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RE Restricted to a group specified by the consortium (including the Commission Services)	
CO Confidential, only for members of the consortium (including the Commission Services)	

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Glossary

AS	Advanced System
AGRIDEA	Swiss Association for the Development of Agriculture and Rural Areas
AGROS	Agroscope (ENDURE partner)
BS	Baseline System
CAF	Cooperative Advisory Group, the Netherlands
CH	Switzerland
DE	Germany
ENDURE	European Network for Durable Exploitation of crop protection strategies
ES	Spain
EUR	Euros (official currency of the European Union)
FR	France
JKI	Julius Kühn-Institut (ENDURE partner)
INRA	Institute National de la Recherche Agronomique (ENDURE partner)
IS	Innovative System
KOB	Kompetenzzentrum Obstbau-Bodensee (Research center for horticultural production in the Lake Constance region)
NL	The Netherlands
P	Price
UdL	Universitat de Lleida (ENDURE partner)
WUR-PPO	Applied Plant Research, Wageningen UR (ENDURE partner)
Y	Yield

Definitions

Average productive year: a typical year when the highest peak in terms of yield is achieved.
Cash flow: the movement of capital into (i.e. incomes) and out (i.e. expenditures) of the agri-business during the useful life of the orchard.
Direct costs: variable expenditures that change in proportion to the crop production.
Establishment costs: the sum of expenditures to start the agri-business.
Expenditures: the resources spent in assets (e.g. buildings, machinery) and in the functioning of the agri-business.
Income: the financial gain from carrying out an agri-business
Liquidity: the ability to cover crop production expenditures with the incomes generated with the agricultural activity performed in the orchard.
Pay-back period: the period of time required for the return of the investment on establishment of an apple orchard.
Returns: the income arising from fruit production.
Structural costs: fixed expenditures, whose values do not change in proportion to the crop production.
Subsidies: public payments that the growers may obtain and constitute an additional income.
Useful life of the orchard: the period of time between the planting of trees and their expiration, including periods during which the trees develop into maturity, complete their highest productivity and decline their efficiency.
Workload: the number of working hours required to complete an specific farm activity

Summary

In this title a “Current System” is meant; however, in the content of this Deliverable these type of systems are not taken into account. Instead of that, a “Baseline System” is assessed. The baseline corresponds to a theoretical system, in which crop protection exclusively depends on chemical protection. The reason for this lack of accuracy on the title is that in collaboration with researchers involved in RA3.1 and RA2.5, it was decided that a clear and unique system of reference should be defined in order to become able to perform economic evaluations of advanced and innovative orchard-systems in different regions with the same methodology. Therefore, the idea of having a current system and taking it as a reference was dismissed with the argument that in each region several systems should be considered as current systems. The regional description of the baseline systems was made in the orchard case study (RA2.5 purpose). The use of the same methodology was indispensable to complete the multi-criteria assessment of crop protection strategies (RA3.1 purpose). The title that we, researchers working in the RA3.2, proposed for this Deliverable was “Report on economic assessment of crop protection strategies” and not this one that was submitted to the European Commission.

This report on economic assessments of crop protection strategies in orchard systems represents one of the contributions of AGROS to attain the overall objectives of ENDURE of achieving sustainable use of pesticide and developing durable crop protection strategies. Furthermore, this investigation has been performed in line with the priorities of ENDURE, since the outputs produced resulted from cooperation between different activities and interaction among several partners.

The three specific objectives of this report are: 1) to provide economic calculations required for a holistic evaluation of the sustainability of crop protection strategies, 2) to examine the potential of innovative crop protection strategies that include the use of new technologies, and 3) to develop a coherent framework for the economic assessment of existing and innovative crop protection strategies.

The economic calculations included in this report are evaluations of four type of crop protection strategies designed by the ENDURE teams working in the orchard systems case study (Research Activity 2.5) and in the assessment of crop protection strategies based on multi-criteria methods (Research Activity 3.1).

In the design of these four types of crop protection strategies, existing and innovative farming systems are taken into account. The former are systems, in which biological technology and technical resources that are currently available may be implemented. Specifically, three schemes are defined, the baseline system which exclusively depends on chemical control, the advanced systems in which strategies of integrated pest management are partially as well as fully implemented, and the innovative system that includes modern, original and futuristic elements of crop protection.

The economic evaluations of these current, advanced and innovative systems were calculated for five European regions, for which the particularities and framework local conditions were carefully suggested by regional ENDURE partners. In particular, researchers associated to AGROS (Switzerland) and JKI (Germany) for the Lake Constance apple-growing region, and specialists in crop protection working in INRA (France), WUR/PPO (Holland) and UdL (Spain) for the apple-growing regions located in Rhone Valley, the Netherlands and Lerida respectively. Instead of a current system, a “Baseline System” is assessed. The baseline corresponds to a theoretical system, in which crop protection exclusively depends on chemical protection. The reason for this is that in collaboration with

researchers involved in RA3.1 and RA2.5, it was decided that a clear and unique system of reference should be defined in order to become able to perform economic evaluations of advanced and innovative orchard-systems in different regions with the same methodology. Therefore, the idea of having a current system and taking it as a reference was dismissed with the argument that in each region several systems should be considered as current systems. The regional description of the baseline systems was made in the orchard case study (RA2.5 purpose). The use of the same methodology was indispensable to complete the multi-criteria assessment of crop protection strategies (RA3.1 purpose).
The economic indicators employed in this economic assessment are grounded in valuations of incomes and expenditures related to orchard production and are used to evaluate the crop profitability, farm autonomy and productivity risk. For the estimation of the economic indicators, a managerial-economic software-tool was utilised, the ARBOKOST model, which was created in AGROS (Research Station Agroscope Changings-Wädenswil) and has been tested with data collected from large-scale monitoring studies in orchard production in Switzerland.

The methodology and the results presented in this report are useful to: 1) set a generic technique for the economic assessment of crop protection strategies, which can be adapted to specific regional conditions, 2) provide economic estimations for sustainability assessments of crop protection strategies (ex-post evaluations), which at the end allow elucidating the optimal conditions for the implementation of innovative and durable cropping systems, 3) to assess potentially innovative and futuristic methods of crop protection (ex-ante evaluations), which are needed towards identifying the most efficient elements of innovative crop protection systems.

Introduction

The economic dimension is a fundamental component of sustainable crop protection strategies. For instance, the European Parliament and the European Council state that in integrated pest management the levels of use of plant protection products and other forms of intervention to discourage the development of populations of harmful organisms should be ecologically and economically justified[1].

The indicators employed in this economic assessment are grounded on valuations of incomes and expenditures of crop growing and are used to evaluate the profitability, productivity, autonomy and stability of cropping systems. This report provides evaluations of baseline, advanced and innovative apple production systems, which have been designed for ENDURE researchers working in Orchard System Case Study (Research Activity RA2.5).

Our assessments of sustainability describe the economic performance of crop production systems according with their boundary conditions. These results are integrated with social and ecological evaluations with the tool DEXiOS, which has been adapted by ENDURE researchers working in the assessment of crop protection strategies based on multi-criteria methods (Research Activity RA3.1). At the end, the potential of appropriate crop protection strategies that are less reliant on the use of pesticides, minimise ecological risk for ecosystems, avoid adverse health effects on humans, and maintain or increase the income of farmers may be identified.

1. Economic assessment

In this section it is explained how the indicators for the assessment of crop profitability, farm autonomy and production risk are constructed, and how these indicators are explicitly applied in the evaluation of apple production systems, having as a reference the Swiss conditions and particularities.

1.1. Data required

1.1.1. Incomes

In this investigation two types of revenues are distinguished, market returns and direct payments.

1.1.1.1. Returns

Returns are calculated as the sum up of the products of crop yield obtained and the fruit prices.

In economic assessments of apple production in Switzerland, experts of AGROS at the Research Station Wädenswil have proposed a classification of apples, proportion of each of these fruit classes within the total yield, and their respective prices. In Table1, the calculation of the return in apple production is exemplified.

Four types of apples are considered: (1) class-1 (e.g. fruit of superior quality), (2) class-2 (e.g. fruit of good quality with slight defects), (3) industry-demanded fruit (e.g. for juice production), and (4) remaining-fruit (e.g. lost during the production process). The portion of class-1 fruits within the total yield represents the largest share (e.g. estimated by experts as target portion). The remaining percentage of the total yield is divided in class-2 fruit (50 % of

[1] Directive 2009/128/EC of 21 October 2009 establishing a framework for Community action to achieve the sustainable use of pesticides (Chapter 1, Article 3, Numeral 6), available in: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:309:0071:0086:EN:PDF

the remaining portion), industry-demanded fruit (33.3 % of the remaining portion), and lost fruit (16.7 % of the remaining portion). The price paid for fruits of class-2 is equivalent to a percentage (50 %) of the value paid for class-1 apples, which is known as the target price. The price paid for industry-demanded fruits corresponds also to a percentage (27 %) of the class-1 fruits' price.

Table 1. Returns in apple production

Fruit type	Yield	Share Yield	Price	Share price	Return
Class-1	Y_1	Target yield	P_1	Target price	$(Y_1 \times P_1)$
Class-2	Y_2	% (Total -Y_1)	P_2	% P_1	$(Y_2 \times P_2)$
Industry- demanded	Y_i	% (Total -Y_1)	P_i	% P_1	$(Y_i \times P_i)$
Lost	Y_l	% (Total -Y_1)	0	0	0
	Total			**Return**	**Σ (Y $\times$ P)**

1.1.1.2. Subsidies

At European level, financial supports may be given for specific crop production according to the farm acreage that could be cultivated and to environmental services rendered in the orchard.

In Switzerland, apple growers may obtain a monetary subvention, if they fulfil two requirements. One is that the agricultural activity performed in their orchards count with certifications on implementation of integrated fruit production (i.e. Suisse Garantie) and on ecological performance (i.e. ÖLN- Ökologischen Leistungsnachweis). The other is that the ecological compensation area must at least take up 3.5% of the extension of the orchard and at least 7% of the total farm. For the year 2009, the payments corresponded to 1040 Swiss Francs for each ha under fruit production. In addition farmers receive 620 Swiss Francs for growing a permanent crop and 1200 Swiss Francs as compensation for organic production[2].

In this study, subsidies for the establishment of an ecological compensation area within the orchard are taken into account. Specifically, for each 5% of the area of the orchard employed in such environmental service a financial support of 346.5 EUR is added.

1.1.2. Expenditures

In this investigation, expenditures in apple production are divided in direct costs and structural costs.

1.1.2.1. Direct costs

Direct costs include expenditures in fertilisers, pesticides or their equivalents, insurances, irrigation, contributions to agricultural funds or cooperatives, fruit packing and classification, orchard depreciation, and stationery store. In Table 2, the direct costs for apple production are specified.

Calculations of the **costs are based on expert's estimations and Swiss prices**, which are taken from the AGRIDEA price catalogue, edition 2009[3]. For the estimation of disease, insect, and weed control costs two assumptions are made: (1) the implementation of the

[2] Guidelines for the certification of ecological performance and the integrated production of fruits in Switzerland (subchapter 3.1.1, page 5), available in: http://www.lawa.lu.ch/oeln-suisse_garantie_richtlinie_2009_d.pdf (in German)

[3] The AGRIDEA price catalogue contains: (1) producer prices for different crops, (2) direct payments related to farm acreage, animal production, environmental services, rural support, (3) average farm costs of seed material, plants, fertilisers, pesticides, feed and other agricultural inputs, and (4) different costs such as hail insurance, drying operations, storage, soil analysis, laboratory analysis, transport, advisory services, extern labour, interests, etc.

whole range of non-chemical measures has a similar value as the costs of the treatment characterised by the maximum use of conventional pesticides in terms of kg of active ingredients per hectare[4], and (2) the hedonic price[5] of novelty products is approximated equal to an average value of treatments with chemical products and non-chemical measures.

Table 2. Direct costs in apple production

Main variable	Specific variable	Quantity	Cost
Fertilisation			Expert opinion
Crop protection	Disease control	Expert opinion	
	Insect control	Expert opinion	
	Weed control	Expert opinion	
Insurance	Hail-damage		2042 EUR/orchard
Irrigation	System		508.7 EUR/orchard
	Water		0.67 EUR/ m^3
Fund contribution	Class-1, Class-2		200 EUR/ha
	Industrial use		0.6 EUR/100 kg
Packing	Class-1, Class-2		1.3 EUR/kg
Classification	Class-1, Class-2		4.7 EUR/100 kg
	Wastage		8 EUR/100 kg
Orchard depreciation	Investment on establish/# productive years		Cash flow 3rd year /12
Stationery store			400 EUR/ha
Others			413 EUR/ha

For disease control average costs of five elements are assumed. These elements are: (1) use of conventional fungicides, (2) applications of sulphur compounds, (3) employment of copper products, (4) use of novelty fungicides (i.e. without non-target effects), and (5) implementation of non-chemical strategies such as sanitation, exclosure netting, rain shelter, resistant cultivars (single and multi genes), antagonistic micro organisms, and resistance inducers. Average values of these five methods are listed in Table 3.

Table 3. Disease control average costs

Element	Average value
Conventional fungicides	745.6 EUR/ha
Sulphur compounds	179.6 EUR/ha
Copper products	26.2 EUR/ha
Novelty fungicides	230.8 EUR/x 1 treatment
Non-chemical measures	72.2 EUR/x 1 measure

Similarly, average costs of five elements of control of insects are supposed. These elements are: (1) use of conventional insecticides, (2) applications of products used in organic production (i.e. chemicals non-synthetically derived) such as pheromones, granulose virus

[4] Evaluations of conventional, integrated and organic apple production systems have demonstrated that the crop protection costs may be economically comparable among the different schemes. In some cases higher labour costs under integrated production are equivalent with lower costs of pest management inputs (Treskic, 2007). In other cases the production costs are higher under integrated and organic production. However, only slight differences are observed, when comparing them with conventional production mainly due to premium prices (Glover et al., 2004; Van Lierde and Van den Bossche, 2004). Machinery and labour costs might also represent savings that make costs of organic and integrated farming comparable with those expenditures made under conventional production, a condition that may be verified when observing variable cost per hectare and per kg of fruit (Brzozowski, 2004).

[5] A hedonic price is an estimation of economic values for ecosystem or environmental services. It is associated to benefits or costs associated with environmental quality and amenities. The basic premise is that the price of a marketed good is related to its characteristics, or the services it provides. http://www.ecosystemvaluation.org/hedonic_pricing.htm

and bacillus thuringiensis, (3) employment of oil compounds, (4) use of novelty insecticides (i.e. without non-target effects), and (5) implementation of non-chemical strategies such as mating disruption, attract and kill, sanitary methods, mass-trapping, exclosure netting, nematodes, predators and parasitoids, resistant varieties and rootstocks, push and pull plants and cultivars, and warning systems. Table 4 includes the average costs of these five methods.

Table 4. Insect control average costs

Element	Average value
Conventional insecticides	600.5 EUR/ha
Organic insecticides	138 EUR/ha
Oil compounds	88.8 EUR/ha
Novelty insecticides	99.4 EUR/x 1 treatment
Non-chemical measures	16.6 EUR/x 1 measure

Likewise, for weed control the costs of three elements of control are presumed. These elements are: (1) use of conventional herbicides, (2) use of novelty herbicides (i.e. without non-target effects), and (3) implementation of non-chemical strategies such as cover crop from mid June to harvest with mowing, mechanical weeding, sandwich system, plastic cover (first three years), manual weeding. In weed control the percentage of the effective area under treatment should be also taken into account. Table 5 contains the average values of these three methods.

Table 5. Weed control average costs

Element	Average value
Conventional herbicides	583.9 EUR/ha
Novelty herbicides	219 EUR/x 1 treatment
Non-chemical measures	73 EUR/x 1 measure

1.1.2.2. Structural costs

Structural costs include values of buildings, machinery and hail nets, salaries for farm labours and harvesting, and capital interest. In Table 6, the structural costs for apple production are distinguished. In Table 7, the number of working hours required to complete each farm activity are listed.

Calculations of the **costs are based on expert's opinion and Swiss prices**, which are taken from the AGRIDEA price catalogue, edition 2009.

Working requirements based on Swiss conditions. It is assumed that 50% of the thinning and harvesting work is performed by non-family labour force.

Table 6. Structural costs in apple production

Main variable	Specific variable	Quantity	Cost /wage
Buildings			100 EUR
Machinery operation	Pesticides applications	Expert opinion	36.2 EUR/1 x spray
	Herbicide applications	Expert opinion	16 EUR/1 x spray
	Mechanical weeding	Expert opinion	10.5 EUR/1 x operation
	Harvesting	Target yield	7.5 EUR/1 bin (960 kg)
	Mulching	Expert opinion	42.6 EUR/1 x operation
	Sawing		52.5 EUR/1 x operation
Hail net	Operation	Expert opinion	260 EUR
Other	Small tools		200 EUR
	Lifting platform		13 EUR/1 x operation
Labour	Fertilisation		19.7 EUR/h
	Crop protection		19.7 EUR/h
	Plant breeding		19.7 EUR/h
	Mulching		19.7 EUR/h
	Thinning		16.8 EUR/h
	Hail net opening/closing		33.6 EUR/h
	Irrigation maintenance		19.7 EUR/h
	Irrigation operation		19.7 EUR/h
Harvest	Picking fruit		16.8 EUR/h (130 kg)
	Wastage		16.8 EUR/h (300 kg)
Management			23.3 EUR/h
Interest	Land		440 EUR
	Capital	Invested capital	2.4% cash flow 3rd year

Table 7. Workload for each farm activity

Main variable	Specific variable	Workload
Machinery operation	Pesticides applications	1 h/1 x spray
	Herbicide applications	1 h/1 x spray
	Mechanical weeding	1 h/1 x spray
	Harvesting	17 h/960 kg
	Mulching	1 h/1 x spray
	Sawing	2 h/1 x spray
Hail net	Operation	20 h
Labour	Fertilisation	2 h/1 x operation
	Crop protection	10 h (mice control) + decisions + training
	Prune (winter, summer)	100 h
	Mulching	1 h/1 x operation
	Thinning	100 h
	Hail net opening/closing	25 h
	Irrigation maintenance	10 h
	Irrigation operation	4 h
Harvest	Picking fruit	1 h / 130 kg (class-1 fruit + class-2 fruit)
	Wastage	1 h /300 kg (lost fuit)
Management		40 h

1.1.3. Particularities of perennial crops

1.1.3.1. Useful life of the orchard

In this study is assumed that the useful life of the orchard is of 15 years, in which five stages may be differentiated: (1) establishment of the orchard, (2) development of the trees into maturity, which occurs between the 1st and the 3rd year, (3) completion of highest productivity of trees, which occurs between the 4th and the 5th year, (4) performance of full productiveness of trees, which occurs between the 6th and the 10th year, and (5) declination on the efficiency of productivity of tress, which occurs between the 11th and the 15th year.

For this economic assessment three factors are fundamental: (1) the costs of orchard's establishment, (2) the period of investment, and (3) the period of full productivity.

1.1.3.2. Establishment costs

Establishment costs consist of investments on land preparation, planting, trees, and provision of facilities required to start the operation of an apple orchard such as irrigation systems and hail nets. In Table 8 the costs of establishing an apple orchard are listed.

Table 8. Establishment costs

Activity	Cost
Fencing, soil analysis, management, machinery, and others	19247 EUR/ha
Apple trees	5.7 EUR/tree
Installing a hail net	12995 EUR/ha
Installing an irrigation system with droppers	8250.7 EUR/ha
Installing an irrigation system with micro-sprinklers	10361.3 EUR/ha

Calculations of the **costs are based on expert's opinion and Swiss prices**, which are taken from the AGRIDEA price catalogue, edition 2009.

1.1.3.3. Period of investment

The period of investment includes the establishment of the orchard and the three first years of its useful life. At the end of this period, when the maturity of the trees is reached, is expected that the liquidity level of the apple production would be above 50%.

1.1.3.4. Full productive period

This economic assessment is thought to represent an evaluation of one average productive year, which occurs between the 6th and the 10th year when is expected that the orchard reach its maximum productivity in terms of apple yields (in t/ha).

1.2. Indicators proposed

Indicators provide evidences on information that is not easily accessible (Zahm et al., 2008) and help in guiding decisions (see Gras et al., 1998). In this investigation, crop profitability indicators are meant to evaluate the economic efficiency of the orchard systems in securing grower's incomes. Farm autonomy indicators are centred in analysing the grower's capacity to invest, as well as the economic viability of the orchard production. Production risk indicators are intended for making estimations of the potential costs (i.e. downside risk) that could be caused or the potential benefits (i.e. upside risk) that could be attained due to the variability on crop productivity and on fruit quality.

1.2.1. Crop profitability

1.2.1.1. Total revenue

Total revenue is equal to the gross income, which is the addition of all the returns (i.e. sum up of the products of yields and prices) and the subsidies.

Total revenue = returns + subsidies

$$\text{Returns} = (\text{Price}_{\text{class-1}} \times \text{Yield}_{\text{class-1}}) + (\text{Price}_{\text{class-2}} \times \text{Yield}_{\text{class-2}}) + (\text{Price}_{\text{industry-demanded fruit}} \times \text{Yield}_{\text{industry-demanded fruit}})$$

1.2.1.2. Net profit

Net profit is the difference between the total revenue and the total production costs. The direct costs plus the structural costs add up to total production costs.

Net profit = total revenue – total production costs

Total production costs = direct costs + structural costs

Direct costs = fertilisers + pesticides (or their equivalents) + irrigation water + contribution to grower's cooperative +orchard depreciation + stationery

Structural costs = buildings + operation of machinery + irrigation operations + interest on capital + labour costs

1.2.1.3. Total production cost per kg of class-1 fruit

Total production cost per kg of class-1 apple results of dividing the percentage of class-1 fruit production costs within the total production costs into the quantity of class-1 apples

Total production cost per kg of class-1 = (share within total production costs) $_{\text{class-1}}$ ÷ yield $_{\text{class-1}}$

Share within total production costs $_{\text{class-1}}$ = (return $_{\text{class-1}}$ ÷ return) × total production costs

produced.

1.2.1.4. Family income per hour

Family income per hour represents the gain attained per each hour of work provided with the internal labour force (i.e. not hired labour) in the apple production. Intern labour income is calculated as the difference between the total labour costs and the extern labour costs. According with expert's opinion, in apple production in Switzerland 50% of harvesting and thinning works, and 100% of the disposal of fruit lost are performed by external labour force.

Family income per hour = (net profit + family labour costs) ÷ internal workload

Family labour costs = total production costs – extern labour costs

Total production costs = Σ (# operations × workload × wage) $_{\text{farm activity}}$

Farm activities = fertilisation + crop protection (decision + training + control) + pruning + thinning +hail net (opening + closing)+ irrigation (checking + maintenance) + harvesting (picking + sorting + disposal of fruit lost) + management

External labour costs = Σ (# operations × workload × external labour wage × percentage of hired labour) $_{\text{farm activity}}$

Internal workload = total workload – external workload

Total workload = Σ (# operations × workload) $_{\text{farm activity}}$

External workload = Σ (# operations × workload × percentage of hired labour) $_{\text{farm activity}}$

1.2.2. Farm autonomy

1.2.2.1. Invested capital

The invested capital is equal to the cash flow at the end of the third year of the useful life of the orchard. Thus, invested capital include the establishment costs and the net profits of the first, second and third year, which are expected to be negative, since this period corresponds to the growing phase of the apple trees. The quotient of the invested capital and the number of productive years of the orchard (i.e. 12 years, between the 4th and the 15th year of the orchard's useful life) is equivalent to the depreciation of the orchard.

Invested capital = cash flow at the end of the 3rd year

Cash flow 3rd year = establishment costs + Σ (net profit) $_{1\text{-}3\ \text{year}}$

1.2.2.2. Return on investment

The return on investment is the monetary benefit obtained from the capital laid out in the orchard. The return on investment is the quotient of a division, in which the sum of the net profit and the interest on capital is the dividend, and the invested capital is the divisor. The interest on capital is the product of an interest rate (which in this study has a value of 2,4%) and the invested capital.

Return on investment = (net profit + interest on capital) ÷ invested capital

Interest on capital = interest rate × invested capital

1.2.3. Production risk

1.2.3.1. Risk related to income variability

The risk related to income variability is defined by the potential costs or benefits that the instability in crop production and in fruit quality may cause. Estimations of probable changes on the intern labour income, which is also known as family labour income, are used to quantify the upside-risk (i.e. failure to attain potential benefits) and downside-risk (i.e. potential cost incurred) effects generated by insecurity in attaining target yields and target shares of class-1 fruit in apple production. Risk estimations are corrected with the reciprocal factor of the variation of total return. The risk related to income variability refers to the changes in respect to the baseline system. A detailed explanation of the form how the risk related to income variability has been calculated is available in Appendix 1.

Downside risk = intern labour income
The target yield and the share of class-1 fruits are lower than expected

Upside risk = intern labour income
The target yield and the share of class-1 fruits are larger than expected

Intern labour income = labour income – external labour cost

1.2.3.2. Risk related to probability of dramatic yield loss

The probability of dramatic yield loss is an indicator of how likely it is that the crop productivity would be reduced in more than 50% with respect to the average expected or target yield.

Dramatic yield loss = (# times when crop yield < 50% average (or target) yield) $_{\text{in 10 years}}$

2. Material and methods

2.1. Orchard system case study

Experts for fruit growing, who are working in ENDURE within the RA2.5 (Orchard system case study) and RA3.1 (Multi-criteria assessment of crop protection strategies) have designed **four orchard systems**. The differences between these four systems lie in the use of pesticides and non-chemical alternatives, the time horizon, target variables and context parameters.

In addition, these experts have estimated context and target parameters including strategies for the control of diseases, insects and weeds for each orchard system in five regions. Regional context parameters are for instances site quality, orchard quality, infrastructure quality, decision support systems, and labour quality and training. Target parameters include yield, price, resistance management and the impact on beneficial organisms. In the design of crop protection strategies, the implementation of non-chemical methods, and an approximation of the use of conventional pesticides or novelty products are defined. Four systems

2.1.1.1. Baseline

The baseline system relies exclusively on chemical control and is characterised by an acceptable prevention of pesticide resistance problems and for having a high impact on beneficial organisms. In this system, the quality of the infrastructure for crop protection is acceptable, and non-chemical methods of control or resistant cultivars are not employed. Production of apples under this system, from which a good target yield with small variability is expected, may be currently implemented. The baseline corresponds to a theoretical system, in which crop protection exclusively depends on chemical protection. The reason for this is that in collaboration with researchers involved in RA3.1 and RA2.5, it was decided that a clear and unique system of reference should be defined in order to become able to perform economic evaluations of advanced and innovative orchard-systems in different regions with the same methodology. Therefore, the idea of having a current system and taking it as a reference was dismissed with the argument that in each region several systems should be considered as current systems. The regional description of the baseline systems was made in the orchard case study (RA2.5 purpose). The use of the same methodology was indispensable to complete the multi-criteria assessment of crop protection strategies (RA3.1 purpose).

2.1.1.2. Advanced-1

In the advanced some of the integrated pest management strategies that are currently available are put into operation. Therefore, the impact on beneficial organisms is low and the resistance management strategies are good. Good target yields with acceptable variability can be attained under this system, which is characterised by good quality conditions of the infrastructure used for crop protection.

2.1.1.3. Advanced-2

Through the full introduction of the improvements on integrated pest management that are available today, the advanced-2 system will reduce the variability in target yields and the impact on beneficial organisms with respect to the advanced-1 system, from acceptable to small and from low to very low respectively.

2.1.1.4. Innovative

The innovative system is a promising scheme, in which concepts and tools that are under development or will be available in the next years when the today's running research will be completed (e.g. obtaining pyramidised resistance genes, push and pull plants, multi genes resistant plants, automatic scouting) are taken into account. Under these conditions that today seem to be ideal, obtaining an excellent yield with small variability may be expected, as well as an excellent prevention of pesticide resistance problems.

2.1.2. Five regions

2.1.2.1. Switzerland, Lake Constance

Andreas Naef, an expert in crop protection working in AGROS has coordinated the definition of crop protection strategies and the estimation of target and contextual variables for the four orchard systems according with the conditions of the Lake Constance region in Switzerland with the collaboration of Patrik Mouron, Heiri Höhn, Jörg Samietz, Andrea Patocci, Esther Bravin and Michael Gölles.

2.1.2.2. Germany, Lake Constance

Burkhard Golla and Jörn Strassenmeyer who are experts in crop protection working in JKI have coordinated the definition of crop protection strategies and the estimation of target and contextual variables for the four orchard systems according with the conditions of the Lake Constance region in Germany with the collaboration of Christian Scheer and Martin Trautmann, both experts on crop protection working in the research center for horticultural production in Lake Constance (KOB).

2.1.2.3. France, Rhone Valley

Jean-François Toubon, an expert in crop protection working in INRA has coordinated the definition of crop protection strategies and the estimation of target and contextual variables for the four orchard systems according with the conditions of Rhone Valley region in France with the collaboration of Benoît Sauphanor, Claire Lavigne and Aude Alaphilippe.

2.1.2.4. The Netherlands

Bart Heijne, an expert in crop protection working in WUR-PPO has coordinated the definition of crop protection strategies and the estimation of target and contextual variables for the four orchard systems according with the conditions of the Netherlands with the collaboration of Peter Frans de Jong, Herman Helsen, Marcel Wenneker and Jan van Mourik , who works in the cooperative advisory group CAF.

2.1.2.5. Spain, Lerida

Joan Solé and Jesús Avilla who are experts in crop protection working in UdL have coordinated the definition of crop protection strategies and the estimation of target and contextual variables for the four orchard systems according with the conditions of Lerida in Spain.

2.2. Calculations

Farm full cost adds to the base tillage costs (i.e what the farmer paid cash to produce a good) all the expenses that yet affecting the overall outcome cannot be attributed to a single operation (i.e. common costs), and the annual share of previously paid costs designed to last for more than a single productive cycle (i.e. depreciation). That is all the expenses that the farmer's enterprises have to pay for the fruit growing activity (Marchesini et al., 2005).

Full cost calculations for the four orchard systems in the five regions were made with the ARBOKOST[6] model, a programme free of charge developed by experts of AGROS Research Station Changings-Wädenswil and values of contextual and target parameters estimated by experts in crop protection involved in ENDURE.

2.2.1. The ARBOKOST program

ARBOKOST is a managerial-economic software-tool designed for fruit growers and tested with data collected from large-scale monitoring studies in orchard production in Switzerland (Bravin et al., 2008). With ABOKOST full cost calculation per orchard plantation can be performed. Thus, estimations of cash flows, incomes, profitability and production costs may be obtained, when target variables such as price and yield are changed under pre-established contextual parameters.

2.2.2. Input data

Estimations of contextual and target parameters made by crop protection experts according to the particular conditions of each region were taken into account in the ARBOKOST calculations. These input data are detailed for each region and each orchard system in Appendix 2.

2.2.2.1. Context variables

The contextual parameters include eight variables: 1) crop density, which is expressed in number of trees per hectare, 2) costs of fertilisation, which are expressed in terms of Euros per hectare, 3) number of mulching operations required during one growing season, 4) percentages of ecological compensation areas per each hectare of the orchard, 5) portion of apple orchard area under hail net in the region. For ARBOKOST calculations is assumed that a hail net is incorporated, in the case that the estimation of the regional average is larger than or equal to 50%, 6) portion of apple orchard area irrigated in the region and the quantity of water (in m^3) that is used in one growing season. For ARBOKOST calculations is assumed that an irrigation system is employed, in the case that the estimation of the regional average is larger than or equal to 50%, 7) number of hours used in one growing season for crop protection decisions, including visual control and monitoring for each hectare of the orchard, and 8) number of days used in one growing season to participate in training and educational activities concerning with integrated pest management. For ARBOKOST calculations one day of training is equivalent to 8 working hours.

2.2.2.2. Target variables

The target parameters include three variables: 1) target yields in tonnes per hectare, 2) target portion of class-1 fruit. These values represent an estimation of the average quality of the fruit, and 3) target price in Euros per kg of fruit. These prices represent the average values of class-1 fruit in the market.

2.2.2.3. Disease control

The strategies proposed by experts on crop protection for the control of diseases define the quantities (in kg of product per hectare) of sulphur, copper and conventional fungicides applied, the number of applications with novelty fungicides and the quantity of non-chemical strategies implemented.

2.2.2.4. Insect control

For the control of arthropods in each system and region experts on crop protection made assumptions about the quantities (in kg of product per hectare) of oil derived products and

[6] ARBOKOST conditions and download (software available in German and French) http://www.agroscope.admin.ch/obstbau/00879/00882/index.html?lang=de

conventional insecticides applied, the number of applications with novelty insecticides and the quantity of non-chemical strategies implemented, and some estimations for the use of products used in organic production (e.g. pheromones, granulose virus, bacillus thurengiesis), which have been transformed in an average number of treatments with these type of products for practical reasons.

2.2.2.5. Weed control

Experts on crop protection also designed strategies for weed control in each system; for that they defined the quantities of conventional herbicides applied, the number of applications with novelty herbicides and the quantity of non-chemical strategies implemented. In addition, the percentages of area under weed control (i.e. portion of the orchard in which weed control activities are conducted) in each region were approximated.

2.2.2.6. Production variability

In order to estimate the risk in productivity variations two target parameters were assumed, the target yield and the fruit quality which is represented by the portion of class-1 fruit. These variations have been considered to fluctuate between acceptable and small levels.

3. Full cost calculations

ARBOKOST calculations[7] were performed to estimate the eight economic indicators for the four systems. The results for the Swiss region (in Table 9), the German region (in Table 10), the French region (in Table 11), the Dutch region (in Table 12), and the Spanish region (in Table 13) are presented in this chapter. The economic indicators are presented in relative terms comparing changes of Advanced-1, Advanced-2, and Innovative Systems against the Baseline System, which obviously corresponds to the 100%.

Table 9. Economic indicators obtained for Switzerland, Lake Constance region

		System			
Indicator	**Unit**	Baseline	Advanced1	Advanced2	Innovative
Crop profitability					
Total revenue	EUR/ha	100	101.8	101.8	142.2
Net profit	EUR/ha	100	57.1	58.4	174.6
Production cost of class1	EUR/kg	100	109.6	108.4	85.5
Family income per hour	EUR/ha/h	100	52.6	53.9	212.9
Farm Autonomy					
Invested capital	EUR/ha	100	125.7	125.5	124.5
Return on investment	%	100	79.8	81.0	217.8
Production risk					
Related to family income	baseline=100%	100	100.0	150.0	103.3
Ramatic yield loss	% in 10 years	100	100.0	150.0	50.0

Table 10. Economic indicators obtained for Germany, Lake Constance region

		System			
Indicator	**Unit**	Baseline	Advanced1	Advanced2	Innovative
Crop profitability					
Total revenue	EUR/ha	100	101.9	103.8	134.1
Net profit	EUR/ha	100	100.4	67.6	134.2
Production cost of class1	EUR/kg	100	100.0	111.1	87.5
Family income per hour	EUR/ha/h	100	110.7	-45.6	378.9
Farm Autonomy					

[7] Latest update 14.06.2010, results available upon request jose.hernandez@art.admin.ch

Invested capital	EUR/ha	100	99.5	126.8	124.1
Return on investment	%	100	99.9	94.3	159.3
Production risk					
Related to family income	baseline=100%	100	140.2	100.0	90.1
Dramatic yield loss	% in 10 years	100	150.0	100.0	50.0

Table 11. Economic indicators obtained for France, Rhone Valley region

		System			
Indicator	**Unit**	Baseline	Advanced1	Advanced2	Innovative
Crop profitability					
Total revenue	EUR/ha	100	98.3	96.3	96.3
Net profit	EUR/ha	100	95.9	95.8	96.7
Production cost of class1	EUR/kg	100	104.9	109.9	109.9
Family income per hour	EUR/ha/h	100	90.4	85.3	108.6
Farm Autonomy					
Invested capital	EUR/ha	100	102.2	102.8	119.0
Return on investment	%	100	97.8	116.2	115.5
Production risk					
Related to family income	baseline=100%	100	147.0	101.9	101.9
Dramatic yield loss	% in 10 years	100	100.0	100.0	50.0

Table 12. Economic indicators obtained for the Netherlands

		System			
Indicator	**Unit**	Baseline	Advanced1	Advanced2	Innovative
Crop profitability					
Total revenue	EUR/ha	100	126.4	127.9	137.3
Net profit	EUR/ha	100	163.4	152.7	171.6
Production cost of class1	EUR/kg	100	85.7	89.3	85.7
Family income per hour	EUR/ha/h	100	257.4	240.5	278.9
Farm Autonomy					
Invested capital	EUR/ha	100	97.7	98.7	97.9
Return on investment	%	100	184.7	170.7	196.3
Production risk					
Related to family income	baseline=100%	100	133.2	133.2	105.1
Dramatic yield loss	% in 10 years	100	200.0	200.0	100.0

Table 13. Economic indicators obtained for Spain, Lerida region

		System			
Indicator	**Unit**	Baseline	Advanced1	Advanced2	Innovative
Crop profitability					
Total revenue	EUR/ha	100	102.3	103.6	111.9
Net profit	EUR/ha	100	121.3	129.3	124.2
Production cost of class1	EUR/kg	100	89.7	87.2	91.0
Family income per hour	EUR/ha/h	100	52.1	26.6	23.7
Farm Autonomy					
Invested capital	EUR/ha	100	96.5	94.4	109.9
Return on investment	%	100	121.1	128.7	135.5
Production risk					
Related to family income	baseline=100%	100	101.1	101.1	68.0

Dramatic yield loss	% in 10 years	100	50.0	50.0	50.0

4. Economic evaluation and analysis

In this section, the tendency of each indicator is described by comparing each system against the baseline one. It means, differences between advanced-1, advanced-2 and innovative systems respect to the baseline system are highlighted. In other words, the baseline system is taken as a reference. Moreover, explanatory reasons for performances of each variable are elucidated. It is important to note that the results obtained for the Swiss region are taken as the reference.

4.1. Crop profit

4.1.1. Total revenue

The estimations of the total revenue (in EUR/ha) for each system in the five regions are depicted in Figure 1. In the case of the Switzerland, in the transition from the Baseline to the Advanced-1 or to the Advanced-2 System a slight increase is denoted as a result of the higher payments obtained for environmental services (ecological compensation area is augmented from 10% to 15% of the orchard); although target variables remain unchanged. The progression to the Innovative System is characterised by a significant increment resulting from simultaneously rise in yield and fruit quality (from 35 t/ha to 45 t/ha, and from 75% share of 1st class fruit to 85%).

In the German region a similar tendency is observable as in Swiss region. In the Dutch the increases are mainly due to augments in the target yields and in the fruit quality. In the Spanish region the uninterrupted increase follows improvements in the portion of class-1 fruit. In the case of the French region the reductions are due first to a reduction in the fruit quality and later to decreases in the target yield. The larger changes in Switzerland are explained by stronger variations in target yield combined with the highest target price.

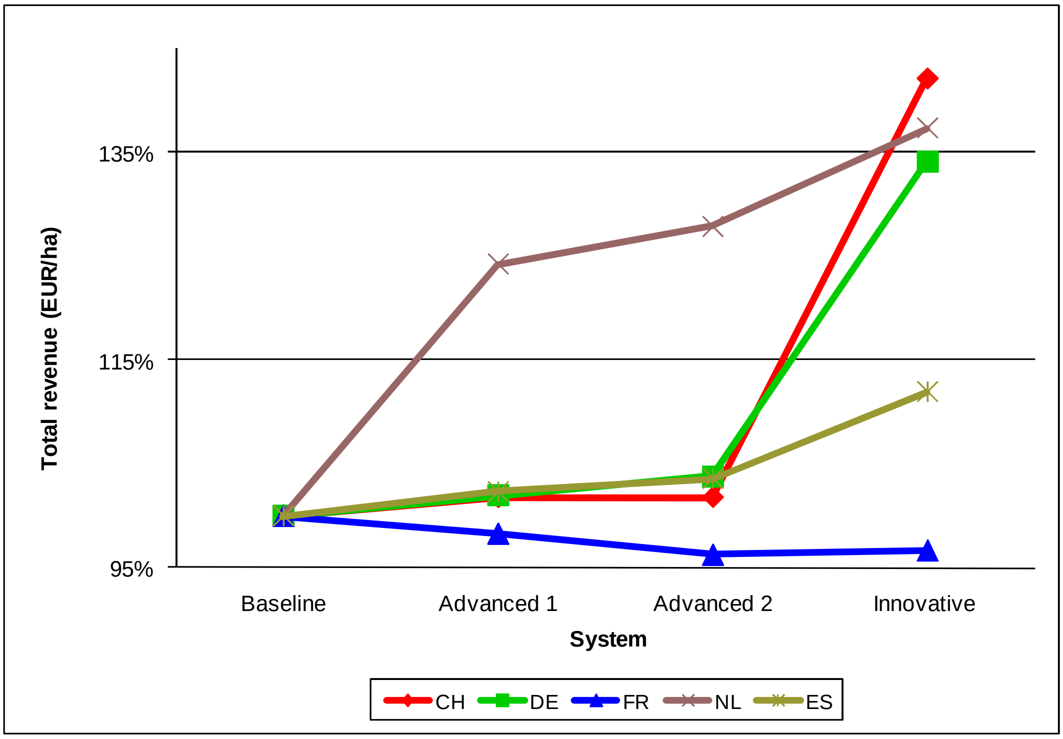


Figure 1. Total revenue for four orchard systems in five regions

4.1.2. Net profit

Figure 2 illustrates the net profit assessment (in EUR/ha) for each system in the five regions. In the Lake Constance region in Switzerland, two changes are remarkable. The strong reduction in the Advanced-1 System, which is a consequence of the higher investment incurred in the establishment of the orchard; specifically, the installation of the hail net. This explanation is also valid for changes in the German region for the case of the Advanced-2 System, and for the Spanish region in the case of the Innovative System. However, the softer effect in the Spanish region is because the higher costs in the installation of the hail net are compensated with saves achieved in irrigation costs. In the case of the French region, although a hail net is also taken into account in the Advanced-2 System, the augment in the investment of the orchard (and its subsequently effect in the depreciation of the orchard) is practically compensated with reductions in the functioning costs of the orchard (i.e. structural and direct costs). The reason behind the lower augment in the Advanced-2 System than in the Advanced-1 System that is observable in the Dutch region is associated to the increment in both direct and structural costs. Direct costs are higher under the Advanced-2 System because the value of the non-chemical methods applied or the methods of crop protection equivalent to the pesticides that are used are higher. Structural costs augment due to higher costs in machinery, labour and harvest labours.

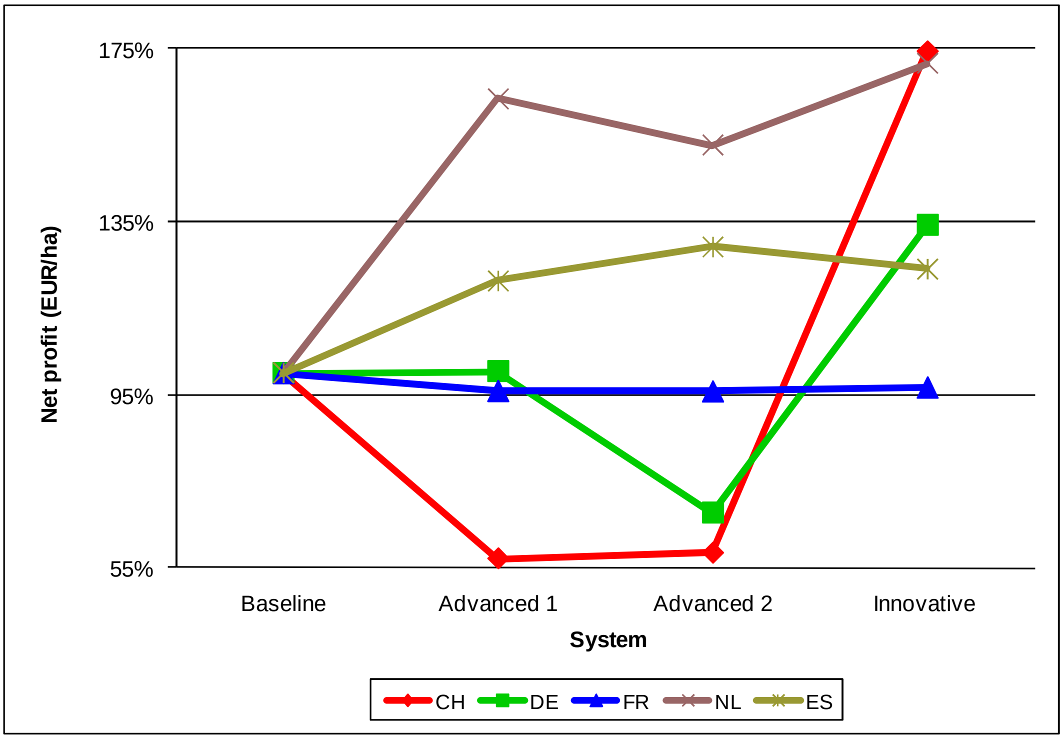


Figure 2. Net profit in five regions for four orchard systems

4.1.3. Total production cost per kg class-1 fruit

In Figure 3, the estimations of the total production costs per kg of fruit class-1 obtained (in EUR/kg) for each system in the different regions are represented. For all regions, excepting the French one, the tendency is depicted in the Figure 3 is exactly contrary as the forms illustrated in Figure 2. It means that the following contextual factors matter: (1) establishment costs, which are affected by the cost associated with the installation of a hail net (effects of higher establishment costs are observable as higher depreciation of the orchard and higher interest on capital), (2) labour cost, (3) differences between costs of pesticides and the value of their equivalents (i.e. non-chemical mechanisms and innovative products), (4) machinery costs, (5) harvesting labours, and (6) contributions to cooperatives and producers' organisations. In the French region, the increment in this indicator is a direct consequence of the reduction in the quality of the fruit produced for the Advanced-1 System, and the lower productivity (i.e. lower yield) in the Advanced-2 and the Innovative System. In the Spanish region the reduction of the quantity of water required for irrigation (in about 50%) is the reason behind the decrease in the total production costs per kg of fruit class-1 obtained.

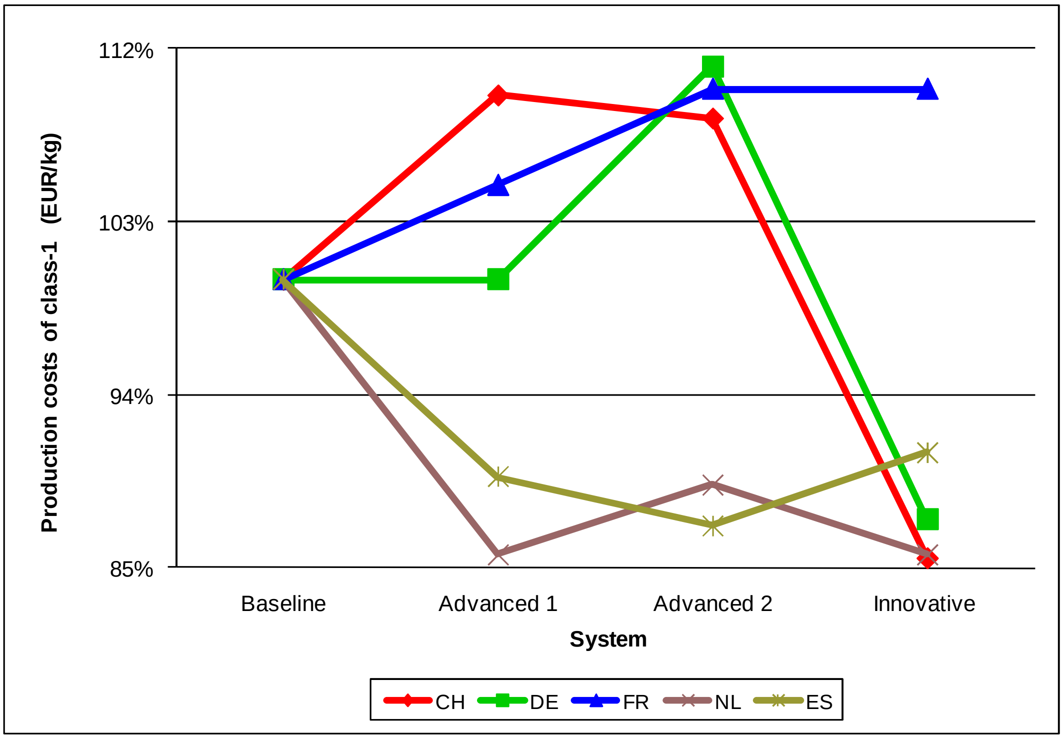


Figure 3. Production costs of apple class-1 produced in five regions for four orchard systems

4.1.4. Family income per hour

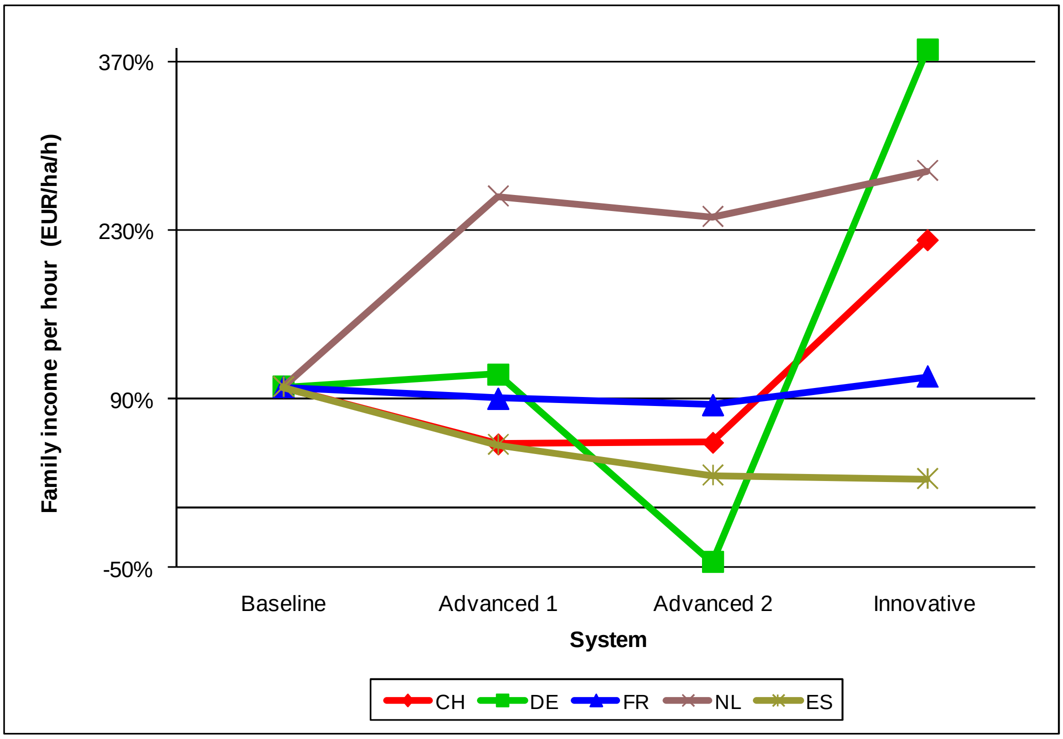


Figure 4. Family income per hour in five regions for four orchard systems

Estimations of the family income per hour (in EUR/ha/h) for each system in the five regions are illustrated in Figure 4. In Figure 4 alike forms are drawn as in Figure 2. Therefore, the explanatory reasons following the Figure 2 are confirmed. However, the Spanish region constitute an exemption in Figure 4. Three factors are significant in the case of Lerida. First, more fruit of better quality is produced. Second, the increment in establishment costs (i.e. installation of hail net) is compensated with lower functioning costs (i.e. irrigation requirements). Third, the augments in machinery and labour costs that are incurred when using non-chemical strategies of crop protection do not exceed (are even lower than) the costs of pesticides.

4.2. Farm autonomy

4.2.1. Invested capital

In Figure 5 estimations of the invested capital (in EUR/ha) for each system in the five regions are shown. The invested capital is strongly influenced by expenditures in installation of infrastructure; more precisely hail nets and irrigation systems. Contrarily, mulching requirements (i.e. machinery and labour) and time dedicated to crop protection (i.e. training and decision-making) cause minor modifications in the invested capital. The cash flow in the three first years is also influenced in a low level (as the productivity in this period is very low) by changes in yields, and portion of class-1 fruit.

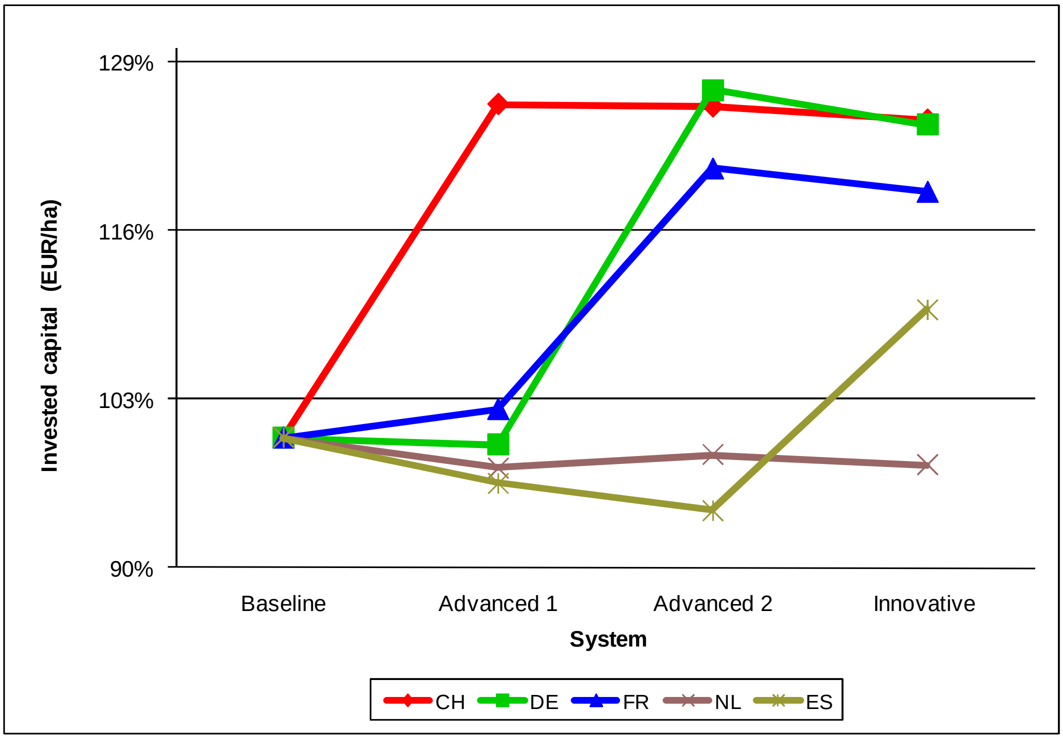


Figure 5. Invested capital in five regions for four orchard systems

The introduction of a hail net coincides with the highest increase in invested capital (i.e. in the Advanced-1 System for the Swiss region, in the Advanced-2 System in the French and the German regions, and in the Innovative System in the Spanish region). In the Spanish region the reduction in the amount of water used in irrigation has a stronger effect in reduction of investment costs that the increase of costs associated with crop protection labours has.

The slight reductions in invested capital that are observable in the Swiss region in the Innovative System (when compared with the Advanced-2 System) are mainly due to higher liquidity caused by higher yield and fruit quality, while lower machinery and labour costs related to mulching activities and lower labour costs associated with crop protection labours have a minor effect. Such effect of a higher liquidity ratio on lower invested capital is also observable in the Dutch region in the Advanced-1 System.

Under apparent similar conditions, changes in the invested capital are produced by increases or decreases in labour requirements, which are a normal consequence when employing non-chemical methods of control instead of conventional pesticides. The challenge of novelty strategies of control is precisely to ensure effective solutions with at least equivalent costs. Increases of labour requirements in terms of expenditures occur in the French region and in the Dutch region in the Advanced-1 System and in the Advanced-2 System, respectively. A contrary situation occurs also in the French region, this time in the Innovative System.

4.2.2. Return on investment

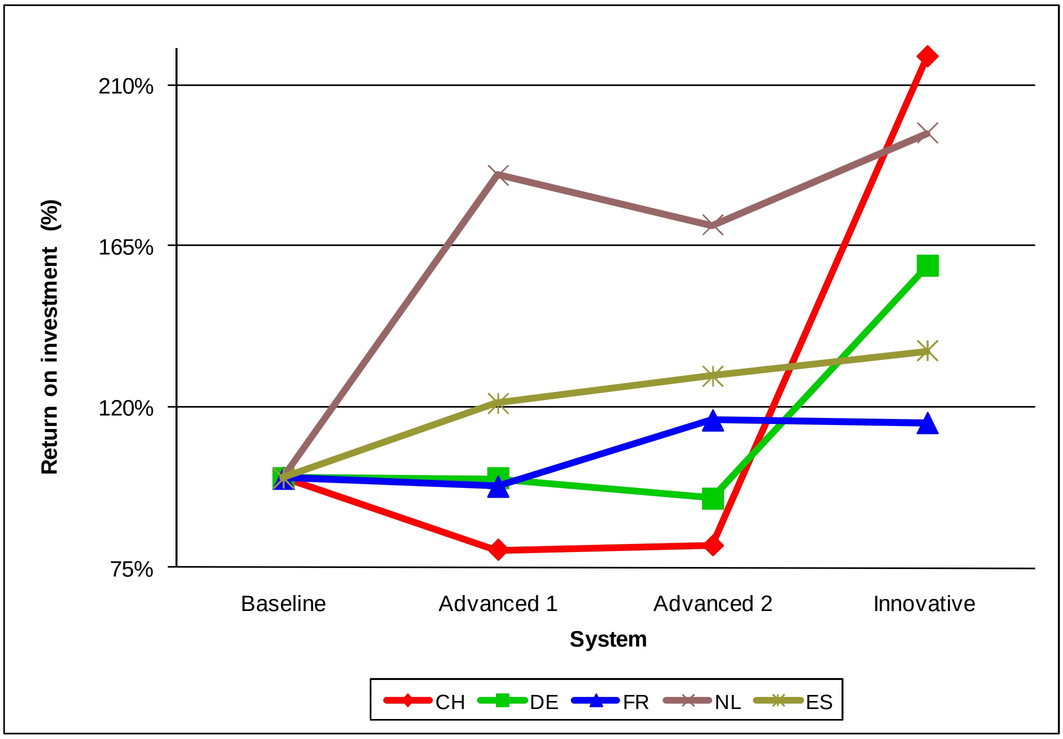


Figure 6. Return on investment in five regions for four orchard systems

The estimations of the return of investment (in %) for each system in the five regions are depicted in Figure 6. Recognising that for each region (excepting the French one) the tendencies, as well as their positions have an identical behaviour as in Figure 2; it is taken for granted that the explanatory reasons are the same that these described before: portions of class-1 fruit and target yields. In the French region, higher rates of return in the Advanced-2 and the Innovative Systems results from higher investments under unaffected net profit. It is equivalent to say that for each Euro invested the possibility to lose capital is reduced. This case of the Rhone Valley region demonstrates that it is worthy to reduce productivity (i.e. yield), always when the quality is increased (i.e. portion of class-1 fruit) and the costs are reduced (i.e. lower costs of machinery and labour as well as equivalency between value of non-chemical strategies and innovative products with conventional pesticides).

4.3. Production risk

4.3.1. Risk related to family income variability

In Figure 7, effects generated by the potential variation in yield and fruit quality on farmer's income are illustrated. The income of apple growers is represented by the family labour income (expressed in EUR/ha). And the assessment of the risk is related to the variability of family labour income for the production of apples under the baseline system.

Figure 7 reflects the opinion of experts on crop protection (who estimated the contextual and target parameters for the different orchard systems) in each region. For these experts the probability of incurring in additional costs or unsuccessfully attaining extra benefits is exactly the same for crop productions carried out under the Baseline and the Innovative System with the exception of the production in Lerida, where the variability of yield is expected to be reduced. In the case of Advanced Systems (1 and 2) there is not a consensus. Either the Advanced-1 System (e.g. in France and Germany) or the Advanced-2 System (in Switzerland) is pointed as having more uncertainty in the production in terms of both yield and fruit quality. In the Netherlands, only the variability of the yield is pointed out as the risky factor; therefore the uncertainty is lower even when the price is the highest. In the German and in the Spanish region the reduction in the risk related to family labour income variability that observable in the Innovative System is boosted by the high levels of the portion of class-1 fruit.

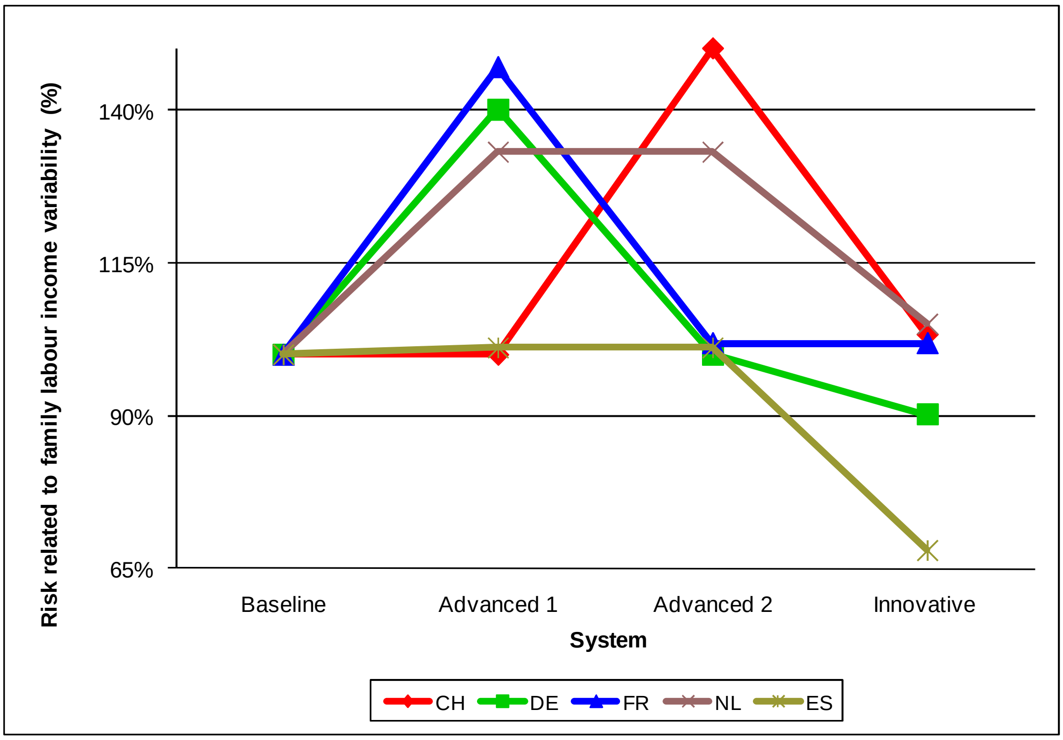


Figure 7. Risk related to family income in five regions for four orchard systems

4.3.2. Probability of dramatic yield loss in 10 years

In Figure 8, estimations of the potential variation of yields in the long run are depicted. This variability, which is expressed in terms of %, is an indicator for how possible is that a very extreme (i.e. more than 50%) reduction in crop productivity comes about in a period of ten years. In all the five regions, experts on crop protection coincide in allocating the lowest risk to the Innovative System. However, differences are noted in the distribution of yield losses among the other three orchard systems.

For the Swiss apple productions under the Baseline and the Advanced-1 Systems enclose a similar risk that is higher that the uncertainty faced under the Innovative System, but the risk under the Advanced-2 System is even higher. The risk of dramatic yield loss in the French region is equal for apple production under the Baseline, Advanced-1 and Advanced-2 Systems. In the Spanish region the highest risk is associated with the baseline system, for all the other three systems the probability of dramatic yield loss is reduced. In the Dutch region the risk is associated to the implementation of strategies of integrated crop protection; that is, the Advanced-1 and the Advanced-2 systems. In the German region, a partial implementation of the strategies of integrated crop production that are available is pointed out as the most risky situation.

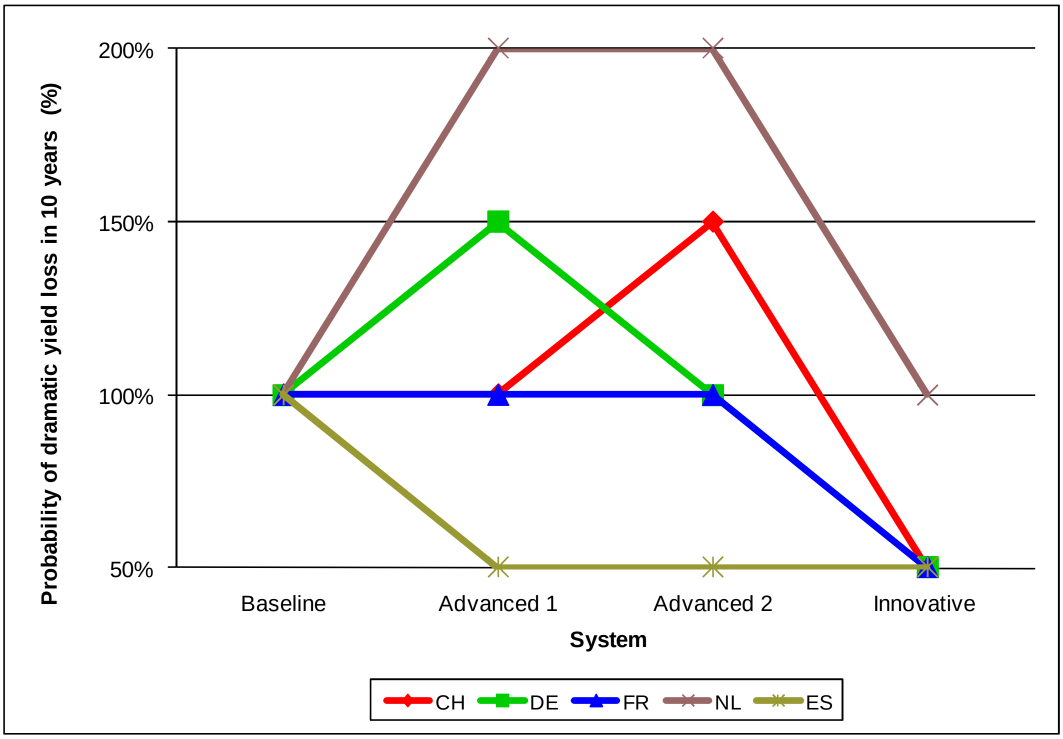


Figure 8. Dramatic yield loss in five regions for four orchard systems

Conclusions and recommendations

From the analysis of the eight indicators proposed to evaluate the economic sustainability of the four orchard systems it can be concluded that the target parameters crop yield and fruit quality own the explanatory power when clarifying the reasons behind the different tendencies obtained. Thus, it can be asserted that growers should opt for these strategies of production that allows them securing high yields and improving fruit quality in order to enhance the economic productivity and to acquire higher autonomy in terms of returns on investment.

The invested capital is linked to the contextual parameters; irrigation requirements and the necessity to install a hail net depend on the climatic conditions, which determine the potential occurrence of pest and diseases. Based on this conclusion, it can be asserted that the design and implementation of crop protection strategies would be successful only when these strategies are adjusted to the regional condition. In other words, it is absurd to conclude that one region is better than others only based on lower investment costs. The goal of the research should focus on the improvement of profitability by providing elements that are applicable in particular contexts and not to pretend to find out a perfect system that should be implemented everywhere.

The stability of the production constitutes a key credible element when introducing a new system of production. Expert's opinions pointed that those techniques of crop protection that are under development (i.e. the Innovative System) are promising in guaranteeing this condition of stability in a comparable (or even better) level as the chemical control does. Under the Advanced-1 and Advanced-2 System higher stability of production can be obtained when very high levels of fruit quality (i.e. portion of class-1 fruit) are produced; an issue that is demonstrated in this investigation. In other words, productions with high-fruit quality are an effective tactic to decrease the potential of variability in incomes.

So far, conclusions related to the analysis of crop profitability, farm autonomy and production risk have been included. However, it is also important to comment about the composition of the cost of production and their variation when evolving from chemical based systems to full implementation of strategies of integrated control. The composition of production costs depends on three factors, the local context, the productivity, and the strategies of crop protection.

As before mentioned, local context is related to investments; at the end it generates changes in depreciation of the orchard and interests on capital. The productivity affects the harvesting costs. Crop protection strategies define the value of pesticide products or their equivalents, labour and machinery costs. These findings do not differ from results of previous studies about the economics of crop protection. However, the added value of this investigation is that the importance of ex-ante analysis is demonstrated. In this research was observed that the transition from the Baseline System (i.e. based on chemical control) to the Innovative System (i.e. based on integrated control) is worthy, because profitability is increased, rates of return are enhanced and risks related to variability of incomes are decreased. Intermediate stages (i.e. Advanced-1 and Advanced-2 Systems) are competitive only in the case that crop yields and fruit quality are increased (e.g. the Netherlands). Although, in these systems machinery costs are reduced, higher structural and direct costs may be incurred because expenditures in pesticides or their equivalents may increase, as well as the demand for labour (e.g. training in integrated crop protection and time invested in decision-making on fields including monitoring and visual control). This situation becomes in a bottleneck in the implementation of integrated crop protection strategies and therefore, research on crop protection aimed at overtaking this situation is required.

Literature

Bravin, E., Weible, F., Hofmann, D.M., and Kockerols, K.(2008). Arbokost: A managerial-economical software-tool for organic apple production. Publications ACW 8605. Agroscope Changings-Wädenswil Research Station ACW.

Brzozowski, P. (2004). Comparation of apple production costs between conventional, integrated and organic farming. *Journal of Fruit and Ornamental Plant Research* **12**: Special edition 2004.

Gras, R., Benoit, M., Deffontaines, J.P., Duru, M., Lafarge, M., Langlet, A., and Osty, P.L. (1989). *Le Fait Technique en Agronomie – Activité Agricole, Concepts et Méthodes d'Etude*, INRA (ed.) L'Harmattan: Paris. In : Zahm, F., Viaux, P., Vilain, L., Girardin, P. and Mouchet, C. (2008). Assessing Farm Sustainability with the IDEA Method – from the Concept of Agriculture Sustainability to Case Studies on Farms. *International Journal of Sustainable Development and World Ecology* **16**: 217-281.

Glover, J., Hinman, H., Reganold, J. and Andrews, P. (2002). A Cost of Production Analysis of Convenional vs. Integrated vs. Organic apple production Systems. Wash. State Univ. Res. Bull XB1041. Pullman: WA.

Marchesini, S., Hasimu, H. and Canavari, M (2005). Production cost of pears and apples in Xinjiang (China). Working paper DEIAgraWP-05-003. Dipartimento di Economia e Ingegneria Agrarie, Università di Bologna: Bologna.
http://ageconsearch.umn.edu/bitstream/14861/1/wp050003.pdf

Treskic, S. (2007). Apples – conventional, IPM and organic. Pesticides News 76. Pesticide Action Network UK: London.
http://www.pan-uk.org/pestnews/Issue/pn76/pn76%20p18-21.pdf

Van Lierde, D. and A. Van den Bossche (2004). Economical and environmental aspects of integrated fruit production in Belgium. ISHS Acta Horticulturae 638: XXVI International Horticultural Congress: Sustainability of Horticultural Systems in the 21st Century.

Zahm, F., Viaux, P., Vilain, L., Girardin, P. and Mouchet, C. (2008). Assessing Farm Sustainability with the IDEA Method – from the Concept of Agriculture Sustainability to Case Studies on Farms. *International Journal of Sustainable Development and World Ecology* **16**: 217-281.

Appendixes

Appendix 1. Calculation of risk related to family labour income variability

Risk estimation and correction			System			
	Name	Units	Baseline **(BS)**	Advanced **(AS)**	Innovative1 **(IS1)**	Innovative2 **(IS2)**
Family labour income	**FI**	EUR/ha	Arbokost	Arbokost	Arbokost	Arbokost
Upside variation	**U**	EUR/ha	↑Y, ↑S	↑Y, ↑S	↑Y, ↑S	↑Y, ↑S
Downside variation	**D**	EUR/ha	↓Y, ↓S	↓Y, ↓S	↓Y, ↓S	↓Y, ↓S
Potential variation	**VI**	EUR/ha	BS (U – D)	AS (U – D)	IS1 (U – D)	IS2 (U – D)
Risk related to variation (baseline 100%)		%	BS (VI) / BS(VI)	AS (VI) / BS(VI)	IS1 (VI) / BS(VI)	IS2 (VI) / BS(VI)
Total return	**TR**	EUR/ha	Arbokost	Arbokost	Arbokost	Arbokost
Variation in total return (baseline 100%)	**VR**	%	BS (TR) / BS(TR)	AS (TR) / BS(TR)	IS1 (TR) / BS(TR)	IS2 (TR) / BS(TR)
Correction factor	**CF**		1 / BS (VR)	1 / AS (VR)	1 / IS1 (VR)	1 / IS2 (VR)
Corrected risk estimation		**%**	**Risk x CF**	**Risk x CF**	**Risk x CF**	**Risk x CF**

Detailed procedure:

Estimation of risk related to variability of family labour input (FI)

1. The FI is calculated with ARBOKOST for each orchard systems.
2. The upside variation (U) of FI is calculated for each system. For that in ARBOKOST the larger than expected values of target yield (Y) and target portion of class-1 fruit (S) are taken into account for the full cost calculations.
3. The downside variation (D) of FI is calculated for each system. For that in ARBOKOST lower than expected values of Y and S are considered for the full cost calculations.
4. The potential variation in FI is calculated for each system as the difference of U and D.
5. Taking the baseline system (BS) as a reference, risks related to potential variations of FI are compared among systems.

Correction of the risk estimation with the reciprocal variation of total revenues[8]

6. The total return (TR) is calculated with ARBOKOST for each orchard system.
7. Taking the BS as a reference, variation in TR for each system is calculated.
8. In each system, the reciprocal coefficient of the variation in TR is taken as the correction factor (CF).
9. The risk estimation related to the variability of FI is multiplied by the CF for each system.

[8] To avoid distortion caused for significant differences in absolute values (e.g. a 10% change in 45 t/ha would have a larger effect than 10% change in 25 t/ha). Total revenue has been chosen because is an economic indicator calculated with target prices, yields and quality (i.e. share of ckass-1 fruit).

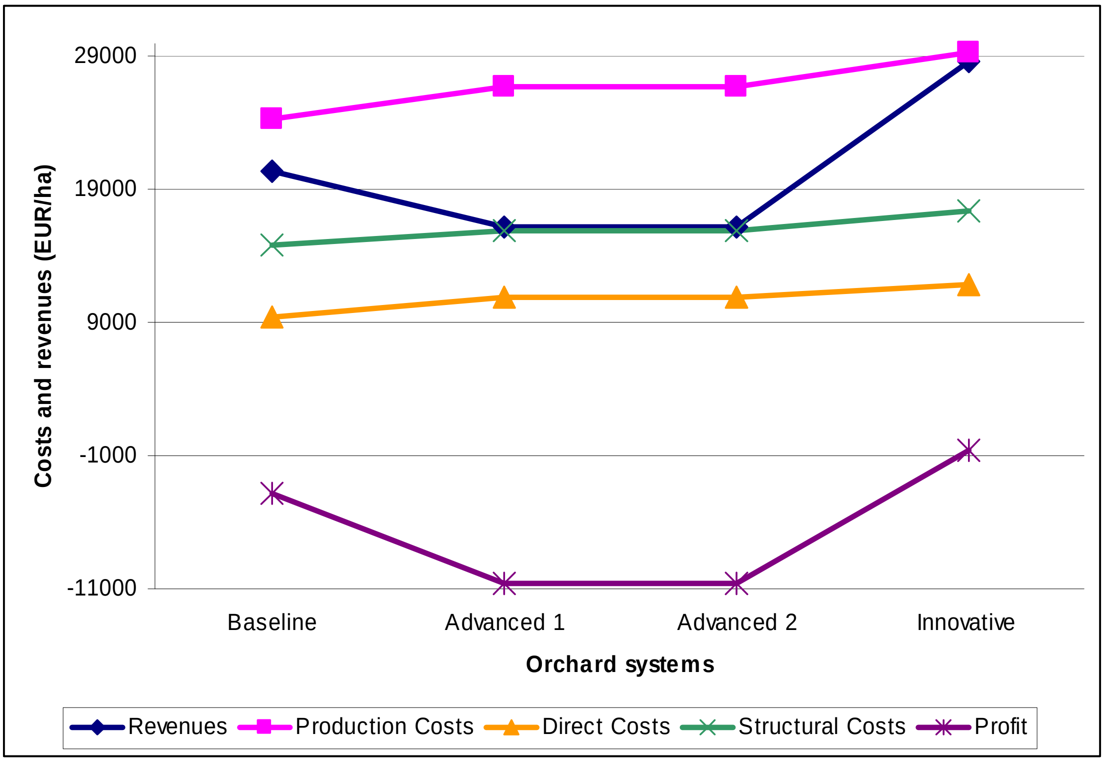
Appendix 2. Input data

	Variable	System	Switzerland	Germany	France	Holland	Spain
Context parameters	Crop density (# trees/ha)	Basic	3000	3000	1500	3000	2500
		Advanced 1	3000	3000	1500	3000	2500
		Advanced 2	3000	3000	1000	3000	2500
		Innovative	3000	3000	1000	3000	2500
	Fertilisation cost (EUR/ha)	Basic	186.7	186.5	184	157.3	564
		Advanced 1	186.7	186.5	92	157.3	398.3
		Advanced 2	186.7	186.5	92	157.3	265.5
		Innovative	186.7	186.5	92	157.3	200.9
	Mulching (times/season)	Basic	7	7	8	0	7
		Advanced 1	7	7	6	4	3
		Advanced 2	7	7	6	7	3
		Innovative	7	7	4	7	3
	Ecological compensation area per ha (%)	Basic	10	10	0	10	0
		Advanced 1	15	15	5	15	1
		Advanced 2	15	20	15	20	5
		Innovative	20	20	15	20	20
	Hail net, region-specific (%)	Basic	40	30	0	1	2
		Advanced 1	80	40	0	5	2
		Advanced 2	80	50	50	5	30
		Innovative	80	50	50	5	50
	Irrigation, region-specific (%, m^3)	Basic	10, 400	5	91, 2000	90, 400	100, 9500
		Advanced 1	10, 400	5	91, 2000	95, 400	100, 7500
		Advanced 2	10, 400	5	91, 2000	99, 400	100, 6000
		Innovative	10, 400	5	91, 2000	99, 400	100, 5000
	Crop protection decisions (h/ha)	Basic	15	5	5	15	5
		Advanced 1	25	10	25	25	10
		Advanced 2	25	15	35	30	30
		Innovative	35	15	15	35	20
	Training in integrated pest control (days/season)	Basic	1	1	0	3	1
		Advanced 1	2	2	2	5	1
		Advanced 2	2	3	3	5	1
		Innovative	3	3	3	5	5
Target parameters	Yield (t/ha)	Basic	35	35	40	41	50
		Advanced 1	35	35	40	48	50
		Advanced 2	35	35	35	48	50
		Innovative	45	45	35	50	50
	Portion of class-1 fruit (Y_1) (%)	Basic	75	95	80	75	88
		Advanced 1	75	95	75	85	91
		Advanced 2	75	95	85	85	91
		Innovative	85	98	85	90	96
	Shared yield	(Y_2,Y_i,Y_l)	50,33.3,16.7	50,50,0	72,14,14	72,14,14	72,14,14
	Price (P_1) (EUR/kg)	Basic	0.65	0.5	0.52	0.65	0.45
		Advanced 1	0.65	0.5	0.52	0.65	0.45
		Advanced 2	0.65	0.5	0.52	0.65	0.45
		Innovative	0.65	0.5	0.52	0.65	0.45
	Fruit price	(P_2, P_i)	50,27	50,30	50,15	50,27	50,27
Production risk	Variability of yield (+ or - %)	Basic	10	10	10	10	8
		Advanced 1	10	15	15	15	8
		Advanced 2	15	10	10	15	8
		Innovative	10	10	10	10	5
	Variability of class-1 share (+ or - %)	Basic	10	10	10	10	10
		Advanced 1	10	15	15	10	10
		Advanced 2	15	10	10	10	10
		Innovative	10	10	10	10	10

	Variable	System	Switzerland	Germany	France	Holland	Spain
Disease control	Sulphur use (kg S/ha)	Basic	7200	16800	7200		
		Advanced 1	7200	8000	7200	4800	
		Advanced 2	14400	4000	4800	7200	
		Innovative				9600	
	Copper use (kg Cu/ha)	Basic	300	2551.5	250		500
		Advanced 1			250	52750*	500
		Advanced 2			250	101250*	
		Innovative				102500*	
	Conventional fungicides (kg a.s./ha)	Basic	18038	12208.8	3086.4	18246	8894.4
		Advanced 1	9679	7205	1271.6	9505	9811.4
		Advanced 2	5719	4155	551.6	4737	4445.7
		Innovative			380	2361	
	Novelty fungicides (# treatments)	Basic					
		Advanced 1					
		Advanced 2					
		Innovative	3	3	3		3.2
	Non-chemical methods (# strategies)	Basic		1			
		Advanced 1	4	3	1	2	1
		Advanced 2	5	4	2	3	2
		Innovative	4	6	4	5	5
Insect control	Conventional insecticides (kg a.s./ha)	Basic	1058.6	1147	3866.9	959	5219
		Advanced 1	380.2	651.3	1826	560	1271.6
		Advanced 2	345.5	616.3	140	278	116.5
		Innovative			35	65	
	Oil-derived Products (kg oil/ha)	Basic	7600	16380	20000	6375	11620
		Advanced 1	10032	8190	20000	3188	6640
		Advanced 2	7600	8190	20000	1275	1660
		Innovative					
	Products use in organic production (# treatments)	Basic			1.2	0.1	
		Advanced 1	1	7.75	3.5	4.1	1
		Advanced 2	1	9	2	5.1	4.4
		Innovative	4	9	3	6.1	4.4
	Novelty insecticides (# treatments)	Basic					
		Advanced 1					
		Advanced 2					
		Innovative	1		1		1.2
	Non-chemical methods (# strategies)	Basic				1	
		Advanced 1	3	2	6	3	3
		Advanced 2	4	5	6	3	5
		Innovative	9	8	9	9	9
Weed control	Conventional herbicides (kg a.s./ha)	Basic	8850	7236.3	8950	8040.2	5350
		Advanced 1	3950	3236.3	3950	5974.8	3032.4
		Advanced 2			1000	4238.4	3032.4
		Innovative				1800	
	Natural herbicides (# treatments)	Basic					
		Advanced 1					
		Advanced 2					
		Innovative				2	
	Non-chemical methods (# strategies)	Basic	1				
		Advanced 1	2	2	2	2	2
		Advanced 2	2	3	3	3	2
		Innovative	2	3	2.5	4	3
	Area under control (%)		22	22	33	43	25

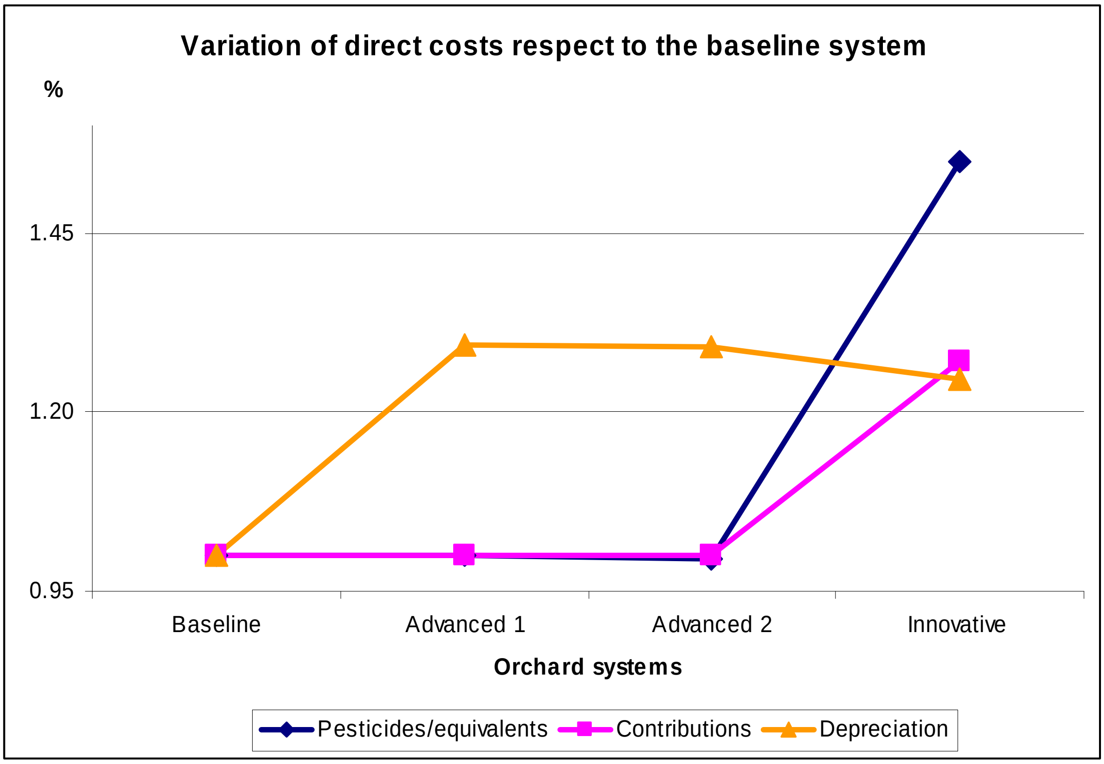
Appendix 3. Costs for different orchard systems in Switzerland

Tendencies of costs



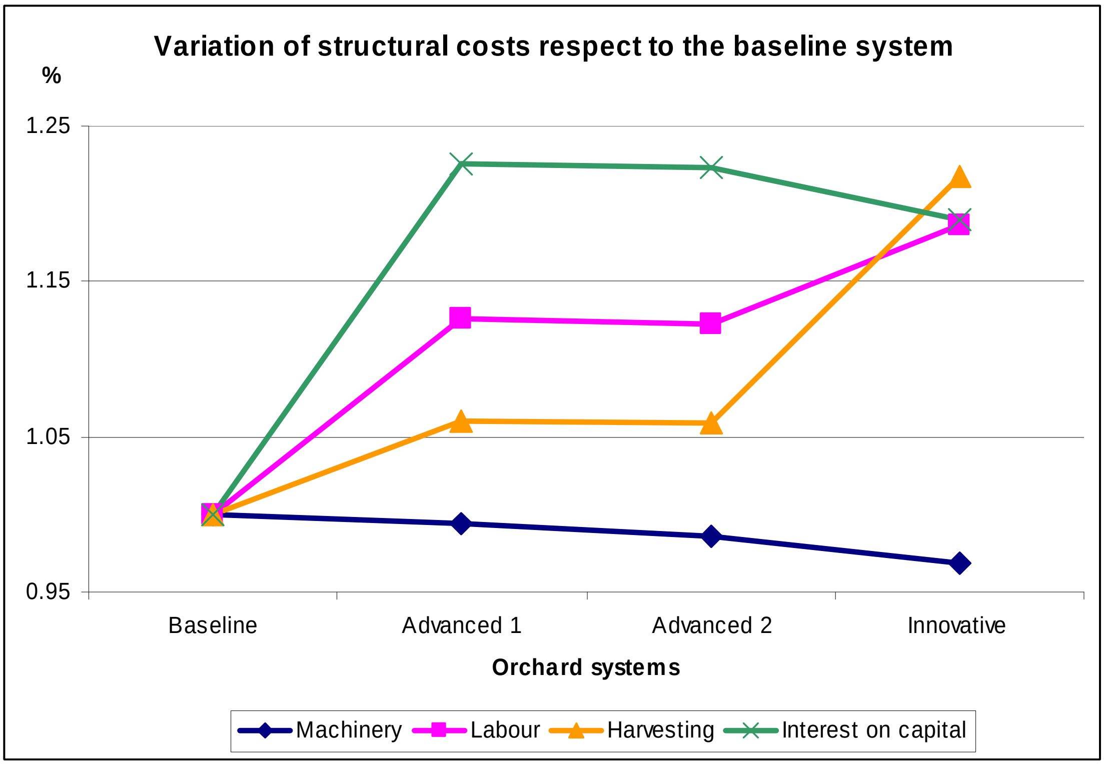
Observations:
Production costs seem to have lower influence in profit as revenues has. It can not be concluded whether direct costs are more decisive for total costs than structural costs are.

Variation of direct costs respect to baseline system



Observations:
Three factors affect direct costs: 1) the selection of pesticides or their equivalents, which have a maximum value under the Innovative System, 2) the crop yield, whose augment act to increase the value of contributions to cooperatives, which is higher under the Innovative System, and 3) the investments on infrastructure; for instance, the costs associated with the installation of a hail net have a proportional effect the establishment cost and thereby on increments of depreciation costs (which are calculated in base on these establishment costs). In the case of the Innovative System, the depreciation costs are reduced due to the outstanding higher yield that increases the liquidity and thereby reduces the establishment costs (when compared with the Advanced-2 System).

Variation of structural costs respect to baseline system



Observations:
Lower machinery costs and higher labour costs are correspond to larger implementation (in number) of non-chemical measure, which occurs progressively from Baseline to Innovative System, whose respective lowest and highest costs are reached under the Innovative System. One reason why the labour cost are lowest under a chemical based system than in the other three orchard systems is that the implementation of integrated pest management strategies is associated with activities that are high time-demanding, specifically the training and the decisions on field including monitoring and direct observation. The interest on capital is particularly affected by two factors, investments on infrastructure and crop yield. Investments on infrastructure such as the installation of hail nets imply that the establishment costs are higher and in that way the interest on capital (invested) is greater, this situation is observable when moving on from the Baseline to the Advanced-1 System. Contrarily, with a higher target yield, the liquidity is higher and the amount of capital invested for the establishment of the orchard is reduced, a situation that can be observed when progressing from the Advanced-2 to the Innovative System. Finally, it is confirmed that harvesting cost increase when the yield (e.g. in the Innovative System) and the fruit quality (e.g. in both Advanced Systems with respect to the Baseline System or when comparing the Innovative System with the Advanced-2 System) are higher.