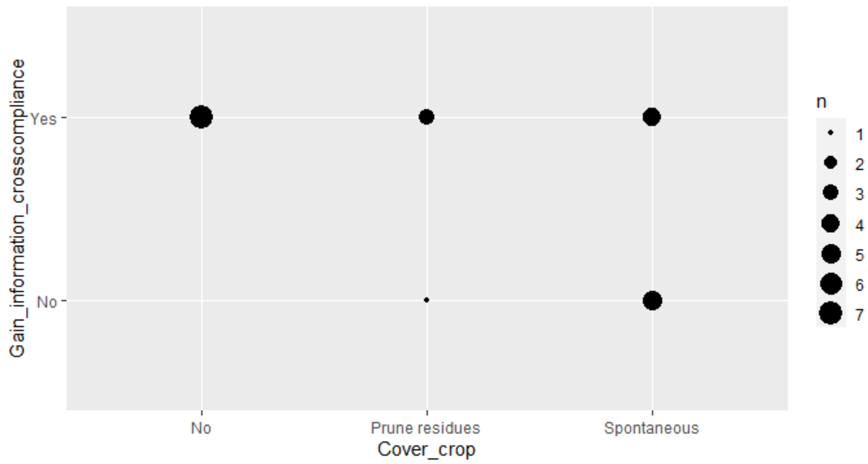
Appendix E
Results of Exploratory Factor Analysis

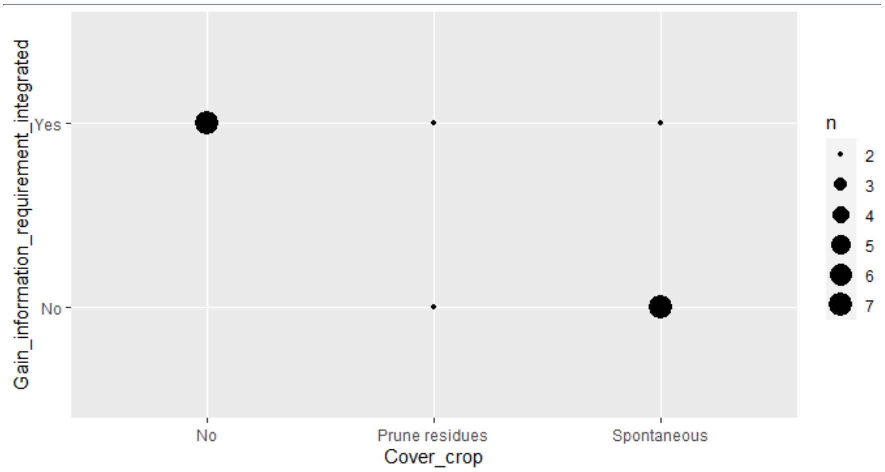
Adoption of cover crops

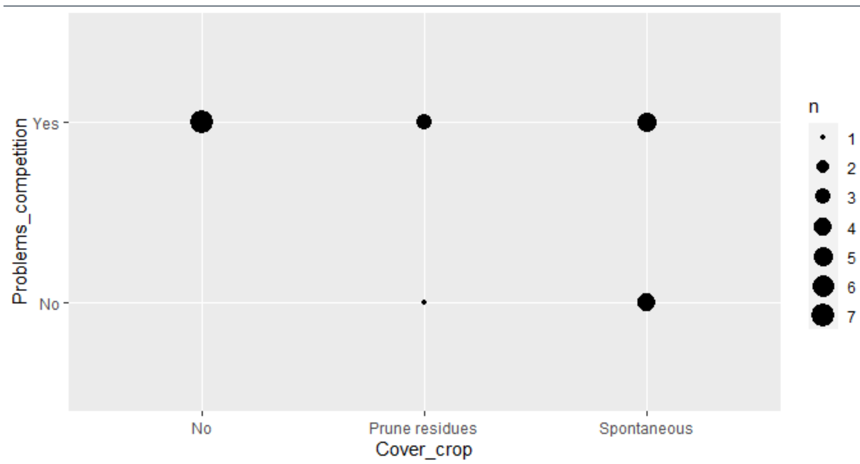


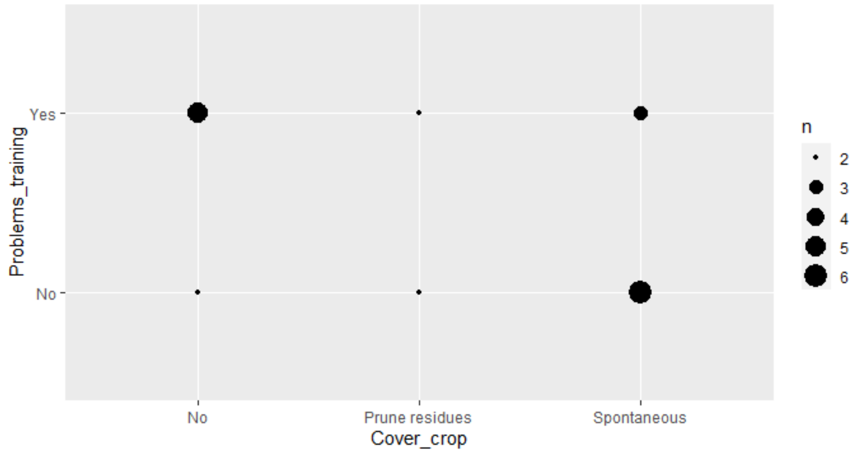


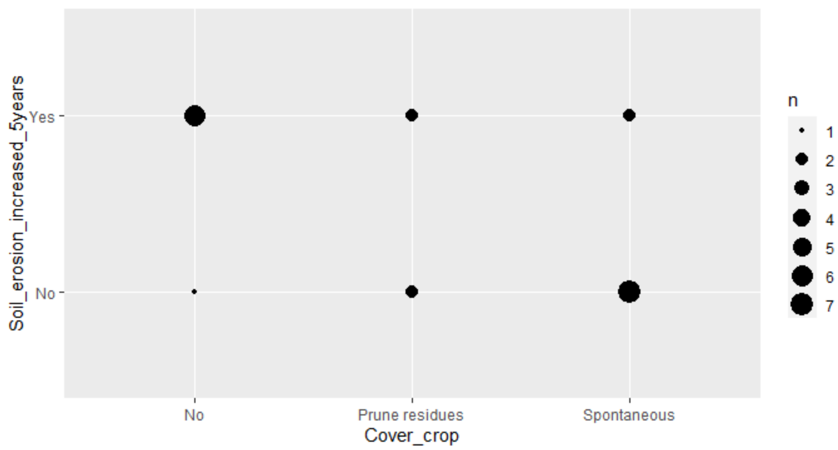


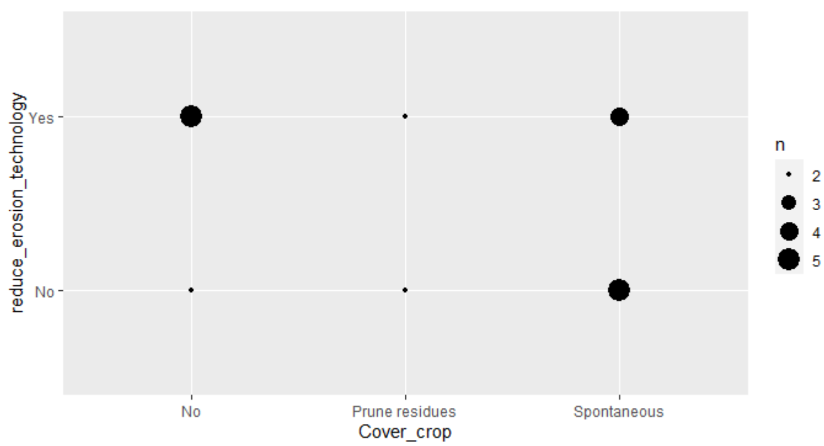

Gain_information_crosscompliance
Yes
No
No
Prune residues
Spontaneous
Cover_crop
n
1
2
3
4
5
6
7

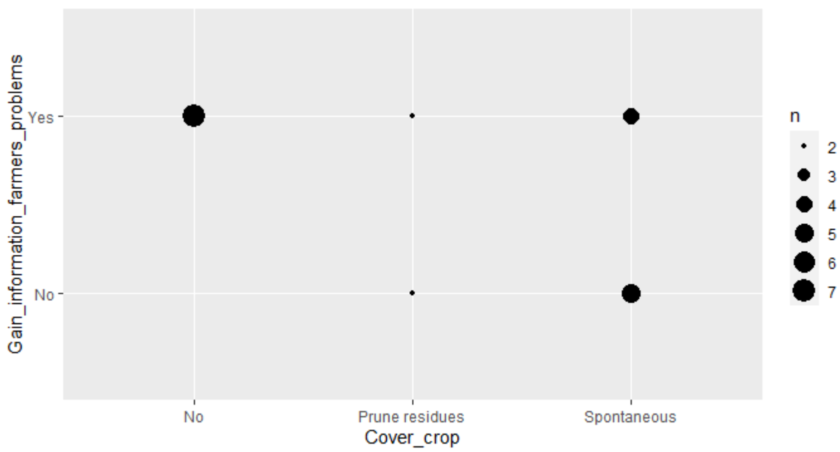

Gain_information_requirement_integrated
Yes
No
No
Prune residues
Spontaneous
Cover_crop
n
2
3
4
5
6
7


Problems_competition
Yes
No
No
Prune residues
Spontaneous
Cover_crop
n
1
2
3
4
5
6
7

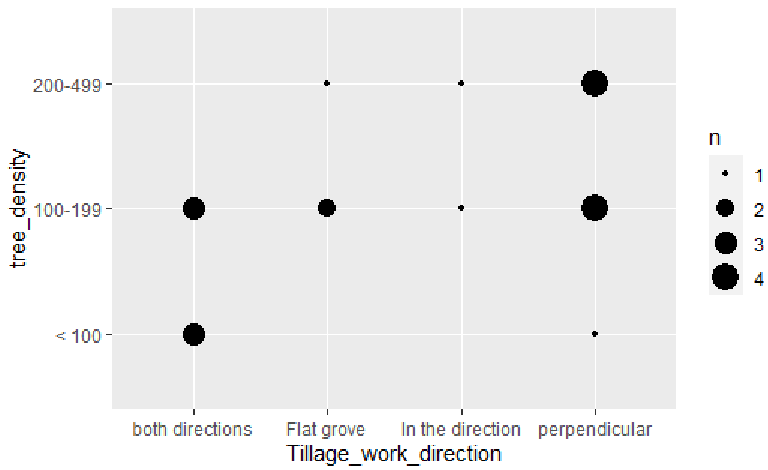

Problems_training
Yes
No
No
Prune residues
Spontaneous
Cover_crop
n
2
3
4
5
6

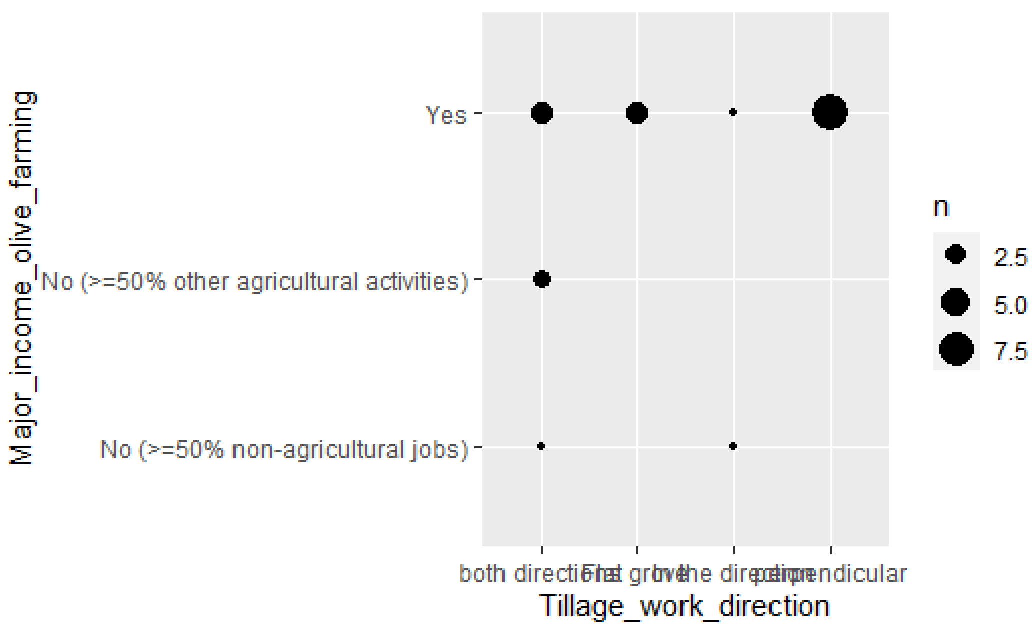

Soil_erosion_increased_5years
Yes
No
No
Prune residues
Spontaneous
Cover_crop
n
1
2
3
4
5
6
7

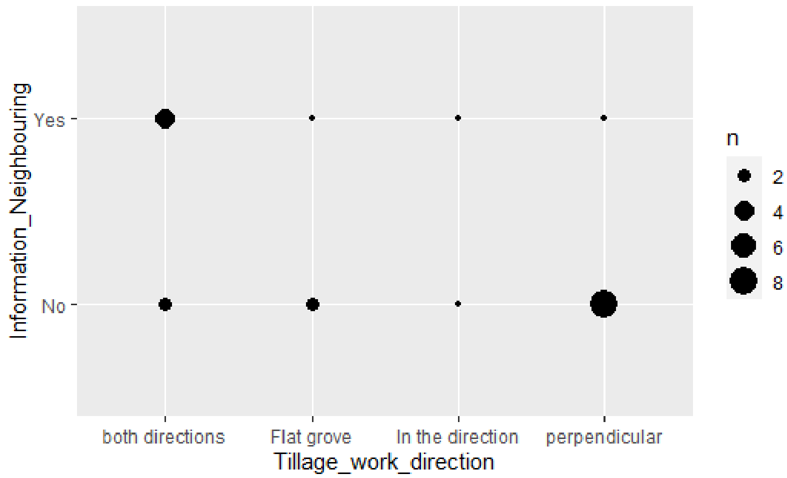

reduce_erosion_technology
Yes
No
No
Prune residues
Spontaneous
Cover_crop
n
2
3
4
5



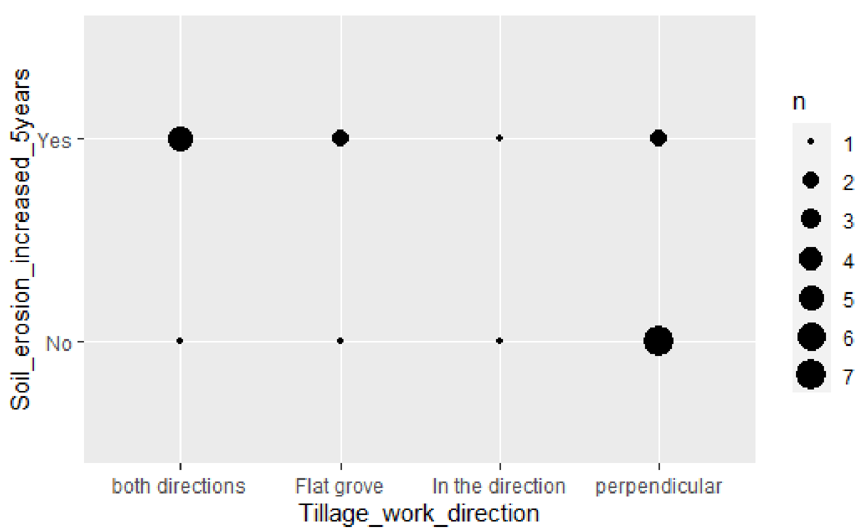
Adoption of tillage perpendicular to the slope



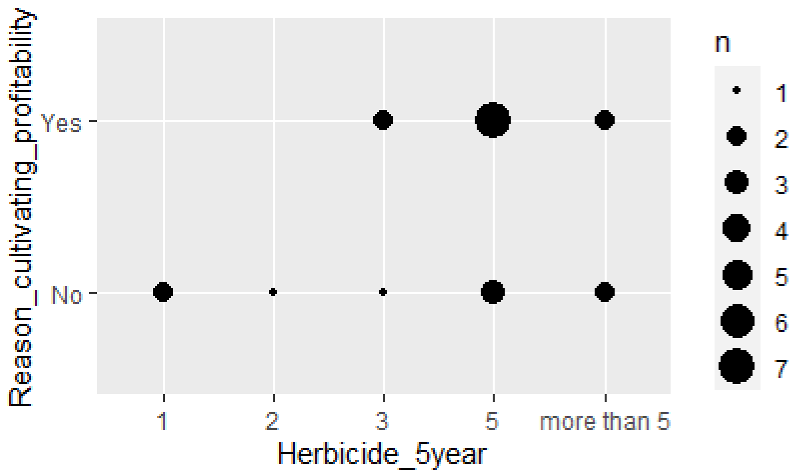


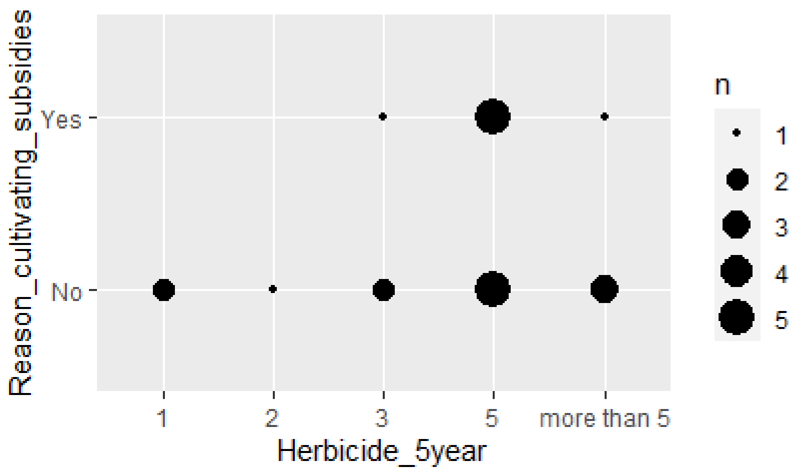

Information_Neighbouring
Yes
No
both directions
Flat grove
In the direction
perpendicular
Tillage_work_direction
n
2
4
6
8

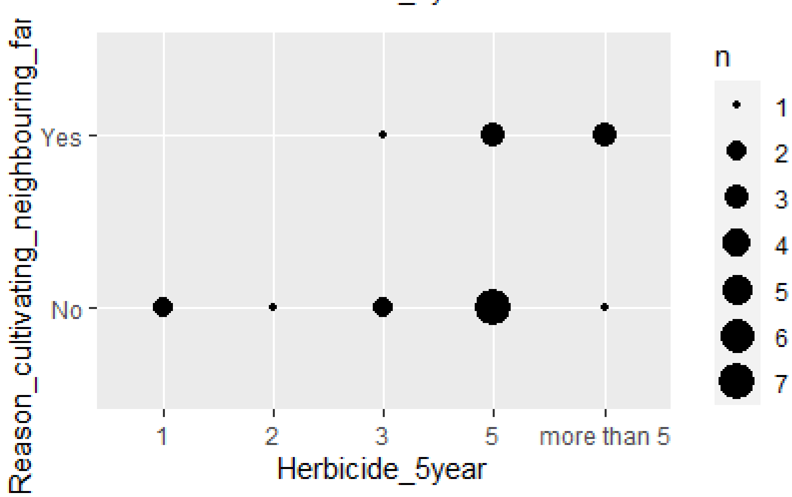

Problems_training
Yes
No
both directions
Flat grove
In the direction
perpendicular
Tillage_work_direction
n
1
2
3
4
5
6
7

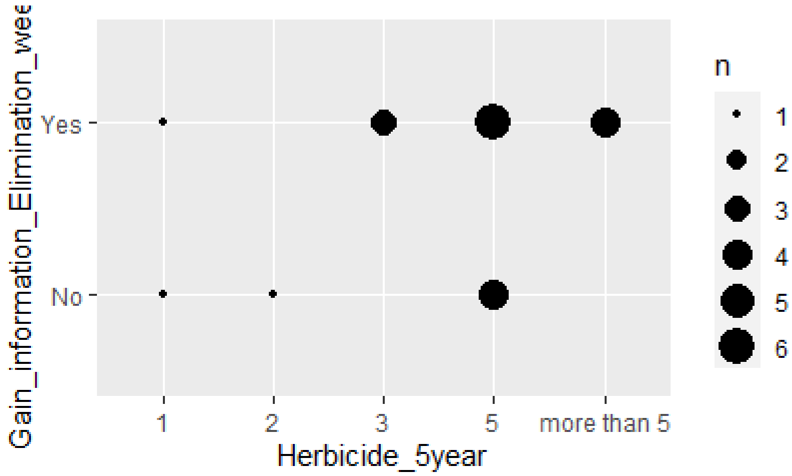

Soil_erosion_increased_5years
Yes
No
both directions
Flat grove
In the direction
perpendicular
Tillage_work_direction
n
1
2
3
4
5
6
7

Adoption of maximum two herbicide applications over a 5-year period

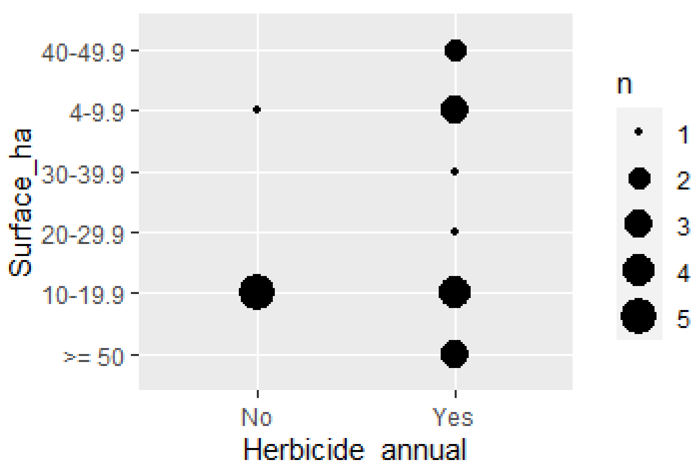


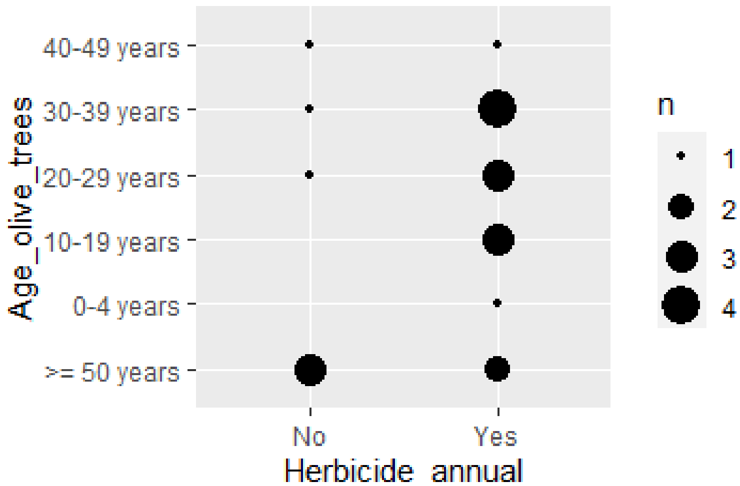




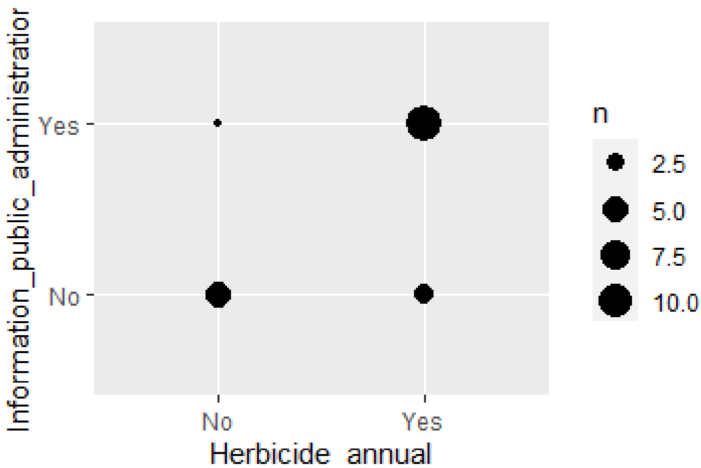


Adoption of maximum one herbicide application annually



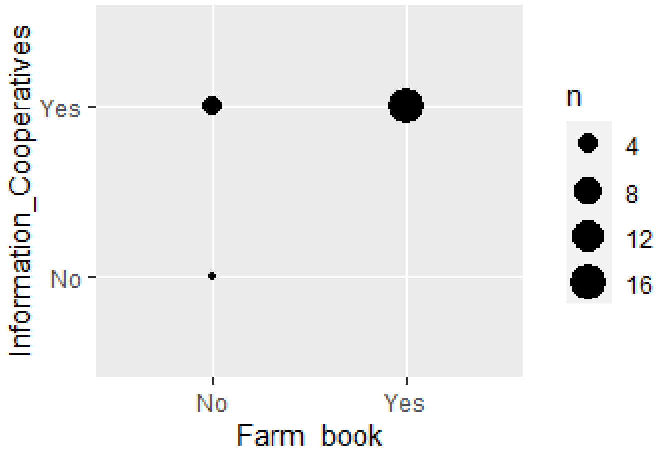


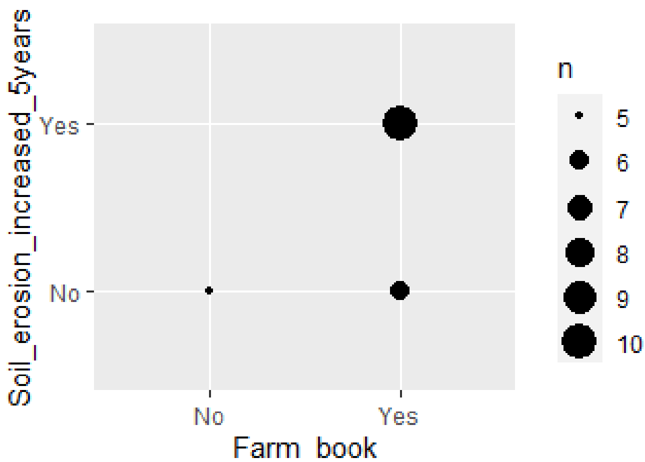
40-49 years
30-39 years
20-29 years
10-19 years
0-4 years
>= 50 years
Age_olive_trees
No
Yes
Herbicide_annual
n
1
2
3
4



Yes
No
Information_public_administratior
No
Yes
Herbicide_annual
n
2.5
5.0
7.5
10.0

Adoption of keeping a farm-book





Appendix F
Dependent and independent studied variables

Table A: The dependent and independent variables considered in the EFA.

Dependent variables		**Independent variables**	
Vector no.	**Variable name**	**Vector no.**	**Variable name**
1	no cover crop	8	surface area
2	tillage direction	9	age olive trees
3	5-yearly herbicide use	10	tree density
4	annual herbicide use	12	profitability
		13	additional subsidies
		17	neighboring farmers' practices
		18	major income olive farming
		19	neighboring farmers 'information exchange
		20	public administrations
		27	lacking information about elimination of weeds
		28	lacking information about cross-compliance requirement
		29	lacking information about integrated farming requirements
		30	neighboring farmers' problems and solutions of soil erosion
		32	stronger competition on the market
		33	lacking integrated farming training
		35	number of requirements to gain subsidy
		43	soil erosion problems
		45	lacking technological access

Appendix G
Cover crop adoption rates put into perspective with other crops and regions in Spain

Table B: Adoption rates of cover crops and prune residues by PDO Estepa and other sectors and regions in Spain.

	Survey	*Survey*	*(Ministerio de Agricultura, 2019)*						
	PDO Estepa Olive (farmers)	PDO Estepa Olive (ha)*	Spain Olive (ha)	Spain citrus (ha)	Spain vineyard (ha)	Spain Stone fruit (ha)	Andalucia All sectors (ha)	Extremadura All sectors (ha)	Castilla-la-Mancha All sectors (ha)
Spontaneous cover	45%	40%	27.9%	30.7%	4.8%	46.5 %	43.7%	19.9%	4.5%
Prune residues	20%	20%	2.4%	10.7%	0.3%	0.8%	2.9%	0.9%	0.2%
Seeded cover	0%	0%	0.3%	0.1%	0.2%	0.6%	0.3%	0.8%	0.1%
No cover	35%	40%	69.4%	58.5%	94.7%	52.1 %	53.1%	78.4%	95.2%

** These values are calculated from the cover crop type data and the surface area data from the survey.*

Appendix H
New CAP reform and Eco-schemes

The Farm-to-Fork (F2F) strategy is presented by the European Commission in spring 2020 and reflects the new sustainable food policy which is at the hearth of the European Green Deal. The Green Deal is the new growth strategy for Europe beyond 2020 and discusses out Europe can become the first climate-neutral continent by 2050. The new CAP (2021-2027), which revise is delayed to the start 2022, reflects the ambitions of the Green Deal and the F2F strategy by focusing on sustainable-farming practices and shifting from compliance to performance. The latter is achieved by the new eco-schemes, which are voluntary sustainable-farming practices – focused on permanent grassland, crop diversification and ecological focus area – for which the farmer gains additional financial support as a reward (EuropeanCommission, 2019; EuropeanCommission, 2020).

The formulated measures under the new eco-schemes counteract air, water and soil pollution, biodiversity loss, climate change, food waste and natural resource use. Stopping soil degradation and controlling soil erosion are covered by sustainable natural resource use measures. As a general rule, bare soils avoidance, soil organic matter increase and soil disturbances reduction are needed to protect agricultural soils. Figure C shows the comparison of the CAP' current and proposed mandatory and voluntary requirements. The cross-compliance and greening rules are replaced by conditionality, which integrate Good Agricultural and Environmental Condition (GAEC) practices that limit soil erosion: GAEC 6) Reducing soil degradation risk by tillage management, including slope consideration, GAEC 7) No bare soil in autumn and winter periods, and GAEC 8) Crop rotation.

The AEMs under Pillar 2 are replaced by Eco-schemes (now part of Pillar 1) and environmental measures in Pillar 2 (see Table C). The eco-schemes' soil-erosion-control measures include organic farming, perennial cover in groves, use of catch crops, and zero-tillage. The CAP Pillar II also considers knowledge transfer and farm advisory (Commission, 2019).

Integrated and organic farming are also in the new CAP examples of possible eco-scheme interventions. The pitfall of integrated farming is that there are no defining EU wide or national regulations for these practices, therefore what farmers have to do in return for additional financial support stays vague. The measures considered in my study, as part of the current AEMs, are similarly formulated in the new eco-schemes (Lampkin et al., 2020). The comparisons are visualized in Table D.

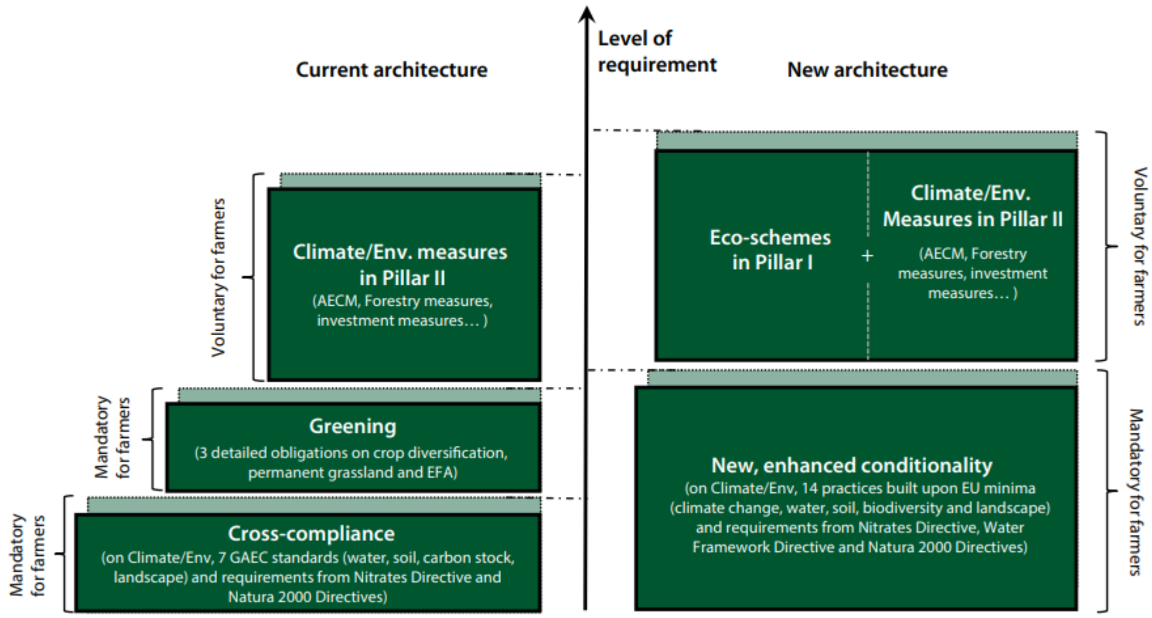


Figure C: Comparison of the current (2014-2020) and future CAP (2021-2027) (Lampkin et al., 2020)

Table C: Comparison of the eco-schemes and the environmental measures of the new CAP (Commission, 2019).

	Eco-schemes	**Agri-environment-climate commitments**
Source of funding	Pillar I budget – **without** co-financing by Member States	Pillar II budget – **with** co-financing by Member States
Possible beneficiaries	Farmers	Farmers, other land managers (e.g. environmental NGOs)
Payments' link to land	Payment per hectare Land concerned must be eligible for direct payments[6]	Payment per hectare Land concerned need not be eligible for direct payments
Obligatory/voluntary?	Member States must make provision for them Participation voluntary for farmers	Member States must make provision for them Participation voluntary for farmers and other potential beneficiaries
Nature of commitments	Annual (i.e. "one year at a time")	Multi-annual contracts (usually of 5-7 years)
Calculation of premia	Compensation for additional costs / income losses arising from commitments concerned, OR Additional payment to basic income support (no particular rules over premium level)	Compensation for additional costs / income losses arising from commitments concerned

Table D: The current AEMs considered in my study and the related proposed eco-schemes.

AEMs	Eco-schemes
Cover crop	Catch crops: a type of over crops that is seeded after harvest of the main crop (olives). Covered soil ensures less leaching of crop protection agents and nutrients and thus contributes to better water quality. The soil life is nourished and strengthened. It also contributes to the build-up of organic matter in the soil. Additional measure: use catch crop during the winter. The cover reduces erosion and provides shelter for various animals. This measure goes further than the regular sowing of a catch crop. The measure only applies if more than 60% of the company surface is covered on 15 January. Covering is valid by adoption of a visible crop or catch crop or spread of crop residues (e.g. prune residues). Additional measure: combination crops which make use of catch crops all year round. By using under-sowing of a catch crop in the main crop, the plot is immediately provided with a catch crop after the harvest. Nutrients will be retained better. The plot does not need to be worked after harvest.
Prevent gullies	Infiltration ditch: to ensures that rinsing water with residues of pesticides and nutrients is collected and absorbed into the soil by making a ditch following the contour lines of the slope.
5-year herbicide use/ Annual herbicide use	Incorporate catch crop to reduce herbicide use: The purpose of the measure is to prevent the use of plant protection products. The reduction of herbicides has a positive effect on soil life and reduces the emission of crop protection products to the environment.
Tillage and watery soil	Early harvest: Harvesting early (<November 1) reduces the risk of driving over the land during the wettest period of the year. The chance of structural deterioration is thus reduced, with the result that there is better rooting, moisture permeability improves, and the soil remains easier to work with.