DIVERFARMING

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

DEVELOPMENT OF A COMMON INTEGRATED RESEARCH METHODOLOGY AND PROTOCOL

Deliverable D8.1
Version 1.0
Issue date: 21/12/2018

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This project has received funding from the *European Union's Horizon 2020 Research and Innovation Programme* under grant agreement No 728003

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Document summary	
Document title	DEVELOPMENT OF A COMMON INTEGRATED RESEARCH METHODOLOGY AND PROTOCOL
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Lead beneficiary	Universidad Politécnica de Cartagena
Deliverable No.	D8.1
Work Package	WP8. Economic Assessment at farms and value chains
Dissemination type	Report
Dissemination level	Public
Deliverable due date	31/12/2018 (month 20)
Release date	21/12/2018
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Executive summary

The first DIVERFARMING objective is to develop and test different diversified cropping systems (rotations, multiple cropping and intercrops for food, feed and industrial products) under low-input practices to increase land productivity and crops quality, and reduce machinery, fertilisers, pesticides, energy and water demands. It means, in short, to reach a resilient and sustainable agriculture.

To make this goal effective in a long-term, a comparison between conventional (monocrop) and diversified cropping systems is needed. This comparison utilises data and results from the working packages and case studies of Diverfarming, as well as relevant previous studies on environmental and economic aspects. In this comparison framework, diverse cropping systems can be evaluated and differences to conventional cropping can be shown in detail, in a transparent way. This is crucial information for farmers and other stakeholders who consider diversified farming systems as potential improvements within each agroecosystem. Thus, a cost-benefit analysis is demanded.

Concerning economic aspects, task 8.1 aims to develop a generic common integrated research methodology and protocol, to be applied in evaluating benefits and costs of diversified cropping systems in each case study of Diverfarming. This protocol includes a set of essential guidelines for economic evaluation, such as how to derive and summarise main results from farm level economic analysis, value chain analysis and non-market cost-benefit study. The application of this methodology includes both production costs and benefits and cropping system specific positive and negative externalities and impacts.

In this context, this report developed by UPCT, Luke and UTu in WP8 aims to contribute in a common integrated research methodology and protocol development for financial and economic valuation. Every case study within Diverfarming project should be able to implement a financial assessment, and Finnish, Italian and Spanish case studies will add non-market valuation to develop a comprehensive economic assessment.

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1. Introduction

The main objective of this report is to complete 8.1.1 subtask, to develop ***a common integrated research methodology and protocol*** for calculating the costs and benefits of diversified cropping systems. This contributes in analysing economic rationale for shifting to diversified cropping systems, and in finding robust approaches to achieve long-term sustainability, accounting for sensitivity to future prices of inputs and outputs. Our leading question is: "***What do the specific diversified cropping systems contribute?***".

Economic assessment in WP8 integrates many economic and bio-physical aspects in the case studies, e.g. results produced in other WPs – just as farms and value chains have to do in real life, to produce products and value chain operations responding to market and societal demands. Thus WP8 has an important role, not least with respect to stakeholder interests and interaction, and policy development.

A common methodological framework provides guidelines to be applied in WP8 working closely linked to each case study: what kind of information is needed (e.g. first in farm level gross margin calculations, and later in value chain level), how that is to be used in economic assessment, and how different results of the economic analysis are brought together with environmental and societal benefits, identified in other WPs and key literature. Integrating different information and results would help to see the big picture of diversified cropping systems.

Comparisons between conventional and diversified cropping systems improve the knowledge of agroecosystem goods and services fluxes as well as the consequences of implementing distinct management practices within these ecosystems. Thus, more effective management and policy decisions could be made. This common protocol would integrate results from:

(a) stakeholder analysis

(b) farm level economic analysis

(c) value chain level economic and socioeconomic analysis

(d) available information on environmental impacts and field experimental data

(e) non-market benefit-costs identified - estimated using existing studies and results from our valuation efforts

This would allow a financial assessment from private economy point of view (a, b) which will be carried out within each case study or one case study per pedoclimatic region (c). In some cases, environmental effects could be given some estimated economic value. However, economic assessment (a, b, c, d, e) considering also non-market values will be carried out in detail only in Italian, Finnish and Spanish study cases. Subsequent comparisons between different crop diversifications would be possible due to the common methodology used, considering both market and non-market benefits, depending of the case study. Thus, we can eventually also compare "what do the diversified cropping systems contribute" within different case studies. Comparisons between different case studies in different countries are also interesting if similar or different patterns of the results or e.g. technical or policy challenges emerge.

Sustainable diversified cropping systems selected and specified within every case study are the basis of this integration. This selection was the main objective of WP2. Using this information, WP8 carries out an economic assessment at farms and value chains, and implements non-market valuation experiments. Farm level economic analysis is directly dependent on information about inputs and outputs at the field plot and farm levels. Therefore, differences between conventional and diversified cropping systems and how they contribute to farm economy will be made clear and transparent. Non-market valuation attempts to quantify various societal and other values of diversified cropping systems that are not directly involved in farm or value chain economic analysis. Financial, societal and ecological facts affecting market and human well-being should be eventually identified and considered in Diverfarming through a cost-benefit analysis. WP8 makes integration of information and analysis crucial to this aim. The results obtained by WP8 will be essential for WP9 which will address policies related to agriculture, agricultural value chain and rural development.

2. Case study description

Diversification strategies within Diverfarming case studies were analysed and selected in WP2. Both experts and additional stakeholders took part in decision making about agronomic and technical facts. Diversified cropping viability and potential value chain gains were also considered at case study selection.

Both Diverfarming diversified cropping systems and every case study description within this project can be consulted at Diverfarming deliverable D2.2. It is essential that economic analysis, especially at the farm level, follows closely the set up and analysis logic in each case study. Thus the case study descriptions and related data available are crucial information for WP8. It is essential that WP8 working is presented regularly to case study leaders and other project staff related to case studies to ensure correct understanding of the case study characteristics. It is also essential that case study leaders and other related project staff understand the results of WP8 and comment on possible inconsistency early on.

3. Farm level economic analysis

The main objective of farm level economic analysis is to study cropping systems efficiency, both within monocultures and diversified systems. This analysis includes farmers cost and benefits (e.g. harvest, fertilizers, pesticides, machinery, labour), changed use of inputs and gross margin (GM) if shifting to diversified cropping system.

If few or no existing data on the use of inputs per ha of individual crops on “typical” / “average” farms in the case study region, data gathering is crucial in farm level economic analysis. An essential tool in data gathering is the fulfilling of field data collection sheets. They might be useful in your case study. Both input and output values should be considered at this point.

WP8 developed a field data collection sheet where farmers and researchers contribute to data needs through filling in key information (figure 3.1). The whole field sheet is available among Diverfarming beneficiaries, and can be consulted at Diverfarming OneDrive WP8 folder. The sheets with collected data material can be stored in WP8 subfolders for each case study.

	Date	Plot Code	Crop	Operation	External Service	Hours	Machine	Tool/Equipment	Machinery Driver	Skilled work	Unskilled work	Water		Fertilizer		Pesticide		Seeds / Plants		Yield		
	[mm/dd/yy]	[text]	[name]	[name of operation]	[Yes/No]	[Timing for operation	[machine's name]	[name]	[hours]	[hours]	[hours]	[Name of pump]	[l]	[name]	[kg-lt]	[name]	[kg - lt]	[name]	[Kg or N. of plants]	[product]	unit (kg)	[Quantity]
1																						
2																						
3																						
4																						
5																						
6																						
7																						
8																						
9																						

***Figure 3.1**. Field data collection sheet fragment.*

After collecting data, before using it in the gross margin calculations, it may be necessary to arrange information according to a useful format for its management.Data sheets are organized by input categories, specific on:

- Plot archive
- Seeds pesticides fertilizer
- Labour costs
- Machineries
- Diary
- Subsides
- Revenue
- Resume

An extract fragment of this sheet is showed at Figure 3.2 as an example.

Insert the plot code Multiple crops can be identify with the same plot. In the case of intercropping to the same plot must correspond the crops concerned (two lines of registration). To standardize a plot code we suggest to use: the first 3 character to	*Insert the Name of the Crop; I.E. Durum Wheat In the case of intercropping to the same plot must correspond the crops concerned (two lines of registration). I .e. Line 1 Plot XY Crop*	*Insert the forecast production tipology (i.e. Grain, Straw)*	*Area of the whole crop; 1 hectare=10,000 square meter*	*Insert the answer chosen in between [Arable Crop/ Horticultural Crop/ Orchard]*	*Insert the answer chosen in between [Yes/No]*	*Insert the Variety/Cultivar Name; I.E. Marco Aurelio*	*Provide the name of previous crop*	*Provide the average number of plants per hectar (only for horticultural/perennial crop)*
Plot or Subplot Code	**Crop**	**Products / Output**	**Area**	**Category**	**Perennial**	**Variety**	**Previous Crop**	**Density**
[text]	*[text]*	*[text]*	*[hectares]*	*[text]*	-	*[text]*	*[text]*	*[plant/hectar]*

***Figure 3.2**. Data sheet fragment.*

It may be that the case study descriptions of crop management, i.e. the use of machinery or other inputs, do not match very well the typical farm practice in the region. In that case you may first still make the GM calculations based on the data material available from your case study. Then when diversifications costs and benefits are specified in alternative crop rotations / cropping systems, you may also consult farmers of your region, or agricultural extension, to use input use data close to the typical farm case in the region. Then you may have two versions of the GM calculations which may sound cumbersome but which in fact makes sense – you need to interpret your case study results for farmers in the region.

Nevertheless, it is important to understand how much input use and crop yields are different in diversified cropping system and why. The GM calculations should make this transparent. You may add comments to the excel sheet on this since we also need to report the GM calculations which in fact will serve as attachment on the report describing farm level net benefits of diversified cropping systems.

Each specific diversification by case study produces the data sheet for economic analysis. Moreover, non-market facts could also be taken into account at farm level economic analysis. Information about these items will be provided by WPs 3, 4 and 5, as will be shown later.

Farm level economic analysis is much based on **gross margin (GM) calculations** utilising crop specific input use, crop output and price data gathered, specific per crop and (conventional and diversified) cropping system. The GM, available at Diverfarming OneDrive WP 8 folder, are to be modified according to the crops and related inputs and outputs in each case study. Certain farming practices such as intercropping and specific fruit tree production practices with different kind of irrigation schemes require some modifications in the GM calculation sheets. Such case specific modifications are most likely needed and WELCOME, according to the inputs applied per each crop, or crops if several crops are grown as part of the same activity.

Nevertheless, it is useful to consider the following **3 levels** in farm level economic analysis:

- **Farm level**: Land use and production management at a farm. Crop diversifications and crop allocation at a farm level, over all field parcels. Total use of inputs.
- **Plot and sub-plot levels**: Crop choices per plot (field parcels) at different years and growing seasons – crop rotations, multiple cropping or intercropping schemes are in the core of cropping system diversification. Consult the case study specification on the use of inputs and crop yields - if there are data gaps utilize relevant data sources to the region. Data may be also recorded and updated during the project.
- **Crop level**: Use of inputs, crop yields (quantity and quality). Compare to other relevant data sources relevant to the region, if available.

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

(1) Describe what is the starting point / baseline / common practice – **what is to be diversified**. One may call this “farming system 0”. This may be a typical, somewhat monocultural farm management scheme of the case study region, possibly documented in some existing literature.
(2) Describe alternative, diversified farming systems – “diversified farming systems 1,2,3,..” etc. These may be linked to case study experiments, or typical diversified farming systems of the case study

region, possibly documented in some existing literature. If somewhat “new” in the case study region, explain why this kind of farming system is chosen and what is expected from it.

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

Gross margin calculations per crop are linked to case specific farming systems with certain crop rotations. These farming systems must be described e.g. based on material produced by case studies. Current dominant farming systems - which might be the ones that require diversification - provide an important benchmark and point of comparison, a “baseline” for more diversified farming systems with different crop rotations, use of inputs, crop yields and quality, and environmental effects.

Thus “filling in” the GM sheets must be done in close cooperation with the case studies. Depending on what factors of production are accounted for per crop one can differentiate **gross margin A** (only variable factors except labour considered as costs), **gross margin B** (variable factors and labour considered as costs) and **gross margin C** (all factors except land are considered as costs per crop). This kind of categorization improves comparability between the results of different case studies.

The following steps are recommended in practical working with the farm level economic analysis, and in the results reporting per case study:

1. Describe “farming system 0”, “farming system 1”, … “farming system N”, based on your case study plans: What are the typical / diversified crop rotations? Examples: crop sequencing such as barley-barley-barley-barley (in no-till); barley-winter rapeseed-wheat-barley-wheat (in conventional tillage); Organic barley-clovergrass-ley-vetch+oat. Conventional barley-ley-ley-barley (whole crop silage), etc.
2. Specify the needed use of inputs per crop in these diversifications, consistent to observed / farm specific / average crop yields of the case study region / farm. Write these input use specifications in the GM sheets, per crop. There might be more than one, alternative input use specifications per crop (e.g. conventional tillage /no-till / different yield levels).
   Specifically: How are the crop specific uses of inputs different in different “farming systems” and crop diversifications? Do diversified cropping systems decrease the use of fertilizers, crop protection, other inputs, compared to simple, often monocultural systems? Leys / oilseeds often leave some N in the soil, at least. If less crop protection, probably less labour and machine hours are needed. If crop yields in different rotations are supported by weak data / evidence, add this on the list of unclear issues, to be clarified with other WPs.
3. Make a list of identified gaps in the needed information – they might be possible to be found in other sources. List expected information from the case study experiments. Collect a list of unclear issues, to be discussed with the case study staff and related partners.
4. Sum input use and GMs over all crops separately within each crop rotation/ intercropping scheme in “farming system 0”, “farming system 1, ”... “, farming system N”. In terms of practical working it may be possible and easy to attach new crops and their input use information as new columns in the excel sheet representing each farming system, and then sum up the use and value of inputs as well as the GMs, within the farming system, taking into account the land use shares of the different crops in the rotation / intercropping. If there are many crops in farming system, use additional excel sheets to collect the key information in order to sum up GMs and input use information.
5. Compare GMs and the use and value of each input **between** the farming systems. Make summary tables showing the main differences. Write a report explaining the differences in GMs between the farming systems, make clear what are the most important drivers for differences and what are the uncertain points in the analysis.

4. Value chain level economic and socioeconomic analysis

We evaluate the increase of the economic value added in the most important value chains (VC) in a selected case study of each pedoclimatic region where a supply chain could play a central role in rewarding food or raw materials sustainability attributes. The analyses focuses on costs and value added related to cultivation, logistic and processing phases for the different chains involved (food, feed and industrial products).

Approaches and methods utilised in value chain will be specified in more detail, based on the characteristics of the case study value chains, closer to the start of the task 8.3 (month 30) and they will use WP6 available information. The main outline is given below.

Main crops and experimental design within each Diverfarming case study are available at deliverable D2.2, but it is only in task 6.1 outputs where main VC features will be defined. Thus, specific level of inquiry will be carried out at task 6.1.

As reported in deliverables D6.1 and D6.2, the mapping and the VC level economic and socioeconomic analysis will be developed for case studies where diversification practices applied contribute to:

i) relevant expected change in main product value and/or market share;

ii) new target markets or new way to sell “more sustainable” products;

iii) modification in bargaining power of suppliers and buyers.

The case studies developing a detailed value chain economic assessment under each pedoclimatic region are most likely the following:

- Southern Mediterranean (Spain)– case study 2 (citrus fruit);
- Northern Mediterranean (Italy)– case studies 5-7 (durum wheat);
- Pannonian (Hungary) – case study 10 (asparagus) / case study 11 (vineyard);
- Continental (Germany) – case study 9 (vineyard);
- Atlantic (the Netherlands) - case study 15 (diversified onion/lupine/peas/grain/carrots/pumpkins/redbeet)
- Boreal (Finland) – case study 12 (cereal monoculture vs barley/rapeseed/ryegrass) / case study 13 (organic cheese production with barley-ley-ley-barley).

It should be noted that some case studies are rather similar in terms of their set up (e.g. Italian case studies 5-7) and value chain economic analysis for one case study can be considered already well representative. In the case of Hungary and Finland there are two rather different case studies in both countries and it is meaningful to choose the one (or both) with most promising data and potential for increased value added.

Value chain level economic analysis utilises farm level analysis results of WP8. However, for estimating the increase of the economic value added in value chains, a gross margin data collection at farm level is not sufficient. WP8 value chain level economic analysis essentially interacts / is dependent on WP6 outcomes. Value chain level economic considerations may also be dependent on expert knowledge since little quantitative information may be available on new value chains / new variants of existing ones. Hence some part of analysis may be based on both qualitative and quantitative reasoning.

For example, in order to evaluate if there is a potential increase of market share, and thus an increase of production, a non-market evaluation and costs and benefits data collected from literature review and specifics surveys (Task 8.1.2) will be integrated to evaluate how credence attribute food values could be relevant in a new value chain configuration/design.

Value chain analysis provides a holistic and transparent view on the overall functioning of the value chain and identifies individual parts and processes most crucial in creating value added trough (cropping system) diversification. It is important to provide a comprehensive view on what creates economic value / consumer appreciation in a changed value chain based on diversified cropping system. The following core tasks / steps will be made more detailed and explicit based on case study / product characteristics:

First outline the main sources of changed costs and revenues due to reliance on more diversified and low input production systems. Specify and quantify (where possible), based on results collected in WP 6, 7 and 8, the following benefits: **reduced/changed use of inputs**, increased feasibility, quality and value for food processors and end-users, attainable increase in sales prices of the product, and reduced risks. An example of this could be summarised in these 4 main steps:

1. Estimate the increase of the economic value added in the most important value chains.
2. Evaluate, when feasible and relevant, if there is potential for increasing market share and thus increase of production in the optimised value chains.
3. Specify possible bottlenecks and retarding factors limiting shifts to improved operation of the value chain.
4. Outline specific recommendations for SMEs and large cooperatives.

5. Ecosystem Services Indicators

Related to market and non-market valuation, the Ecosystem Services (ES) approach is used. ES are the benefits which people derive from nature. There are different groups of ES, such as provisioning services (i.e. food, raw materials), regulating services (i.e. carbon sequestration, pollination) and cultural services (i.e. recreation, tourism). Additionally, it must be taken into account that biodiversity provides the habitat and support that is essential for ecosystems functioning.

Despite ES obvious importance, it is frequently ignored the value of natural goods and services, as well as their economic and social benefits within policy management of ecosystems, especially in agroecosystem. This failure is mainly caused because markets do not provide these goods or services, neither market prices reflect their value to society. Therefore, understanding the full economic value of Ecosystem Services could help policy decision makers regarding trade-offs that society must make.

Even though some ES, such as food or fodder provisioning, are part of real value market, other ES do not take part of market. Therefore, non-market valuation becomes necessary in ES valuation. Different methodologies have been used to accomplish an accurate ecosystems valuation. In that context, Stated Preference techniques proved to be a useful tool for environmental goods' valuation. Furthermore, comparing different management practices or policies is allowed when this methodology is implemented.

Diverfarming project compares both diversified and monocropping schemes. For these project case studies, stated-preferences method has been found as an adequate tool to estimate non-market ecosystem services. It must be taken into account that diversity within agricultural systems can exist in many forms and scales, which provides a large number of management alternatives for farmers. Diverfarming gazes at species diversification within fields, and also within crop, field and landscape diversification scales. Some study cases also consider temporally diversity, changing crop species (every one or part of them) during the trial period.

ES indicators simplify information about ecosystems functioning, therefore it can be easily understood and manageable. This fact is very relevant within nature systems, which usually are too complex to be analysed and managed directly by policy makers. Diverfarming project compares mono-cropping and diversified cropping (Table 5.1) from an interdisciplinary way.

__Table 5.1__. Differences between monoculture and diversified cropping systems

Monoculture	Diversified cropping systems
Efficient use of labour and machinery	Inefficient use of labour and machinery
Higher need for external inputs	Less need for external inputs
Low marketing and logistic costs	High marketing and logistic costs
Higher sensitivity to extreme events	Lower sensitivity to extreme events
Decreasing soil organic carbon (SOC)	Increasing / maintaining SOC
High greenhouse gas (GHG) emissions	Low GHG emissions
Soil degradation	Maintaining / improving soil quality

WP8 objective implies the use of a set of indicators that will show differences between these cropping practices. Therefore, a set of indicators is presented at this report. This set is as small as possible, but not smaller than necessary. Table 5.2 shows the selected ES indicators to be measured in Diverfarming that provide an important baseline information for non-market valuation. Information about which WP will measure each variable is also given.

__Table 5.2__. Set of indicators to be used for non-market valuation development.

Biodiversity or Ecosystem Service	Indicator	WP
Biodiversity quality	Plant species richness	4
Biodiversity quality	Earthworm species richness	4
Regulation – Erosion prevention	Runoff sediments	5
Regulation - Carbon sequestration, emission and storage	CO_2 footprint	5
Cultural – Aesthetic appreciation	Agricultural landscape valuation	8

Specifically, Diverfarming project is providing a set of ES indicators relevant to economic valuation (both market and non-market valuation). It is supposed to cover most relevant aspects in a comprehensive and compact way, always avoiding double counting. Three reasons determined the selection of these indicators: (1) both biodiversity and the three types of ES needed to be represented; (2) significant differences between the value of this indicators at monocrop and diverse cropping were expected; and (3) these indicators were selected from the set of mandatory variables to be measured within every study case. This fact allows the comparison between Finnish, Italian and Spanish non-market valuation results (Task 8.4).

At this point, it is important to distinguish “intermediate services” and “final ecosystem services”. Intermediate services concept is referred to the underlying ecosystem processes or, in other words, to the supporting services and those that enable final ecosystem services which are, on the other hand, the ES that are used directly by humans. This distinction is made to avoid potential double counting the value of some ES. Hence, ES as pollination or soil fertility are intermediate services, while food or fodder production are final services.

The ecosystem and biodiversity indicators description to be developed for valuation purposes within the Diverfarming framework is described below.

5.1 Plant species richness

WP4 will inform annually of the plant species richness. As only the number of different species, will be considered, not densities of species or individuals, Margalef index is the best option to consider within this biodiversity indicator. Unless this index is actually useful only if species are uniformly distributed, it is the only index found to be calculated with the available information about plan richness.

Marfalef diversity index is dimensionless, and it is calculated as follows:

$$d = (S - 1)/\ln N$$

Where, *S*= number of species

N= total number of individuals in the sample

If counting *N* was not a feasible option, number of species (*S*) would be used.

5.2 Earthworm species richness

The measures of earthworm species richness will be taken by WP4 at the end of third crop cycle (2020).

Shannon-Weaver diversity index is calculated as follows:

$$H' = -\sum_{i=1}^{S} p_i \log_2 p_i$$

Where, S = number of species

p_i = species *i* individuals proportion within the total (relative abundance, $\frac{n_i}{N}$)

n_i = number of individuals of species *i*

N = total number of individuals in the sample

Shannon-Weaver index value in most natural ecosystems figures between 0.5 and 5, whether its value is rarely lower than 2 or higher than 3. Commonly, agroecosystem Shannon-Weaver index value is lower than 2 in most taxa, which implies biodiversity poverty. Only rich ecosystems or biodiversity hot-spots, as tropical forests or coral reefs present a Shannon-Weaver index value over 3.

5.3 Runoff sediments

The measures of runoff sediments will be taken by WP5 after runoff events, if exist. This fact will provide information about soil erosion within the samples. The analytical method to obtain runoff sediments measures is through setting-up sediment traps.

It is expected to reach lower erosion rates within diversified systems where vegetation coverage has been increased. Intensified systems where tillage practices are more frequent are supposed to show higher erosion rates.

In this context, more frequent extreme storm and wind events are expected as a consequence of climate change. Therefore, the importance of figuring out the best options to reduce erosion rates gains importance.

5.4 Agricultural landscape valuation

Cultural services are often difficult to measure in agroecosystems due to they are rarely touristic or recreational places. Consequently, aesthetical value of agricultural landscape will be measured through an indicator. Some studies (i.e. Campbell, 2007; Dupras *et al*., 2017) stablish that elements as stone walls, or landscape heterogeneity increase willingness to pay (WTP) for maintaining or modifying agroecosystem landscape.

The selected methodology to obtain information about social preferences regarding to landscape valuation is Choice Experiment or contingent valuation. These landscape alternatives could include the presence of cultural elements, if exist, beyond representing different diversification options.

5.5 Carbon sequestration, emission and storage

Carbon sequestration, emission and storage will be valued through carbon balance, derived from carbon footprint. Carbon footprint represents the equivalent carbon (CO_{2eq}) emission of a complete production, processing and transport of a product. Nevertheless, for agricultural goods, this approach is not completely adequate due to only a part of carbon cycle is considered. Different greenhouse gases (GHGs) are captured and emitted by both soil community and agricultural vegetation. Therefore, it becomes necessary to consider these fluxes in the broad analysis. Consequently, carbon footprint approach is replaced by carbon balance.

For the study cases, carbon balance will be calculated through the next equation:

$$B_i = CS_i + SS_i - CE_i$$

Where, B_i = carbon balance in crop *i*

CS_i = carbon sequestration in crop *i*

SS_i = carbon soil storage in crop *i*

CE_i = carbon emission in crop *i*

According to the above, $B_i > 0$ crops will be net carbon sink systems. On the contrary, $B_i < 0$ crops will increase GHG ecosystem stock. The whole set of variables employed to calculate carbon balance will be explained in benefit-cost analysis paragraph.

6. Market and Non-Market Valuation

6.1 Ecosystem Services Valuation

As it is known, the main objective of WP8 is to provide an integrated view on the economic gains and costs with regard to the attainable improvements in sustainability. The economic value describes the change in human welfare generated by a product, and this is what WP8 will determine. This value is the economic gain resulting from the production and consumption of a product. In the case of some ES that are directly consumed as products (e.g. landscape) may be (non-market) by-products of (marker) products, production cost may not exist, therefore consumer surplus accounts of all economic value.

This economic value includes both market and non-market goods values. It must be taken into account that in some cases, non-market values may be even higher than market values. The conversion process from variation of ES indicators to economic value is shown in Figure 6.1.

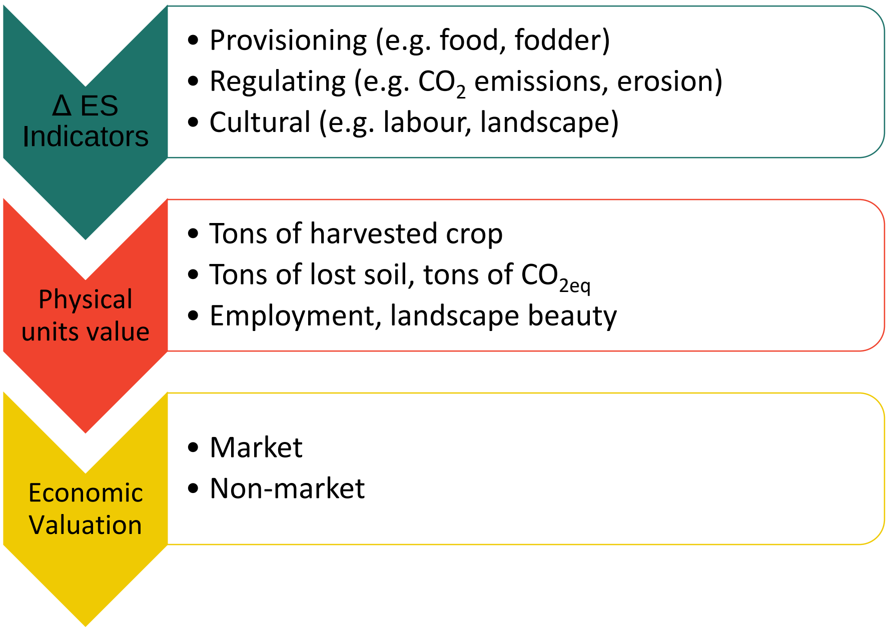


***Figure 6.1**. Scheme of economic valuation process.*

6.2 Market valuation

Market price based method will be used to value provisioning services. This ES, as food or fodder, will be valued through tracing monocrop and diversified samples. Both costs (irrigation water, fertilizers, pesticides, machinery, labour, etc.) and gains (product sales) will be measured by WP8 within every case study (Task 8.2).

According to farm level economic analysis, changes between conventional and diversified plots regarding economic indicators as well as environmental indicators will be known and assed. As it is mentioned before within this document, each case study diversification involves a set of modifications regarding to agroecosystem management. Market valuation is expected to include these differences within market goods.

Significant differences are expected to be found between monocrop and diverse cropping systems due to the distinct management practices. For example, fertilizers and pesticides costs will be - most likely - higher within monocrop systems. Machinery costs (e.g. vehicles, fuel) will be different too, as well as food sales value because of differences in harvested biomass and food quality between mono-cropping and diverse cropping systems.

6.3 Non – market valuation

As some ES do not take part in market activity and are considered as externalities, it becomes necessary to specifically value indicators related to these ES. This task will be carried out through non-market valuation, Task 8.1.2.

Non-market valuation supplies numerous benefits in economic valuation field. This valuation provides a common unit of measure (monetary) for the whole set of variables to be considered within an economic system. Therefore, valuation can be used in conjunction with benefit-cost analysis to obtain potentially helpful information for complex management decisions.

Assuming the existence of a link between quality or quantity of environmental resources and behaviour of people, non-market valuation is supposed to quantify costs or benefits of environmental changes in monetary terms. This technique can be applied for both users and non-users. Different types of methods may be necessary to use due to the complexity of some environmental goods and services.

For running non-market valuation, state preference methods are proposed. Within these methods, Choice experiment imply the performance of surveys whereby respondents determine their preferences through a series of choices between different alternatives (status quo included). Each analysed good is defined in terms of different levels of attributes.

This stated preferences technique pretends to value goods and services by creating a series of scenarios in which respondents (agents) make decisions about an objective. These decisions allow researchers to estimate both use and non-use value associated to the ES. Alternatively, contingent valuation can be used but this method would require the individual assessment of relative ES weights. Both methods use surveys to ask respondents about their willingness to pay or accept for changing from a given situation (status quo) to a different one. Therefore, alternative situations, or scenarios, should be properly identified and described prior to its valuation. Within Diverfarming project, these scenarios would be represented by diversification alternatives. However, for obtaining comparable results through choice experiment and contingent valuation, an extra question should be developed at contingent valuation surveys. The goal of this extra question is to associate relative weights to ES. This fact would allow a deduction of agroecosystem's benefits regarding to ES provision.

Both regulating and cultural services could be valued through Choice Experiment method. It allows simultaneous operation of multiple environmental attributes and their levels. Thereby environmental goods and services are found to be composite, that is they are made up of a variety of attributes that can take of different levels. This method enables the estimation of both use and non-use values.

Target population within economic valuation will be integrated by the set of stakeholders affected by each agroecosystem's ES provision. Therefore, a local or regional scale will be considered, although some ES such as CO_2eq emissions have global benefits. Public in general (consumers and other users, and also non-users would reveal their willingness to pay (WTP) for diverse cropping systems implementation. About payment vehicle, as increase in individual or familiar food expense is proposed. On the supply side, farmers could show through a different choice experiment, their willingness to accept a determined amount of money in exchange of adopting sustainable cropping practices.

Non-market valuation has been planned in Spanish, Italian and Finnish case studies. However, it has turned out that Spanish, Italian and Finnish case studies and their societal contexts are rather different. The resources available for non-market valuation, as well as the experience on valuation methods and their suitability, are also different in participating institutes. Thus the non-market valuation set-ups cannot be identical, nor the valuation methods. Harmonisation of the non-market valuations in a great extent would result in valuation studies that do not consider the relevant aspects in the case studies.

While contingent valuation method was considered most appropriate in the Finnish non-market valuation study, choice experiment methods was adopted in the Spanish study. Italian non-market valuation study is utilising existing consumer panels of partner companies participating in WP8. Nevertheless, the survey questions have been reviewed between country teams and several changes, where applicable, has been made to facilitate meaningful comparison of the results.

6.3 Cost-Benefit analysis

The assessment of the cost-benefit monocrop and diversified cropping systems will be based on cost-benefit analysis (CBA). This method has been widely used to make business and economic-based decisions when public goods are involved. In this case, monocropping and diversified cropping systems are the situations to be compared. This analysis will take into account market and non-market valuation, considering the costs associated with taking each action, its benefits and the value of intangible items (non-market valuation). Furthermore, shadow wage and opportunity costs will be considered within economic value calculation.

CBA process implies an initial compilation of all the costs and benefits associated with each cropping alternative. Costs should include direct and indirect costs, intangible costs, opportunity costs and the cost of potential environmental risks. Benefits should include all direct and indirect revenues and intangible benefits, such as increased production, increased sales from customer goodwill or increased landscape appreciation. A common unit of monetary measurement should then be applied to all items on the list. Finally, the resulting aggregation of cost and benefit values will be used to compare alternatives.

In general, CBA includes the following steps:

1. Define the **objective** of the policy measure. Within Diverfarming project, the achievement of a sustainable agroecosystem management could be determined as the main objective
2. Define the **baseline**, i.e. what would happen if no action is taken. This baseline is defined by the current management practices at each case study
3. Define the alternative **diversifications** at each case study
4. **Quantify** the investment costs for each option compared to the **baseline**
5. **Identify and quantify cash flows associated with both, monocropping and diversified cropping system**
6. Identify and **quantify** the positive and negative welfare effects for each **diversification** option compared to the baseline
7. **Value** the welfare **effects** in monetary terms, using market prices and non-market economic valuation methods (stated preferences methods)
8. Calculate the **present value** of costs and benefits occurring at different points in time using an appropriate discount rate
9. Calculate the **Net Present Value** (NPV), **Internal Rate of Return** (IRR) or Benefit-Cost (B-C) ratio of each alternative option
10. Perform **sensitivity analysis**. This step would be useful to check diversifications reliability
11. **Select the most efficient cropping diversified system**

Carrying out a CBA is a multi-disciplinary process, involving expertise from different fields and the input from policy and decision-makers. While economists are involved in all steps, environmental expertise of many kinds is also needed, especially in steps 2 and 5. Here, WP8 will require WP3, 4 and 5 advices.

Nevertheless, in all case studies in Diverfarming we cannot / it is not relevant to follow all steps above. First we simply bring together the main results per diversification option per case study. Already constructing tables on farm level economic results, value chain level results, non-market values (in case studies of Italy, Spain, Finland), expected / evidenced environmental gains, and possible other effects of diversified cropping systems, facilitates an important overview and comparison. The exact benefits and costs may not be easy to quantify in all cases and some qualitative results could be included as well. There could be societal and environmental effects that may be considered differently by different stakeholders.

Hence at this point it is encouraged that WP8 partners collect all the main results mentioned above in tables in order to facilitate a clear overview and comparison. List possible trade-offs and synergies between different effects. How exactly different effects of diversification should be valued and weighed at the regional and national scale is a topic to be discussed with stakeholders.

6.4 Results summary sheet

Setting a results summary sheet where every case study data is shown as an easy way to compare results between case studies. It would also allow a homogeneous data treatment within every subgroup within WP8. The whole data sheet can be consulted at Diverfarming OneDrive WP 8 folder, and it can be adapted by specific case studies.

An extract fragment of this sheet is showed at Figure 6.2 as an example.

				Plot code		
		Indicator	Unit	*[Insert code]*	*[Insert code]*	*[Insert code]*
MARKET VALUATION		Total Revenues	€/ha			
		Total Variable Cost	€/ha			
	Gross Margin Analysis	Gross Margin A (no own labour, no overheads, no capital depreciation)	€/ha			
		Gross Margin B (no overheads, no capital depreciation)	€/ha			
		Gross Margin C (no land costs)	€/ha			
		Net Profit (no taxes considered)	€/ha			
NON-MARKET VALUATION		Plant species richness	€/ha			
		Earthworm species richness	€/ha			
		CO_2 footprint	€/ha			
		Runoff sediments	€/ha			
		Agricultural landscape valuation	€/ha			
NET PRESENT VALUE (NPV)		Market benefits (only)	€/ha			
		Market and Non-market benefits	€/ha			
INTERNAL RATE OF RETURN (IRR)		Market benefits (only)	%			
		Market and Non-market benefits	%			
COST-BENEFIT RATIO		Market benefits (only)				
		Market and Non-market benefits				

Figure 6.2. *Summary sheet. Proposal.*

6.5 Example – Case Study 1 (Rainfed almond crop in Spain)

This section aims to illustrate the steps to be developed by case study.

Case study description

Almond is the current crop within this study case. Diversification crops are *Capparis spinosa* and *Thymus hyemalis*. *C. sipinosa* was selected as it is very adapted to arid climate and it provides a well valued fruit; *T. hyemalis* was selected because this species grows naturally in this area and it is possible to sell its essential oil as a product

Case study 1 holds three cropping systems (monoculture and two intercropped systems):

- Almond monocrop (MA)
- Diversification 1 (D1): almond intercropped with *Capparis spinosa* for food (April-September), during 2018, 2019 and 2020.
- Diversification 2 (D2): almond intercropped with *Thymus hyemalis* for essential oils (November-March) and food (April-June), during 2018, 2019, 2020.

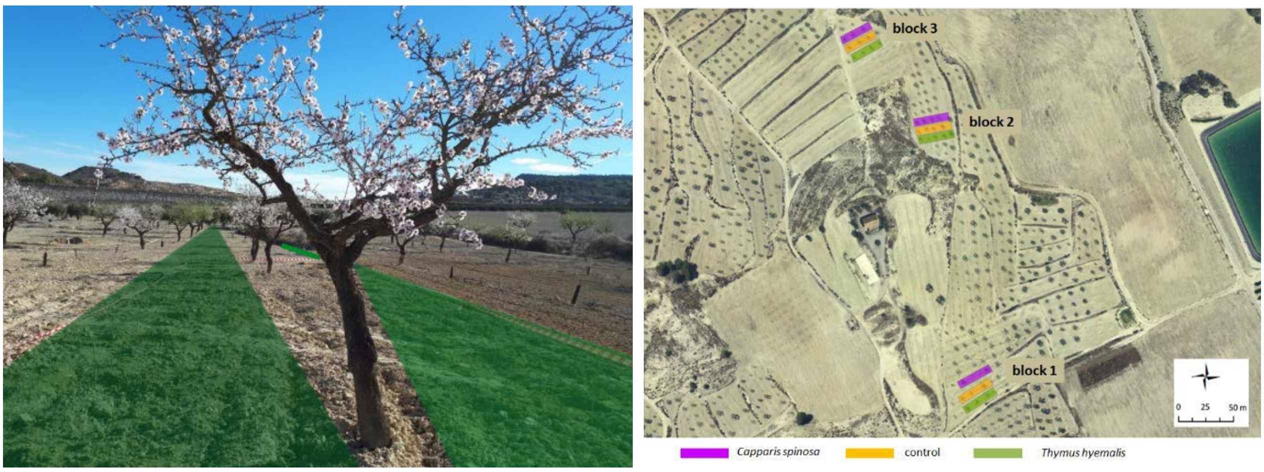


Figure *6.3 Case study 1 scheme.*

Farm level economic analysis

Cropping systems investments, cash in and cash out are estimated by using field data collection sheet showed at Figure 6.4. and 6.5., whose data come from the current crop of almond monocrop (MA). By the final of WP8, three-year data is expected to be available.

	Date	Plot Code	Crop	Operation	External Service	Hours	Machine	Tool/Equipment	Machinery Driver	Skilled work	Unskilled work	Water		Fertilizer	
	[mm/dd/yy]	*[text]*	*[name]*	*[name of operation]*	*[Yes/No]*	*[Timing for operation ending]*	*[machine's name]*	*[name]*	*[hours]*	*[hours]*	*[hours]*	*[Name of pump]*	*[h]*	*[name]*	*[kg-lt]*
1	20/01/2018	MA	ALMOND	Pruning	Yes	70									
2	15/03/2018	MA	ALMOND	Plowing	Yes	82									
3	01/04/2018	MA	ALMOND	Treatment	Yes	21								1-BB5 (SIPCAN	10
4		MA													
5	30/07/2018	MA	ALMOND	Harvest	No	48	New holland T4.95	Harvester	48	96					

Figure 6.4. *Input and output data. Case study 1. Fragment.*

Based on the data from the farm activity, the following gross margins estimation is developed for almond monocrops representing the status quo situation (Figure 6.5.).

				Plot code	
				MA	
REVENUES				Quantity	Value
Market Revenues				kg	€/ha
Almond	Main product	1.75	€/kg	207.32	362.18
Immediate costs			€/ha		
Gross ON-FARM PRICE (€/ha) , no costs subtracted			€/ha		362.18
Net ON-FARM PRICE (€/ha) , immediate costs subtracted			€/ha		362.18
Farm Subsides		190.00	€/ha		190.00
TOTAL REVENUES					
Gross Revenues	**€/ha**				**552.18**
Net Revenues, after immediate costs	**€/ha**				**552.18**
VARIABLE COSTS					
Total Seed cost			total seed	0.00	0.00
Total fertiliser cost			€/ha		0.94
Total substance cost of crop protection (herbicides, insecticides, fungicides...)			€/ha		8.31
Total variable irrigation costs			€/m^3		0.00
Purchased labour, with all labour costs for an employer		11.00	€/h	1.71	18.78
Other Miscellaneous variable costs (not own labour, capital costs)			€/ha		
Machinery Operations				h/ha	€/ha
Primary tillage		27.00	€/h	2.00	54.00
Secondary tillage			€/h		0.00
Fertiliser/insecticide application		35.00	€/h	0.51	17.93
Inter-row tillage			€/h		0.00
Crop protection			€/h		0.00
Planting			€/h		0.00
Misc operation			€/h		0.00
Misc operation, rented / contract machinery			€/h		0.00
Total machinery operations cost				**2.51**	**71.93**
Harvesting				h/ha	€/ha
Own harvesting (fuel, lubricants)		9.36	€/h	1.17	10.96
Contract harvesting (harvesting as a service) - THEN no capital / overhead costs of harvesting machines!			€/h	0.00	0.00
Total harvesting costs					**10.96**
TOTAL VARIABLE COSTS (€/ha)	**€/ha**				**110.92**
GROSS MARGIN A (no own labour, no overheads, no capital depreciation)	**€/ha**				**441.27**
				hours/ha	€/ha
LABOUR cost (Incl. All labour costs)		**7.50**	€/hour	**3.51**	**26.34**
*Assume own labour priced at the level of purchased professional labour	*Purchased labour should be given as "purchased labour" above				
GROSS MARGIN B (no overheads, no capital depreciation)			€/ha		**414.93**
Overhead, maintenance and depreciation related to machinery			€/hour	hours/ha	€/ha
Tractor			8.00	1.17	9.36
Harvesting machines			17.00	1.17	19.89
Other machines					0.00
Total machinery cost					**29.25**
Overhead, maintenance and depreciation related to buildings			€/unit	units/ha	€/ha
Plantation			72.60	1.00	72.60
Other					0.00
Total building cost					**72.60**
GROSS MARGIN C (no land costs)					**313.08**
LAND COSTS				units/ha	€/ha
Land rent					90.55
NET PROFIT (No taxes considered)					**222.53**

Figure 6.5. *Gross margin analysis. Case study 1.*

Value chain level

The current value chain within this case study includes three levels for almond: producer, wholesaler and supermarket. *Thymus sp*. and *Capparis sp*. are industrial products and its value chain is about to be defined.

Ecosystem Services Indicators

ES indicators should be standardized within every case study. Thus, case study 1 will use indicators determined previously at this report:

- **Biodiversity**

Whether one of this case study problems is low soil quality (low organic matter content and high erosion rates), it is expected for diversification practices to improve these lacks and consequently to be able to support a significantly higher earthworm species richness.

It is expected to find a higher earthworms diversity within diversified plots because two reasons: diversification implies no tillage practices, and also a more complex ecosystem structure. It means a richer nutrients balance and availability for biodiversity to develop.

- **CO_2 balance**

CO_{2eq} emissions in rainfed crops is mainly caused by field labours GHGs emissions. These emissions are expected to be higher within conventional almond cropping, as its management practices include reduced tillage, while diversification implies cero-tillage practices. Additionally, CO_2 absorption is expected to increase, mainly due to the plant coverage increase.

- **Erosion**

Erosion is one of the main environmental problems within this case study. Here it will be considered a basic characterization of erosion processes and rates, and also an event-based measures on interrill erosion, rill erosion, gully erosion and runoff generation. Rainfall simulation will be carried out only when no events.

It is expected to obtain lower erosion rates within diversified plots, as both diversification selected species (*Capparis spinosa* and *Thymus hyemalis*) are adequate for soil erosion control. Differences between these species erosion control lies in the fact they have different phenology. In that sense, *Capparis spinosa* experiments dormancy during autumn and winter. Therefore, if both species grow regularly, and rain events occur during plant lethargy period, especially if plants are pruned, it is expected to find higher erosion rates whithin *Capparis spinosa* plots than within *Thymus hyemalis*.

- **Cultural heritage**

A loss of traditional cropping practices has been caused by mono-cropping and cropping intensification. This loss is specially patent at some facts, such as soil conservation, which has become unsustainable in many places. In this frame, diversification allows a higher agricultural heritage maintenance.

- **Agricultural landscape**

Even though this area belongs to a private property with a restricted access and it is far from touristic destinations, it is necessary to value landscape. Thus, it will allow subsequent extrapolations within different locations.

Different agroecosystem management alternatives will be compared within different scenarios. Climatic characteristics will determine landscape at each case study, where diversifications can add significant differences within some cases; i.e. Spanish South-East is mainly covered by dry lands when rainfed crops are developed; therefore, the presence of diversified crops would reduce bare soil, which has a considerable landscape impact.

Non-market valuation

At this point, an assessment of the proposed methodology and choice experiment in case study 1 is developed within non-market valuation. As real data is not available in most subjects, quantities can be approached by using long term experimental plots.

After this, choice experiment levels and attributes and other considerations are presented:

- **Biodiversity**

Choice experiment will consider three levels within this attribute: low (*status quo*), medium and high. As first earthworm diversity data will be available through next autumn season, it is not possible to provide realistic diversity values within this report. This variable will be measured only at the beginning and at the end of experimental period. Therefore, this attribute levels within choice experiment will be estimated by experts from initial data or long-term case studies.

- **CO_2 balance**

Choice experiment will consider three different levels within this attribute: low (*status quo*), medium and high CO_2 net emissions. Concrete quantities will be included within choice experiment surveys when results are available.

- **Erosion**

The Soil and Water Conservation group at CEBAS-CSIC is researching erosion processes and rates in the area, not results per unit of time area available yet, but in similar lithologies with cereals soil losses are on average 0.40 ton ha^{-1} yr^{-1} (Almagro *et al*. 2016), with the diversified crop decrease of erosion rates of 25-30% at least are expected, based on former experiments of the group with other types of cover crops (long term experimental plots).

Choice experiment will consider three different levels within this attribute, considering previous results: 0.8 ton ha^{-1} $year^{-1}$ (high-*status quo*), 0.4 ton ha^{-1} $year^{-1}$ (medium-50 % erosion reduction) and 0.32 ton ha^{-1} $year^{-1}$ (low-60 % erosion reduction). As field data is not available for erosion rate yet, quantities might have been misestimate.

- **Cultural heritage**

Choice experiment will consider two levels within this attribute: low (*status quo*) and high. In this case, a significant loss of cultural heritage is related to mono-cropping practises caused by cropping intensification.

- **Agricultural landscape**

Choice experiment will consider two levels within this attribute: diversified and non-diversified agroecosystem. It is expected to find a higher valuation of diversified systems, as they provide more heterogeneous and colourful landscapes than monocrop systems.

***Figure 6.6.**. Case study 1 landscape alternatives: (A) monocrop; (B) almond – Thymus hyemalis diversification; (C) almond – Capparis spinosa diversification.*

According with the expected change in regulation and cultural services by diversified cropping systems, Table 6.1. describe attributes and levels to be valued in a hypothetical market.

***Table 6.1**. Attributes and levels of the choice experiment.*

Attribute	Levels	Description
Biodiversity	Low^{sq}; Medium; High	Nº of species identified within soil samples
Erosion	High^{sq}, medium, low	Soil lost due to erosion within total rainfed almond crop surface in Region of Murcia
CO_{2eq} balance	Low^{sq}, medium, high	CO_{2eq} sequestered annually by the crop
Cultural heritage	No^{sq}, Yes	Maintenance of traditional agricultural practices
Agricultural landscape	Monocrop^{sq}; Diversification	Perception of agricultural landscape beauty
Cost	0^{sq}, 10, 20, 30, 40, 50 €	Monthly increase in foodstuff expenditure per family (fruit consumption)

Thus, valuation scenario is aimed to show interviewees alternative farming practices which are environmental friendly and implies social benefits (regulating and cultural ES). However, this practices would be costly by the agricultural sector, which would fall on consumers partially, through an increase in retail prices. Moreover, interviewees would know the expected changes in physical terms by region or by unit of production. That is, what range of the services would be achieved due to diversification practices implementation, and the economic effects of such practices to the respondents.

Finally, some environmental and social benefits would be showed to the respondents to make them able to compare diversified and conventional cropping. Therefore, respondents would jointly evaluate decrease at environmental/social impacts and the increase within the foodstuff shopping expenditure.

In a tentative way, we can offer to the interviewee the possibility of buying beneficial environmental fruit (it implies a higher plant and animal biodiversity, lower erosion rates and lower CO_2 emissions) and more beautiful agricultural landscape. The acceptance of diversification practices would signify the assumption of an additional expenditure within the monthly expenditure for foodstuff. A choice-set with two alternative purchase with environmental and social gains is showed to the interviewee and he/she would decide if he/she is willing to generate it by assuming a specific additional cost. Also, the *status quo* option, with no environmental/social benefits provided and no additional cost can be chosen. An example of choice set is showed at Figure 6.7.

The following are proposed environmental/social gain in the region along with an increase in the monthly foodstuff cost. Which option do you prefer the most? Please consider your income before answering this question.

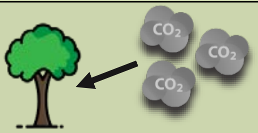
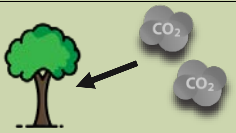
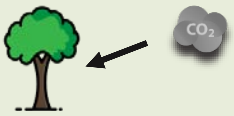
Scenario 1.1	Diversification A	Diversification B	Monocrop (SQ)
Biodiversity	 Low	 Medium	 Low
Erosion	 Medium	 High	 High
CO_2 balance	 High	 Medium	 Low
Cultural heritage	 High	 Low	 Low
Agricultural landscape			
Monthly cost	10 €	15 €	0 €
Choice	☐	☐	☐

***Figure 6.7**. Example of a choice set.*

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