PURE

Pesticide Use-and-risk Reduction in European farming systems with Integrated Pest Management

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SEVENTH FRAMEWORK PROGRAMME

D2.2

Ex-post assessments of the IPM solutions tested the 3rd year on-station and on-farm

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1. Summary

The implementation of integrated pest management (IPM) and the application of measures which reduce the risk related to pesticide use are requirements by the Directive 2009/128/EC. Especially the IPM implementation in arable crops with a relatively low revenue per yield unit is a challenge for the farming community. The PURE project work tested two different levels of IPM solutions (intermediate and advanced) in comparison to the current protection system for important pests of wheat in winter wheat based rotations. In three geographical regions: i) north, ii) central and iii) south the overall, economic, social and environmental sustainability of the systems was assessed. For the assessment of sustainability the DEXiPM model was used and complemented by the SYNOPS web application for site-specific assessment of the environmental risk associated to the pesticide use and a cost-benefit-analysis for the economic assessment. The deliverable presents the results of the assessment from the on-station experiments.

The observations from the experiments indicate that intermediate IPM systems seem to be an attainable production system at the tested locations. Further agronomic improvements and optimisation as well as improvement of knowledge and support would allow better economic and social performance and lead to higher overall sustainability.

The overall sustainability did not change across the systems and location, whereas the environmental sustainability could be improved from the current to the intermediate and to the advanced systems at all locations. The social sustainability remained unchanged for all systems at the location in France and decreased from the high level in the reference and intermediate system to medium level in the UK and from high sustainability in the reference system to medium levels in the intermediate and advanced system in Germany. The lower sustainability originating from the farmers perspective indicates that the shift from current well adopted practices which are supported by easily accessible knowledge and efficient advisory support to the more knowledge intensive intermediate and advanced systems poses a certain constrain to the farmer. The economic sustainability was in all reference systems higher than in the intermediate or advanced systems due to lower gross margins.

Concerning the on-farm experimentation, additional constraints like the loss of the entire crop due to very harsh winter conditions and unpredictable difficulties in the management lead to very inconsistent data. Thus, only a limited assessment was done in a number of locations. However, for example in Germany the results of the on-farm experiments have also better yields in the CS and IS compared to the AS (data not shown). Based on the experience from the locations the implementation of intermediate IPM systems with an careful adaptation of all suitable tools indicates to an feasible option.

2. Objectives

The objective of the work package was to test and validate innovative IPM solutions for important pests of wheat in winter wheat based rotations. During three years two different levels of IPM were tested in on-station and on-farm experimentations, an intermediate IPM (IS) and an advanced IPM strategy (AS) in three geographical regions: i) North: Denmark and Scotland, ii) Central: Germany and Poland and iii) South: two different locations in France. In each region the IPM solutions were compared to the current regional practice. Before the start of the experiments the DEXiPM *ex-ante* assessment was conducted to design and assess the potential sustainability of the systems for each location. After each year and the three year project period the DEXiPM *ex-post* assessment was conducted for each on-station experiment and partly for the on-farm experiments.

The deliverable D2.1 "Ex-post assessments of the IPM solutions tested the 1st year on-station and on-farm" explains the tools and first experiences in applying DEXiPM, SYNOPS and cost-benefit-assessment (CBA). The individual strategies of each location are described in detail in the internal document D2.1. The methods and agronomic results are subject of deliverable D2.3 "IPM guidelines for winter wheat based rotations in Europe".

The deliverable summarizes the results of the DEXiPM ex-post assessment after the completion of the full three year crop rotation. Exceptions are the French experiment as there the project was conducted in existing trials which have longer rotations. The results presented are based on the results of the on-station experimentation as here i) the highest level of detail for the input into the DEXiPM and SYNOPS models could be obtained and ii) reliable permanent data could be obtained. Furthermore, only one example per region is presented in detail in the deliverable, the other results are presented in the third scientific report of the project.

3. Description of the multi-criteria assessment tools adopted

The ex-post assessment of the overall, social, environmental and economic sustainability of the IPM strategies was conducted using DEXiPM. The separately conducted cost-benefit analysis and the assessment of the environmental sustainability with SYNOPS provided quantitative input to the DEXiPM model.

3.1. DEXiPM

The *ex-post* assessment with DEXiPM tool assesses the environmental, economic and social sustainability of cropping systems. For this report estimates (qualitative) and data (quantitative) generated from the on-station experimentation were used.

The DEXiPM[1] model was initially developed for an *ex-ante* multi-criteria assessment of the sustainability of cropping systems. The model has been adapted to the specific needs of the *ex-post* assessment for (i) identifying year after year the practices that should be modified according to the assessment results and (ii) performing a global evaluation of a concrete system in a specific context.

[1] Pelzer, E., Fortino, G., Bockstaller, C., Angevin, F., Lamine, C., Moonen, C., Vasileiadis, V., Guérin, D., Guichard, L., Reau, R., Messéan, A., 2012. Assessing innovative cropping systems with DEXiPM, a qualitative multi-criteria assessment tool derived from DEXi. Ecological indicators, 18, 171-182.

3.2. SYNOPS

For the environmental assessment of the strategies of the on-station experiments the SYNOPS model was used to calculate the environmental risk using the field based functionality of the model SYNOPS web (http://sf.jki.bund.de/synops-web/).
The outputs of the SYNOPS[2] model were used as detailed inputs to the environmental set of criteria to run DEXiPM for ex-post assessment. The chronic and acute risk potentials for all reference organisms (aquatic and terrestrial) and the risk to groundwater were calculated. The risk scores are categorised in the table below.

Table 1: Classification of acute and chronic risk indices calculated with SYNOPS

Four risk categories for SYNOPS results	**acute risk**	**chronic risk**	RsumGW and RmaGW	
very low risk	ETR<0.01	ETR<0.1		
low risk	0.01<ETR<0.1	0.1<ETR<1	ETR<1	no risk
medium risk	0.1<ETR<1	1<ETR<10	1<ETR<10	medium risk
high risk	ETR >1	ETR >10	ETR >10	high risk

3.3. Cost-benefit Analyses

A cost-benefit analysis (CBA) was conducted based on the methodology set up in Task 1.4 (of WP1 and deliverable D1.5), to evaluate the economic benefits and costs of the individual IPM strategies. The cost-benefit analysis was planned to be carried out using primarily the on-farm experiments data but the on-farm experimentation faced several obstacles ranging from loss due to weather conditions to missing monitoring and yield data. To ensure valid results it was decided to perform CBA for the on-station experimentation. A Complete CBA, with information on costs for all operations, was conducted. This approach is relevant when the tested IPM solution corresponds to an important change in the system, i.e. impacting various operations. The operation costs were calculated based on national contractor charges, real cost data were used for variable inputs (e.g. seeds, fertilizer, pesticides) and national price data for outputs. The economic comparison of strategies is based on the entire rotation. The results of the cost-benefit analysis were provided to the economic set of criteria for the DEXiPM for *ex-post* assessment.

[2] Volkmar Gutsche und Jörn Strassemeyer (2007): SYNOPS - a model to assess the environmental risk potential of pesticides; Nachrichtenbl. Deut. Pflanzenschutzd., **59** (9). S. 197–210, 2007, ISSN 0027-7479.

4. Results of ex-post assessment

4.1. Northern Region - Balruddery Farm, Dundee, Scotland-UK

4.1.1. Description of location and systems

Context

Site: Dam Field, Balruddery Farm, nr Dundee, Scotland

Soil and climate: Sandy-loam soil. Average temperature 8.6C, 761 mm precipitation, 1348h sunshine.

Regional context: Arable farming, rotation dominated by barley for malting then soft wheat for distilling, oilseed rape, potato, and less frequently beans, peas and field vegetable crops. Many soft fruit growers in the area, mostly now under polytunnels - raspberries and strawberries, but also blackcurrants in open fields.

Cropping systems

Current system (CS):

Crop sequence: Oilseed rape (OSR), winter wheat (WW), winter wheat (WW).

Tillage: inversion tillage before first year, minimum tillage subsequently.

Pesticide use: high (mean 3 years TFI=6) compared to the Scottish norm.

- WW (both): 2 herbicide applications, a popular cultivar + 2 or 3 fungicides, no insecticide no PGR. Expected yield: 7-10 t/ha.
- OSR: Autumn sown normally, 2 herbicide applications, common cultivar + 1 fungicide, 1 or 2 insecticides. Expected yield: 3-5 t/ha.

Note: In year 1 there was some bird damage to the OSR, particularly in replicate 3.

In year 2 the crop was totally destroyed by birds in the autumn and spring OSR was sown to replace it.

In year 3 no attempt was made to sow in autumn and the crop was spring sown again. The problem in year 2 was accentuated by late sowing due to the late harvest date of winter wheat and thus year 3 sowing date decision was with this consideration in mind.

Intermediate system (IS):

Crop sequence: oilseed rape (OSR), winter wheat (WW), spring barley (SB).

Tillage: As for CS.

Pesticide use: medium (mean 3 years TFI=4.5) compared to the Scottish norm.

IPM tools:

- Use a variety mixture comprising three common soft wheat varieties
- Monitoring crop for disease and spraying in response to these levels
- Half rate herbicide applications
- 80% of CS fertiliser rate

Advanced system (AS):

Crop sequence: Oilseed rape (OSR), winter wheat (WW), spring peas (SP).

Tillage: As for CS

Pesticide use: low (mean 3 years TFI=2.2) compared to the Scottish norm.

IPM tools:

- Use a variety mixture comprising seven or eight common soft wheat varieties

- Reduced seed rate
- Use of resistance elicitors to control disease
- Monitoring crop for disease and spraying in response to these levels, with a fungicide too if necessary
- Half rate herbicide applications
- 60% of CS fertiliser rate

4.1.2. DEXiPM

Year-to-year variation, particularly year 3 compared with the other two, creates problems for whole system comparisons. Despite the fact that the biggest changes were at the end of the rotation cycle, differences could not clearly be associated with any rotation effects. More likely the impacts were effects of weather on yield, big changes in commodity prices, and disappointing performance of the resistance elicitors. Other work has shown little impact of elicitors on wheat, unlike their effect on brassica crops where they can perform better than fungicides.

The design of these three systems needs some more critical evaluation as the component changes in the IS and AS treatments are not delivering the synergies we hope to see in IPM systems across all three sustainability pillars. When brought together with the other trials across Europe we will analyse these more systematically to determine the direction of future improvements.

4.1.2.1. Overall sustainability

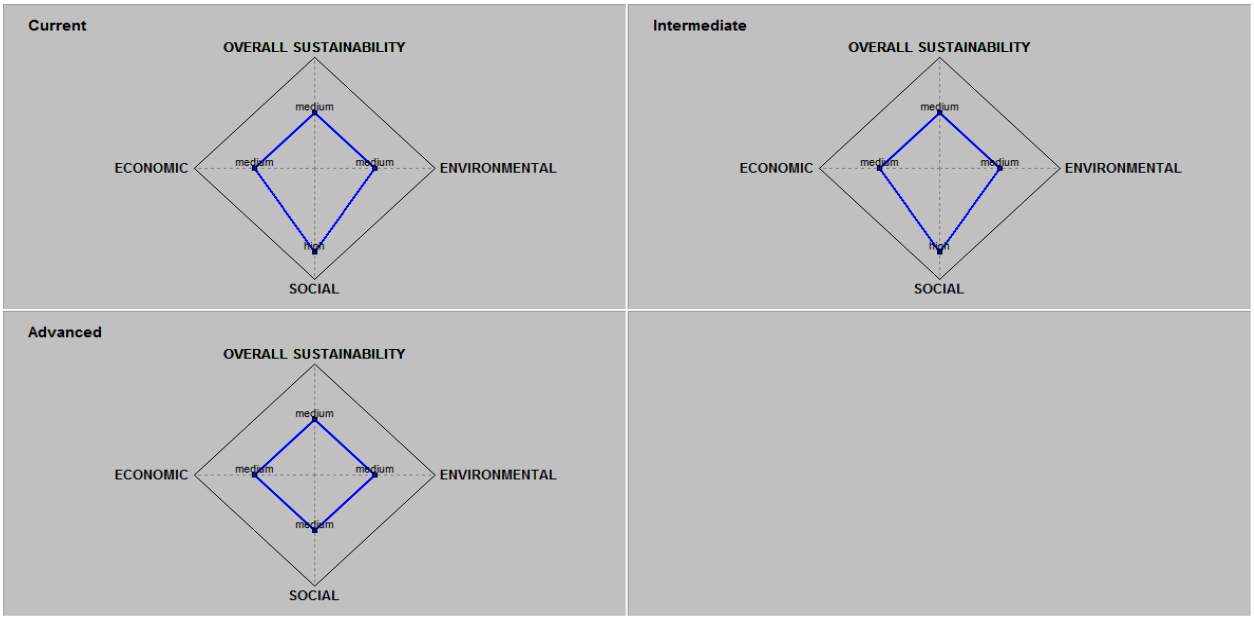


Figure 1: Overall sustainability 2012

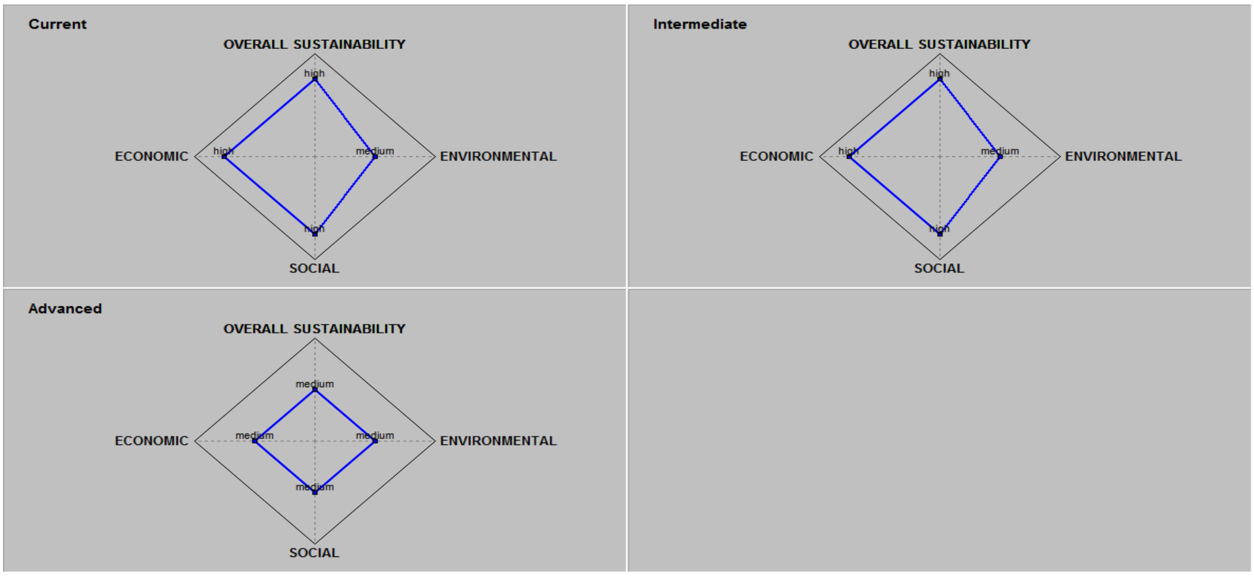


Figure 2: Overall sustainability 2013

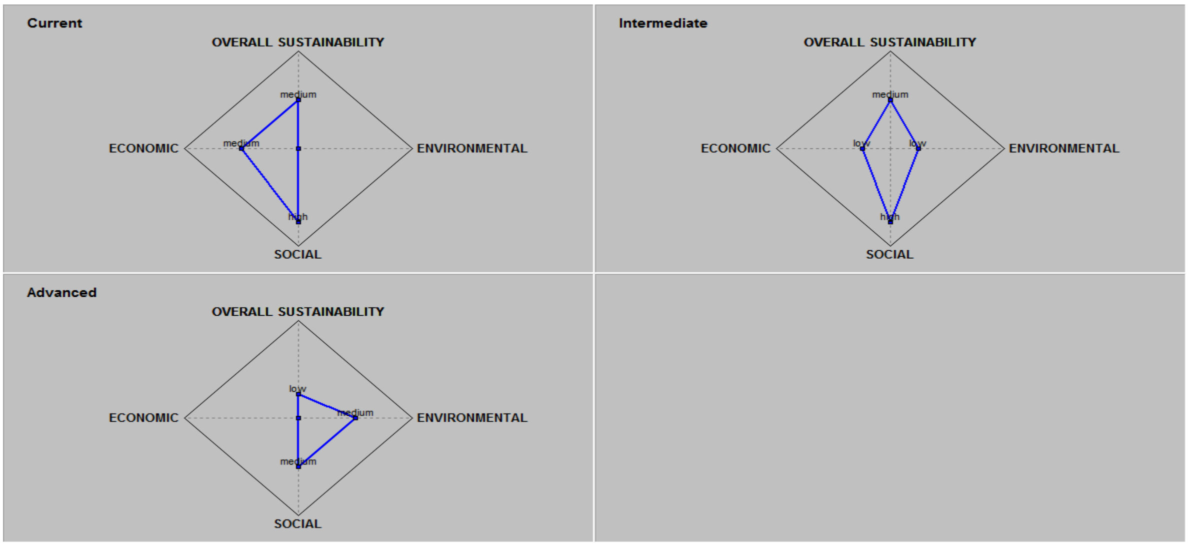


Figure 3: Overall sustainability 2014

Overall sustainability for the CS and IS systems went from medium to high and back to medium across the three years, reflecting very different weather patterns and market prices in particular. The AS system stayed at medium across the first two years then declined to low, reflecting the pattern of the other two systems in the third year. However, AS clearly under-performed in year 2. The charts clearly show that the AS maintained its environmental performance but this was at a heavy cost in both economic and social terms.

4.1.2.2. Economic sustainability

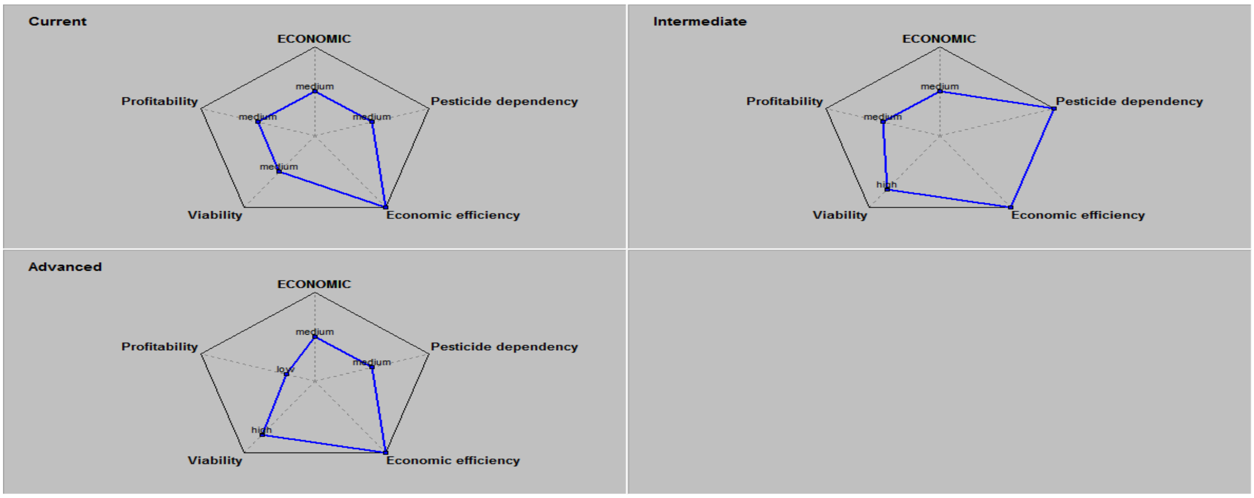


Figure 4: Economic sustainability 2012

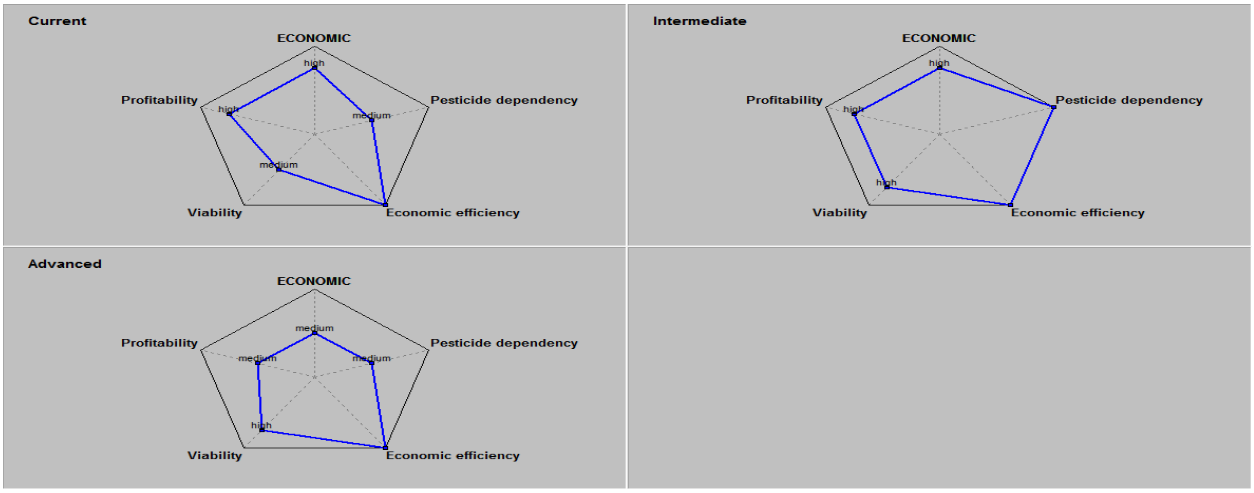


Figure 5: Economic sustainability 2013

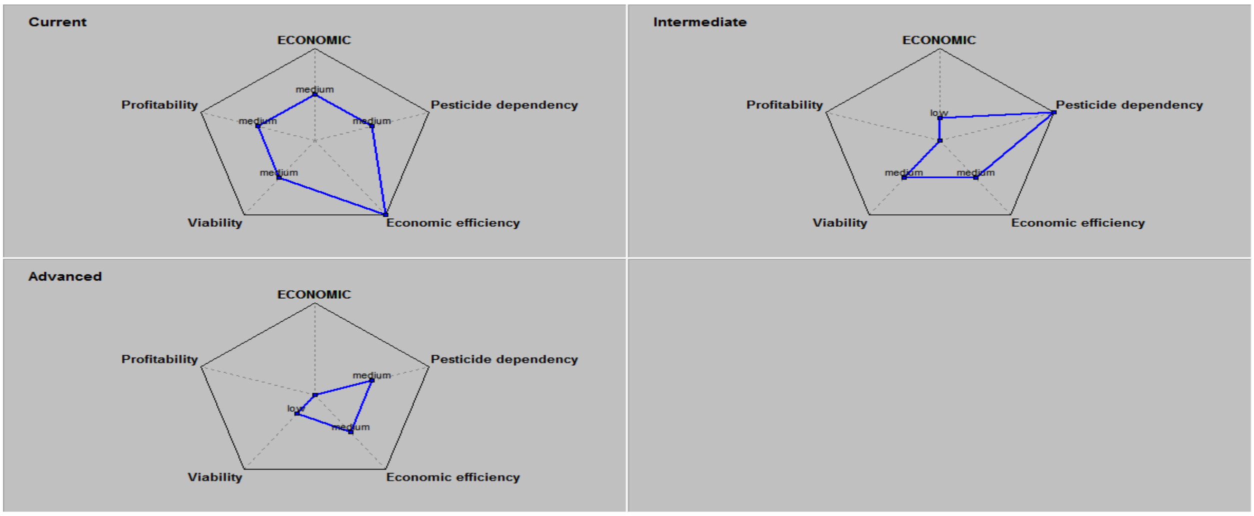


Figure 6: Economic sustainability 2014

Economic sustainability appears best in the IS and whilst it starts well in AS, year three was very poor for this and for the IS system.

4.1.2.3. Social sustainability

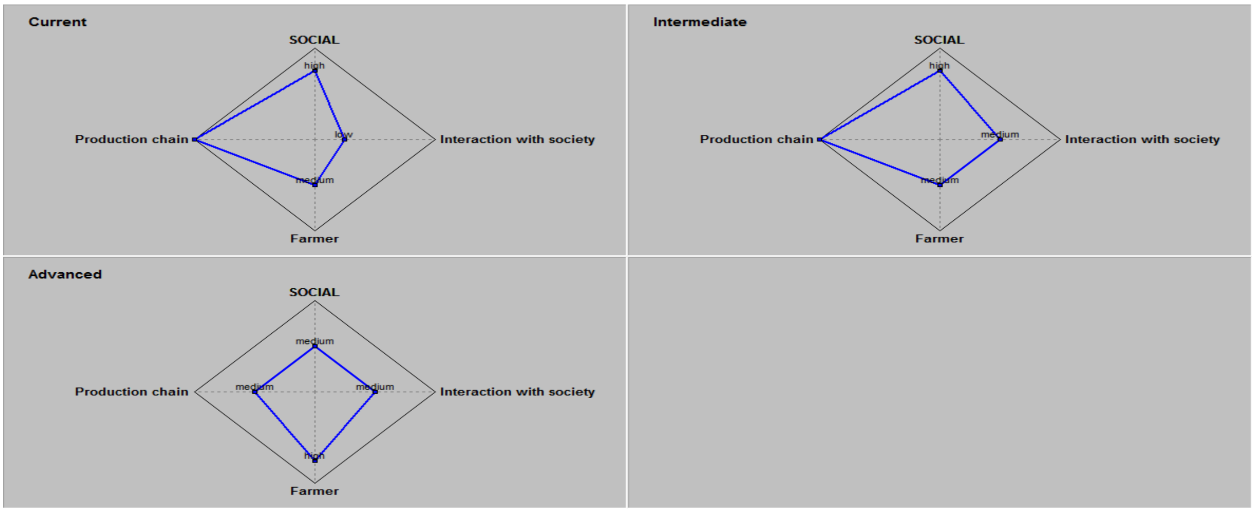


Figure 7: Social sustainability 2012

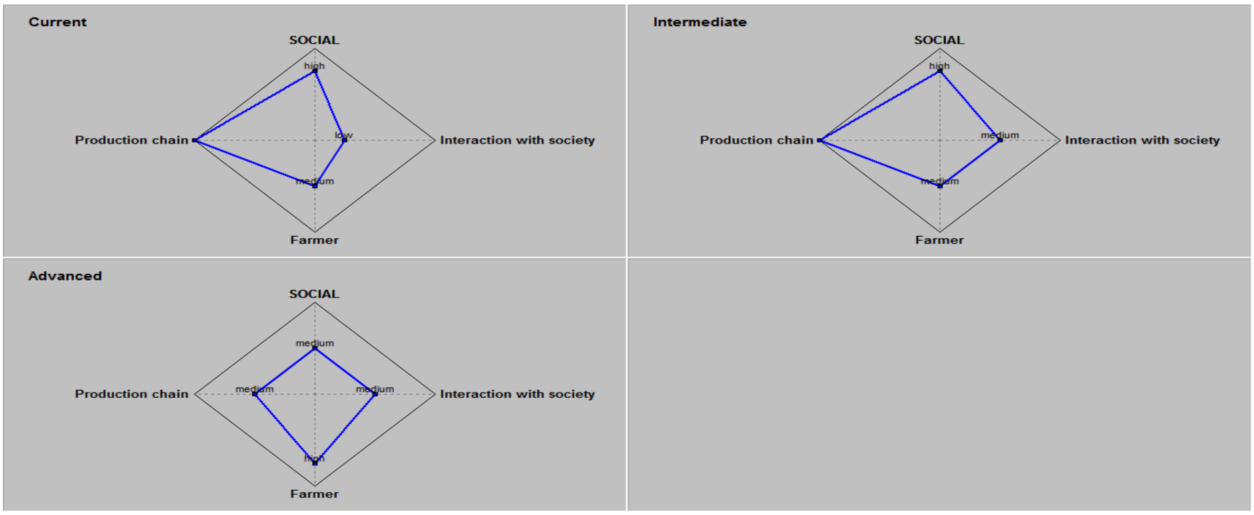


Figure 8: Social sustainability 2013

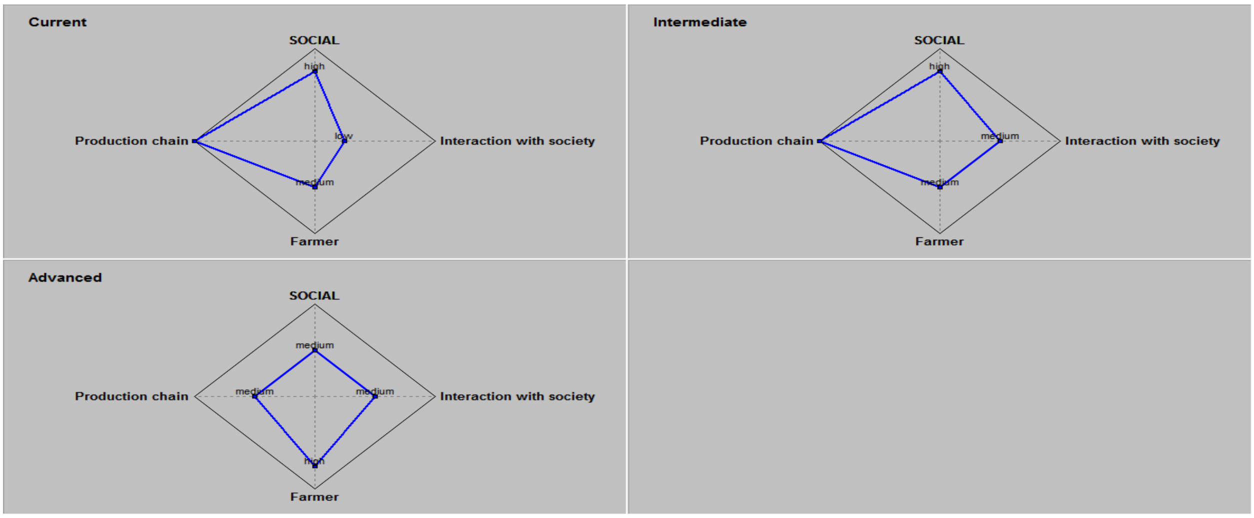


Figure 9: Social sustainability 2014

The social sustainability varied little between years, and between systems the main differences were that AS was better for the farmer but worse for the supply chain. This is probably due to the limited knowledge of how to use the resistance elicitors and how best to optimise their performance.

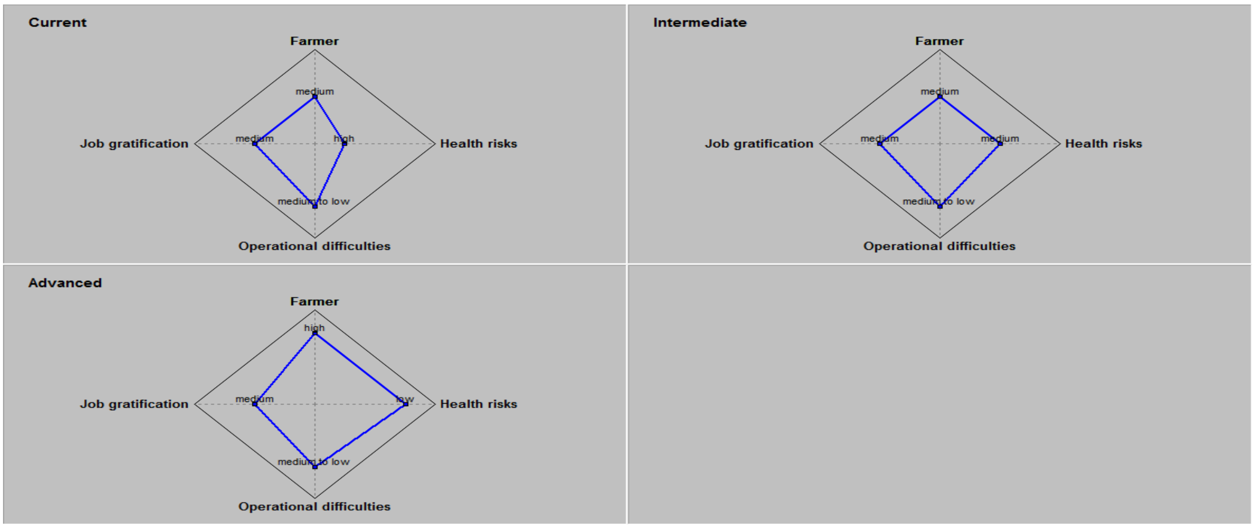


Figure 10: Farmer score 2014

The higher farmer score appears to be mostly attributable to the lower health risks associated with reduced use of fungicides.

4.1.2.4. Environmental sustainability

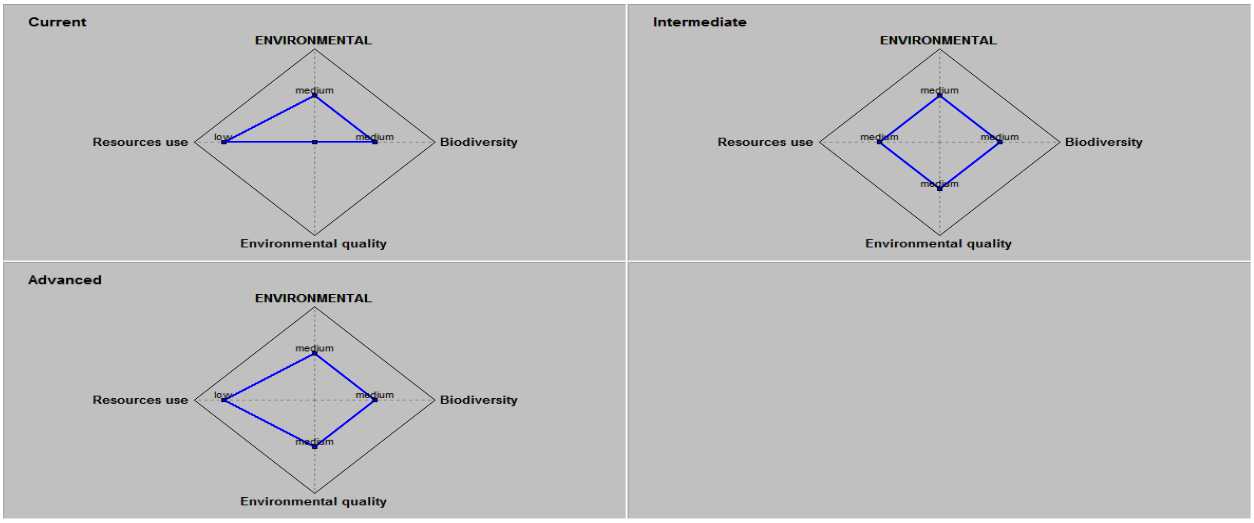


Figure 11: Environmental sustainability 2012

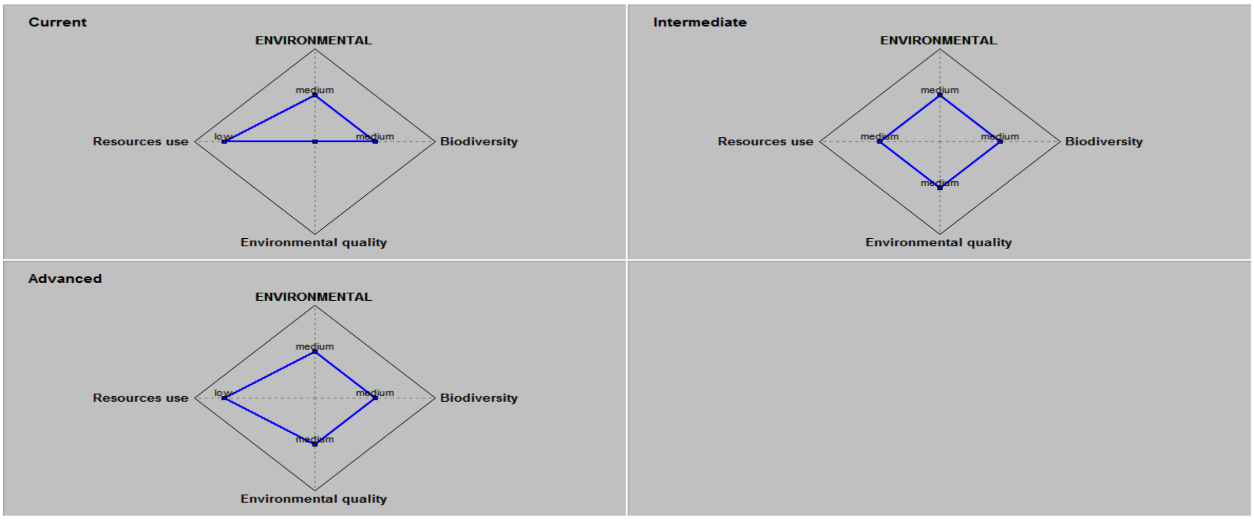


Figure 12: Environmental sustainability 2013

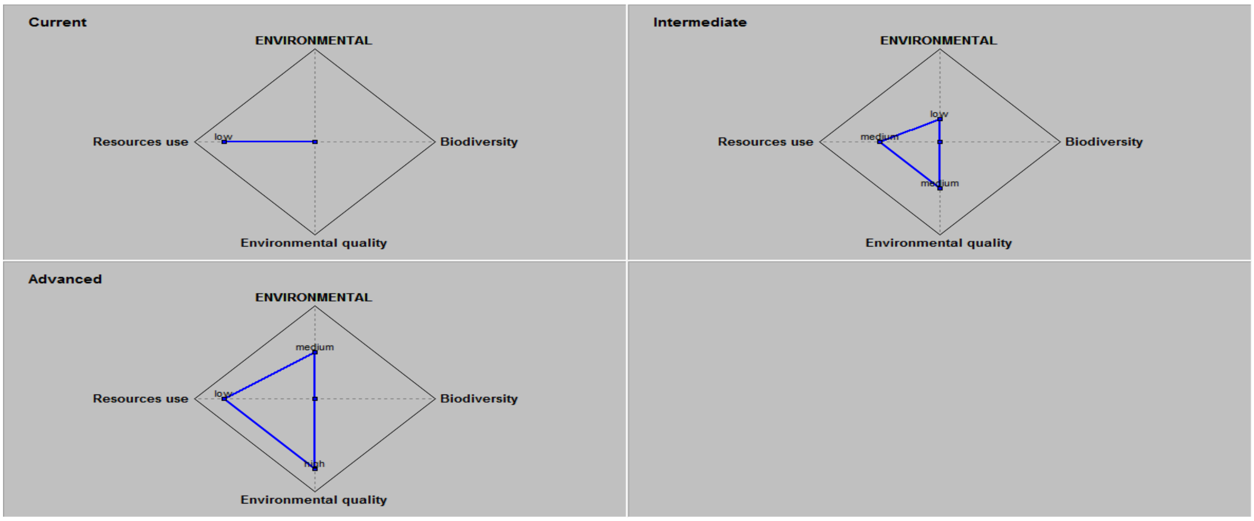


Figure 13: Environmental sustainability 2014

Environmental sustainability is the same in years 1 and 2 but declines in year 3 for CS and IS and changes in nature for AS. The loss of biodiversity in AS is of concern.

4.1.2.4.1 Environmental quality

Environmental quality differs considerably between the systems with both IS and AS performing better than CS. Air emissions and soil quality are both of obvious concerns in the CS.

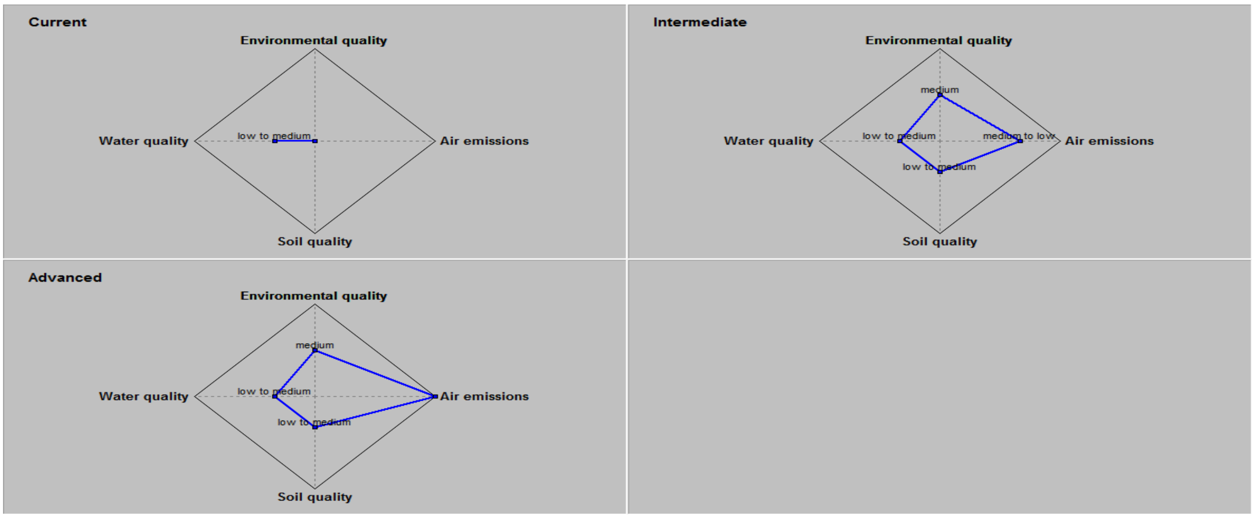


Figure 14: Environmental quality 2012

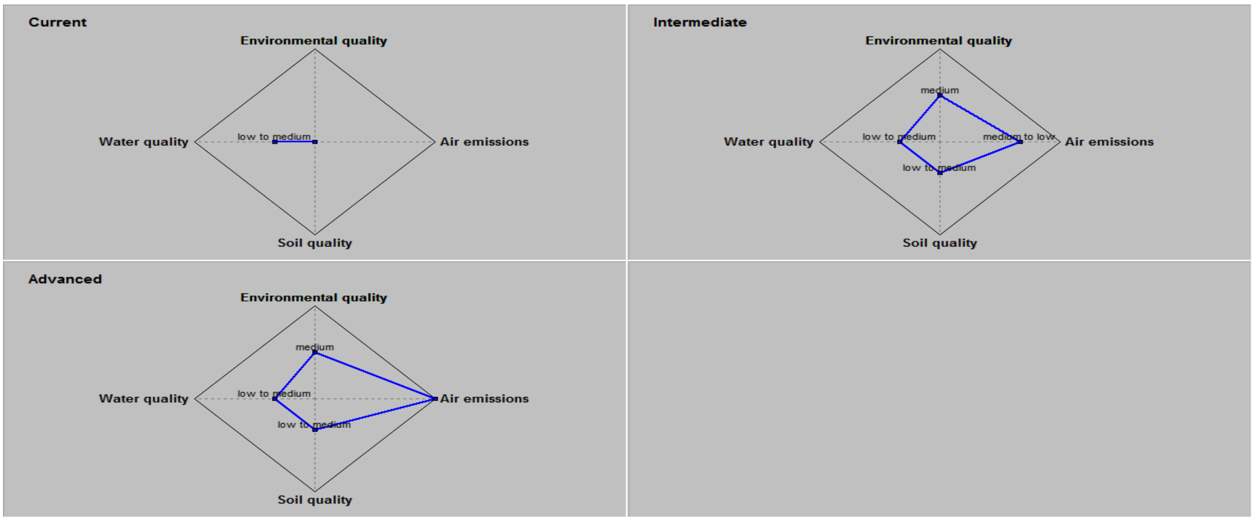


Figure 15: Environmental quality 2013

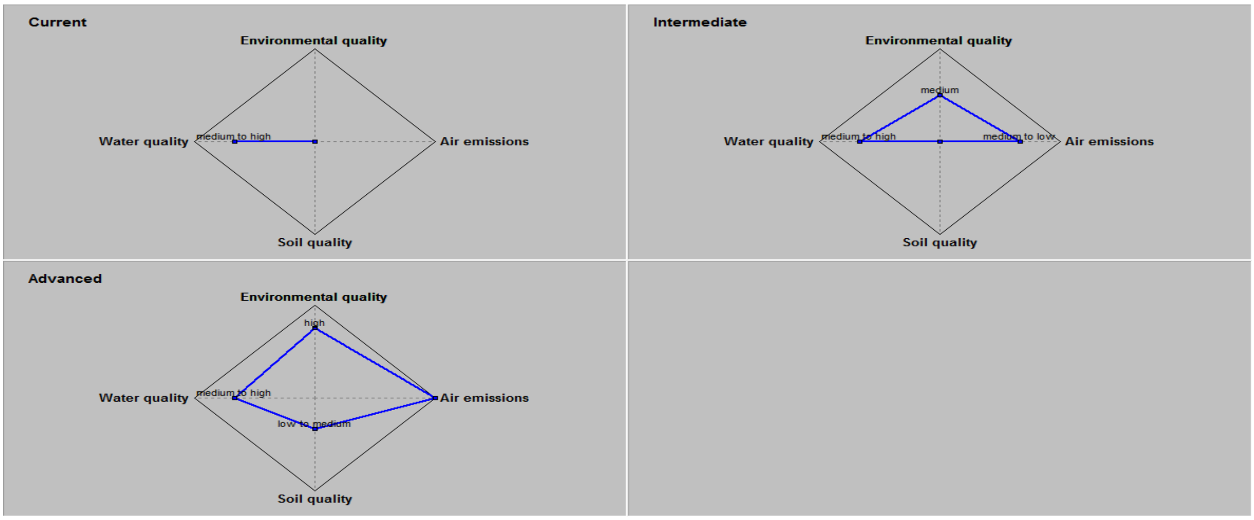


Figure 16: Environmental quality 2014

4.1.2.4.2 Air emissions

Air emissions vary little between years but show marked contrasts between treatments.

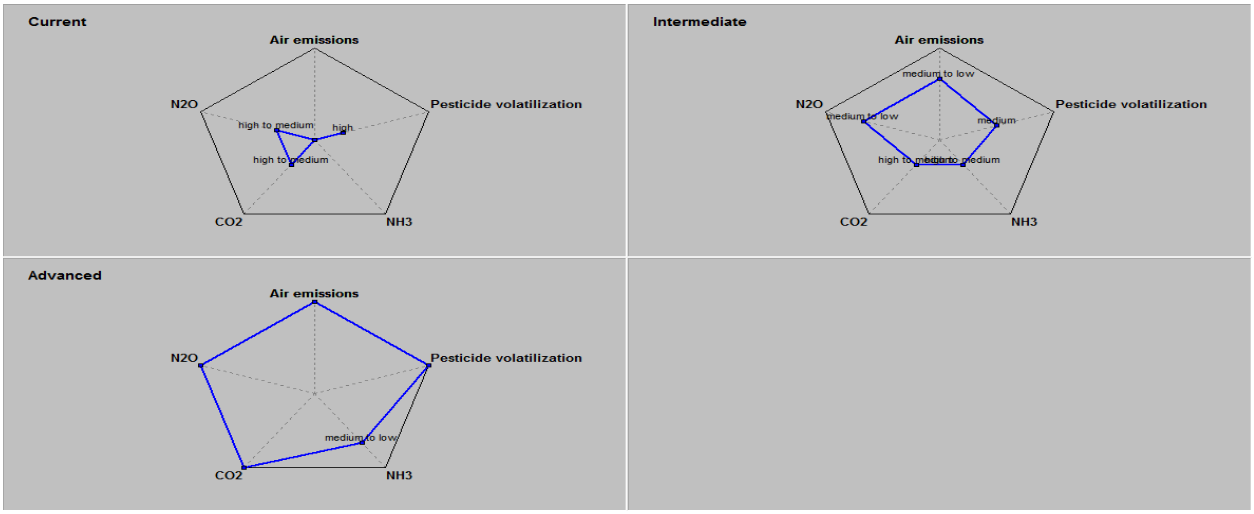


Figure 17: Air emissions 2014

4.1.2.4.3 Soil quality

Like air emissions, soil quality varies little between years but show marked contrasts between treatments.

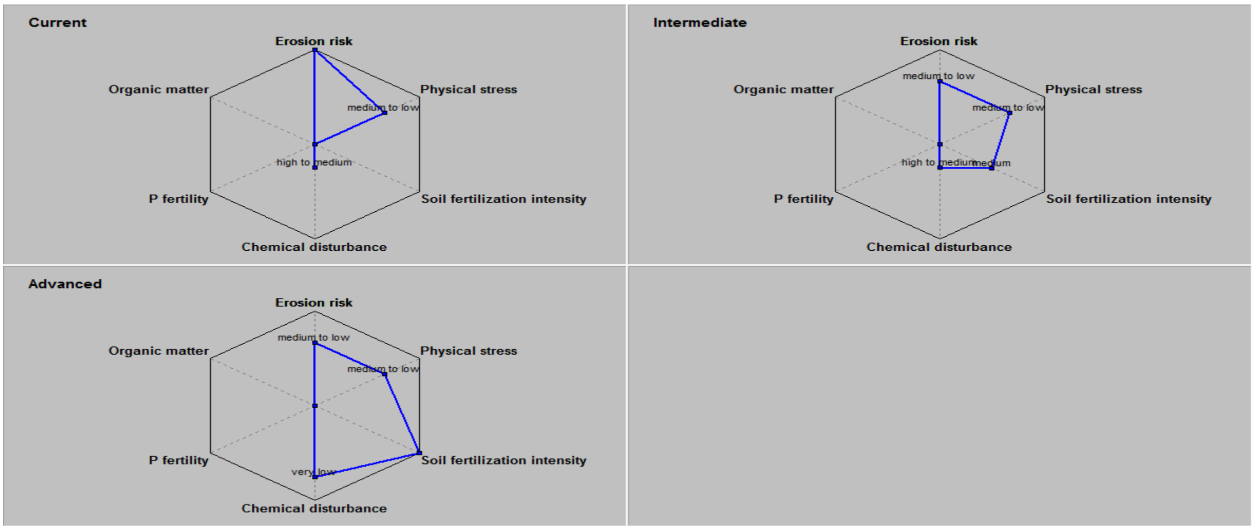


Figure 18: soil quality 2014

4.1.2.4.4 Biodiversity

Clearly the loss in biodiversity in 2014 is related to the TPIs and toxicology and flying natural enemies and pollinators in particular.

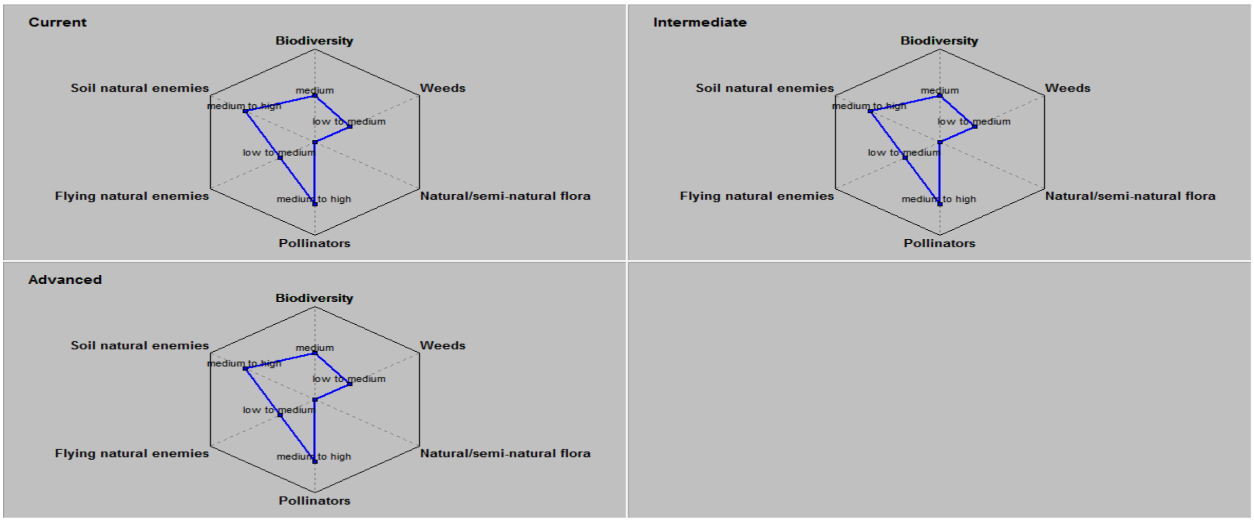


Figure 19: Biodiversity 2012

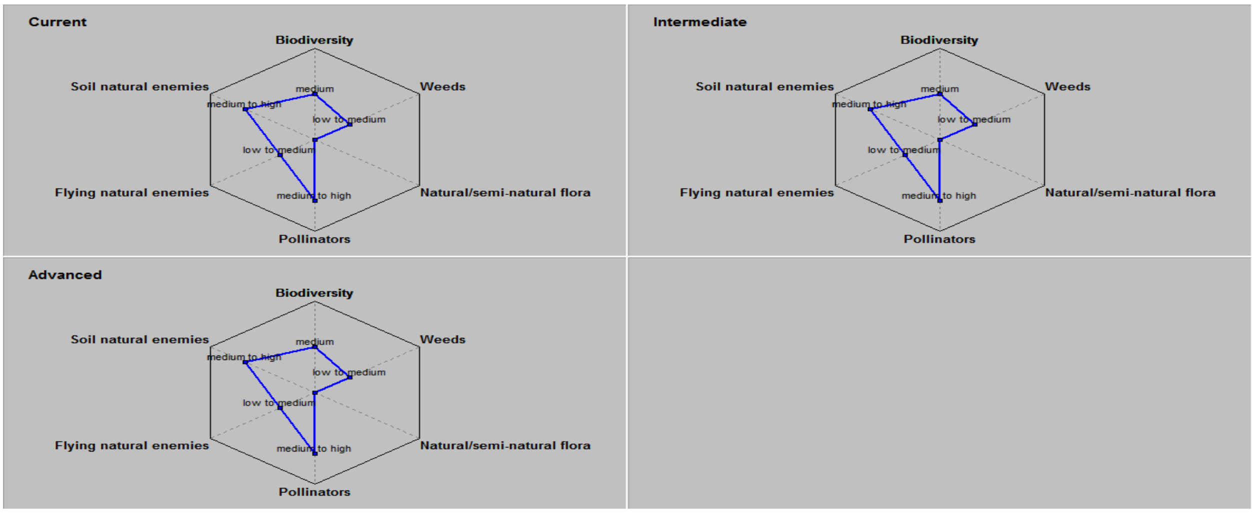


Figure 20: Biodiversity 2013

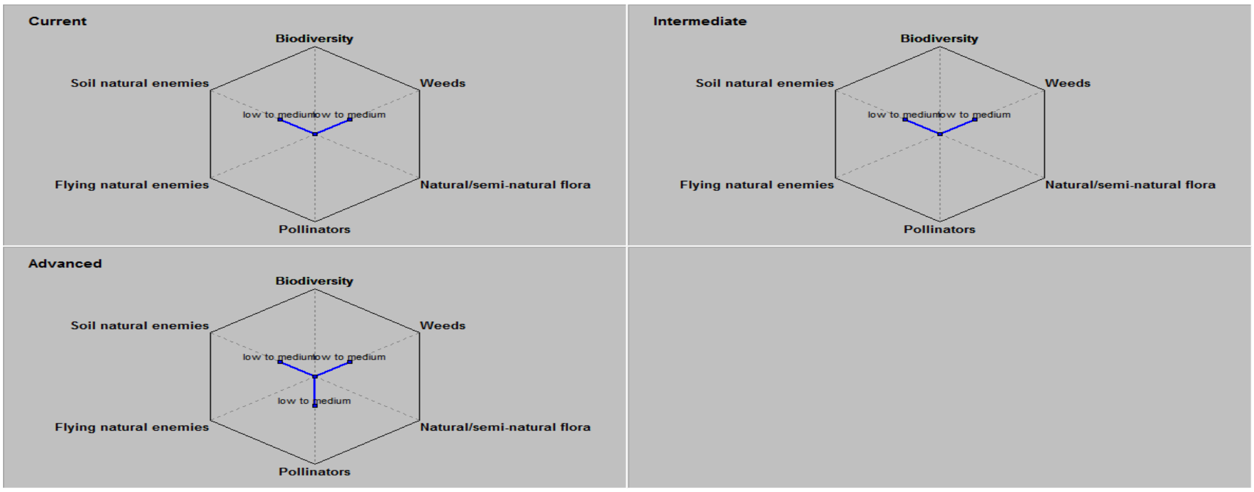


Figure 21: Biodiversity 2014

4.1.3. SYNOPS results

The SYNOPS assessment was conducted for the individual strategies in each crop and year. High risk scores for the aquatic organisms and ground water can be explained by individual active substances especially in herbicides.

Table 2: SYNOPS results for aquatic risk

		Acute risk						Chronic risk					
2012-14		Aquatic	Algae	Daphnia	Fish	Lemna	Chironomus	Aquatic	Algae	Daphnia	Fish	Lemna	Chironomus
CONV	AVG	2,92625167	0,31735956	0,05085933	0,04594022	2,33702522	0,64336522	12,726122	1,70463778	5,56999322	0,28089133	7,52732633	0,29254878
	MAX	3,733972	0,55912333	0,14513533	0,126351	3,733972	1,92019867	20,4909963	3,06397967	16,6046837	0,64003667	10,8159477	0,85994467
INT	AVG	2,42983478	0,13378556	0,04933422	0,04368533	1,84060833	0,64077022	10,9499831	0,72353067	5,54739067	0,23678356	5,75118744	0,28718711
	MAX	2,939821	0,295081	0,143936	0,12445067	2,939821	1,91689767	19,3182773	1,37305433	16,5938593	0,60269467	9,64322867	0,85273333
ADV	AVG	2,059452	0,29971533	0,04842922	0,04120367	1,47022556	0,638134	9,97138789	1,68337889	5,52304089	0,183447	4,77259222	0,28272056
	MAX	4,06962633	0,799207	0,14369	0,12297667	4,06962633	1,91438033	21,252895	4,052441	16,5651107	0,546935	11,5778463	0,848125

The potential risk for groundwater is assessed based on the application of the SYNOPS model A worst-case scenario is expressed by the maximum concentration (MAX) of a single active substance (a.i.) in the full rotation and the average risk values of the rotation are presented by the average (AVG) of all active substances (sum a.i.).

Table 3: SYNOPS results for risk for groundwater

		Pesticide Leaching Risk	
2012-14		single a. i.	sum a. i.
CONV	AVG	4,56750633	0,91350133
	MAX	13,4633537	2,69267067
INT	AVG	4,50575878	0,90115178
	MAX	13,4633537	2,69267067
ADV	AVG	9,78756778	1,95751356
	MAX	25,3984393	5,07968767

Table 4: SYNOPS results concerning the risk for terrestrial organisms

		Acute risk			Chronic risk		
2012-14		Terrestrial	Earthworm	Bee	Terrestrial	Earthworm	Bee
CONV	AVG	0,26415944	0,01034122	0,26043544	1,781876	0,12774233	1,72375633
	MAX	0,778483	0,02044767	0,77043467	5,10910133	0,184506	5,07241233
INT	AVG	0,26387778	0,00913444	0,26078844	1,74406389	0,08713078	1,71205878
	MAX	0,778483	0,02093633	0,77043467	5,10910133	0,184506	5,07241233
ADV	AVG	0,29106178	0,00965056	0,287023	2,01969122	0,10279267	1,96358411
	MAX	0,81786367	0,021404	0,81786367	5,50985933	0,20967433	5,50985933

4.1.4. CBA results

The graph below displays the input cost and the annualized production cost. The annualized production cost is estimated by averaging production costs across years corresponding to the rotation length (2012-2014), and across each of the individual crop of the rotation.
Although the production costs in the advanced system were lower than in IS and CS the overall gross margin of the advanced system was lower than in the intermediate and current system respectively.

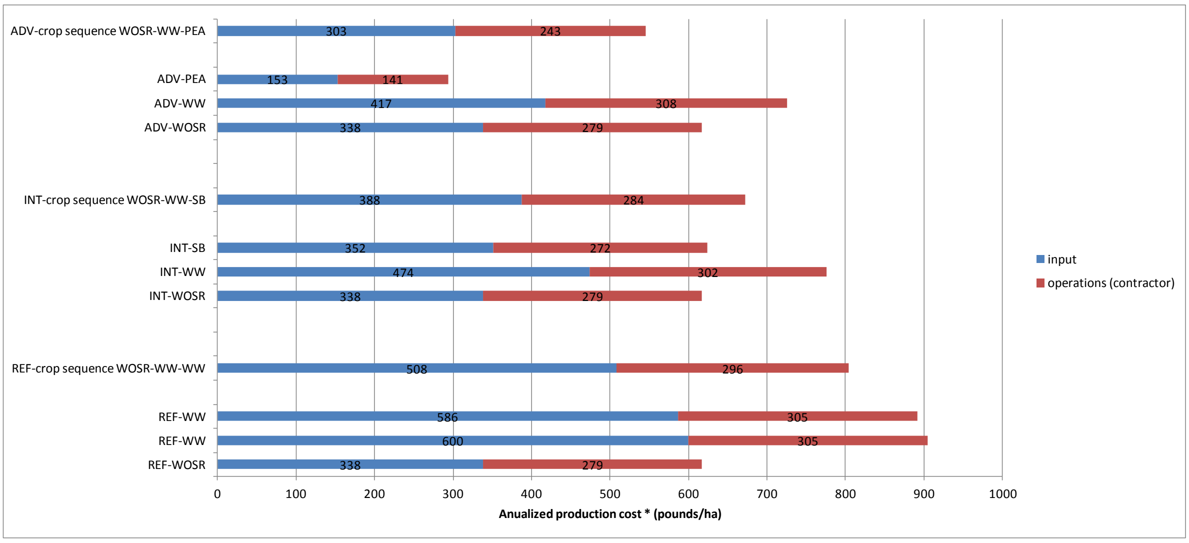


Figure 22: Annualized production costs 2012-14

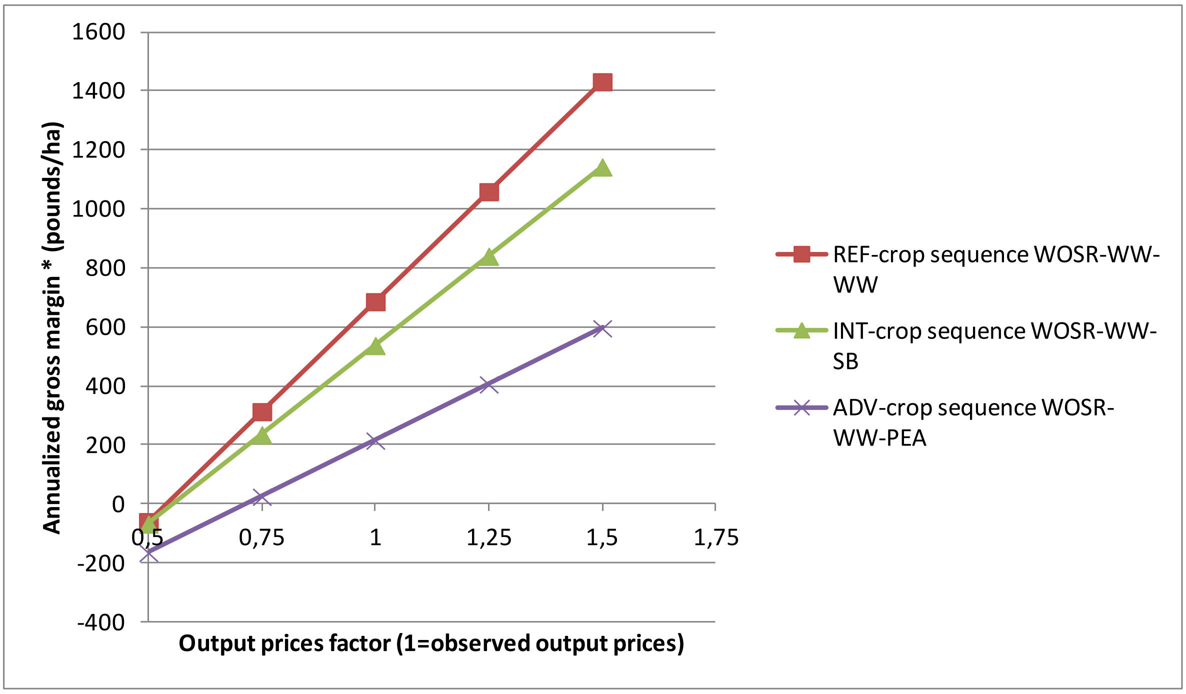


Figure 23: Annualized gross margin 2012-14

4.2. Central Region – Experimental Station Dahnsdorf, Brandenburg, Germany

4.2.1. Description of location and systems

Context

Site: Germany, Dahnsdorf

Soil: lS-sL (loamy-sand/sandy-loam; 57.9% sand, 37.5% silt, 4.6% clay and 1.4% organic content), moraine origin, great variation in depth;

Climate: temperate climate (average temperature 8.5°C, precipitation: 526 mm/year), prolonged dry periods at the end of spring and in early summer.

Regional context: intensive, cash crop farming

Specificity of the farm where the system is proposed: experimental station, no irrigation.

Cropping systems

Current system (CS):

Crop sequence: winter wheat (WW) - winter barley (WB) - (Terra life Rigol, species mixture as intermediate crop) –maize (M).

Tillage: inversion tillage every year.

Pesticide use: medium-to-low (mean 2012-14 TFI=2.59) compared to the German standards.

- WW: 1 herbicide applications based on monitoring (spring), medium resistant but high yielding cultivar *cv. JB Asano* and threshold based fungicide application (regional average: 2 application every year), insecticide generally not necessary, total pesticide TFI 3, expected yield: regional average 60.4 dt/ha, *cv. JB Asano* 82 dt/ha.
- WB: 1 herbicide application (in autumn), medium resistant and high yielding hybrid cultivar *cv. Hobbit,* monitoring and disease thresholds, threshold based dose rates, 1 herbicide and fungicide application, 1 PGR, total pesticide TFI 2.9, expected yield: regional average 56.1 dt/ha, *cv. Hobbit* 93 dt/ha (annual regional variety testing).
- M: 1 herbicide application, TFI 1.8, expected yield: regional average BRB 191.5 dt/ha (regional variety testing 2011-14).

Intermediate system (IS):

Crop sequence: winter wheat (WW) - winter barley (WB) - (Terra life Rigol[3], species mixture as intermediate crop) – maize (M) + undersowing *Festuca sp*.

Tillage: inversion tillage every year.

Pesticide use: medium-to-**low** (mean 2012-14 TFI=1.9) compared to the German standards.

IPM tools:

- Monitoring and warning system use, threshold based pesticides use + 25% reduced pesticides dosages
- WW: 1 spring herbicide application, 1 fungicide treatment; cultivar identical with CS cultivar *cv. JB Asano,* optimised fertilizer no need for PGR, TFI 2.2.
- WB: reduced herbicide application (in autumn), medium resistant and high yielding hybrid cultivar *cv. Hobbit,* 1 fungicide, 1 PGR; TFI 2.2.
- M: undersowing of *Festuca sp*., related use of different species and herbicide treatment respectively, TFI 1.27

[3] https://www.dsv-saaten.de/zwischenfruechte/terralife/rigol.html

Advanced system (AS):

Crop sequence: winter wheat (WW) - winter barley (WB) - (Terra life Rigol, species mixture as intermediate crop) –maize (M) + undersowing *Festuca sp*.

Tillage: inversion tillage every year.

Pesticide use: low (mean TFI=1.61) compared to the German standards.

IPM tools:

- Monitoring and prognosis system use, threshold and disease intensity based pesticides use, 25% to 75% reduced pesticide dosages.
- WW: higher resistant but good yielding cultivar *cv. Meister;* electron treatment for enhancing resistance to soil borne diseases; delayed sowing (10 days) for allowing 2 false seedbed, disadvantaging weed emergence and reducing disease risk; higher sowing density; spring harrowing replacing herbicides (50% effectiveness) in 2 of 3 years, required additional corrective herbicide spray, 1 fungicide spray, TFI 1.05, expected yield regional average WW 60.4 dt/ha, *cv. Meister* 78 dt/ha.
- WB: higher resistant but good yielding cultivar *cv. Souleyka,* delayed sowing (10 days) for reducing disease risk and allowing false seedbed; higher sowing density; 1 herbicide; 1 fungicide, 1 PGR; TFI 2.25; expected yield *cv. Souleyka* 83 dt/ha (2 year average regional variety testing).
- M: undersowing of *Festuca sp*., related more difficult herbicide treatment, TFI 1.55

4.2.2. DEXiPM

4.2.2.1. Overall sustainability

After one complete rotation **the three cropping systems achieved a medium score (3/5) in term of overall sustainability**. Nevertheless, this result is obtained by very different combinations of performances on the three components of sustainability. In the current cropping system (CS) it is due to the high economic performance (4/5) and high social performance (4/5) whereas the environmental sustainability is low (2/5). In the intermediate system (IS), the economic performance remains high (4/5) and the environmental sustainability increases to medium level (3/5) but the social sustainability decreases[4] to medium (3/5). In the advanced system, the economic sustainability decreases to medium (3/5) but a high environmental sustainability (4/5) is achieved. The shifts of individual parameters are discussed in the following subsections.

[4] Decrease of social sustainability is due to the higher requirements to farmer knowledge (IS, AS) in the decision making process.

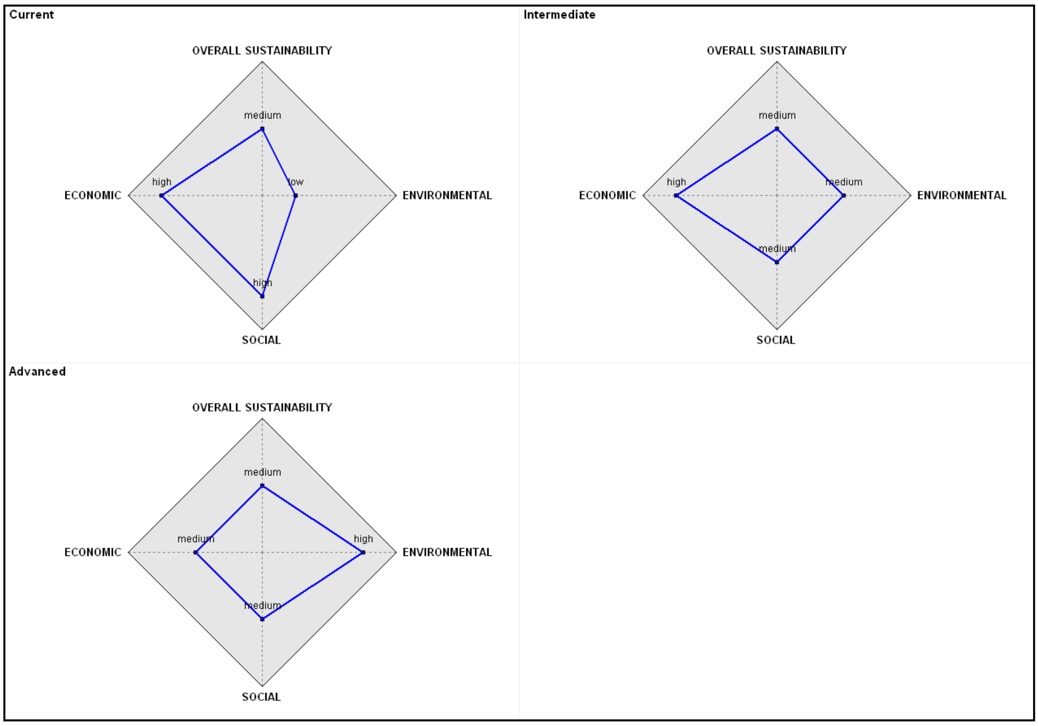


Figure 24: Overall sustainability 2012-14

4.2.2.2. Economic sustainability

Economic sustainability has been judged high for the CS and the IS and medium for AS. The decrease in the AS is due to the decrease of the values profitability and viability from high (CS, IS) to medium in the AS.

Profitability: decreases from high (4/5) in CS and IS to medium (3/5) in AS. The trigger is the low gross margin (2/5) in AS (medium in CS and IS).

Viability: reduction from high (4/5) in CS and IS to medium (3/5) in AS. The decrease is due to medium economic independency (2/3), low economic efficiency (1/3) and medium investment capacity in the AS (2/3) compared to high economic independency and investment capacity in CS and IS (3/3).

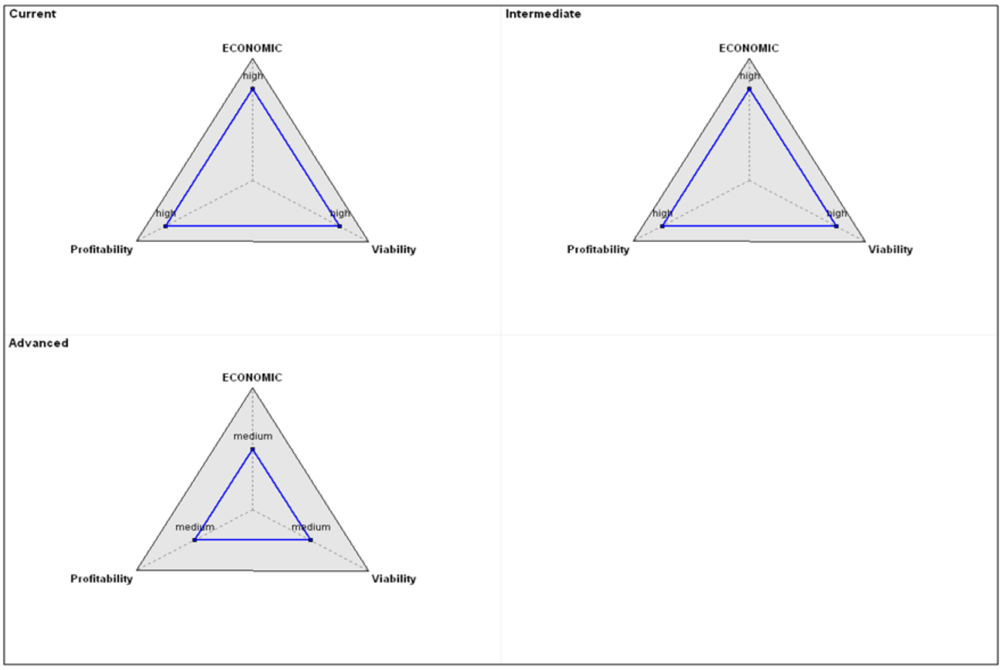


Figure 25: Economic sustainability 2012-14

Economic efficiency: the low economic efficiency (1/3) in AS can be attributed to the low gross margin (2/5) and the medium production value in AS (3/5) compared to medium levels of gross margin (3/5) and high production value (4/5) in CS and IS.

Production value: high in CS and IS and medium in AS. The attribute 'Production value' is the result of the aggregation of yield and selling price. The selling prices remain the same in all systems as there is no price premium for IPM produce. The yields in CS and IS are comparable whereas the yields in AS are considerably lower, due to a lower yield potential and agronomic effects. Moreover, the yield loss, i.e. loss of production value, was not compensated by reduced pesticide costs in the AS.

Investment capacity: high in CS and IS and medium in AS. Capacity of investment differs between the systems but the reduction is triggered by the higher requirements to agricultural equipment mainly for mechanical weed control in the AS.

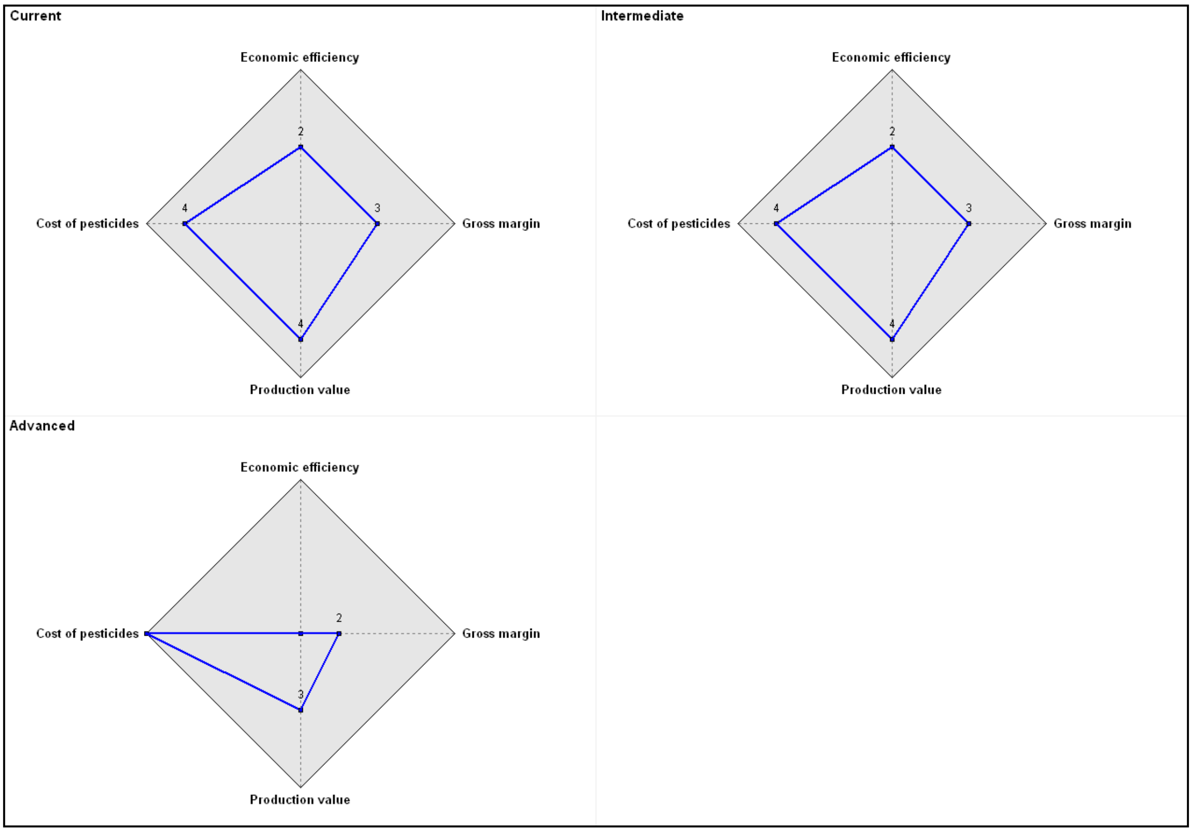


Figure 26: Economic efficiency 2012-14

4.2.2.3. Social sustainability

The social sustainability is high in CS and medium in IS and AS. This results from the combination of different values of the production chain level (CS: very high, IS: high for, AS: medium), the requirements to and effects on the farmer (for CS: medium, IS and AS: low) and the interaction with the society (CS: medium, IS: high, AS: very high) (figure 27).

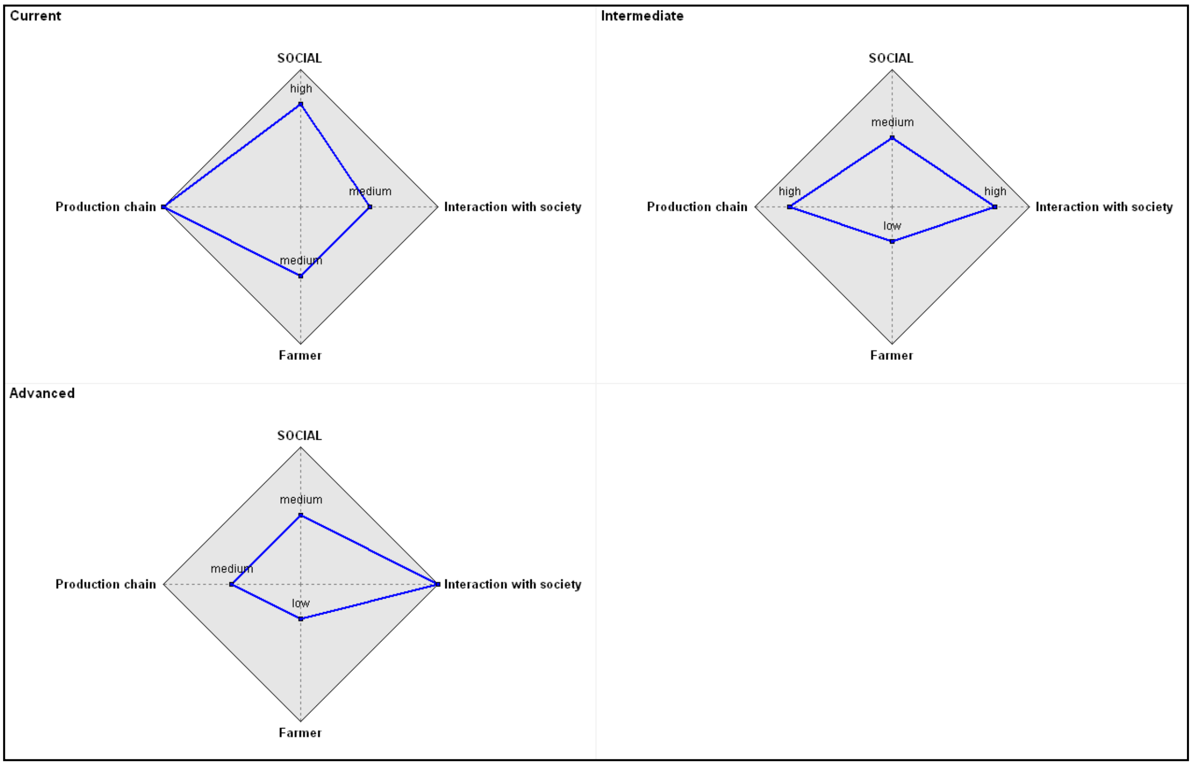


Figure 27: Social Sustainability 2012-14

Production chain level: expresses the feasibility of the system form the production chain perspective. In CS and IS, there are no limitations in accessing to inputs (i.e. innovation) (3/3) but in AS the access to input is restricted (1/3). The parameter access to knowledge is high in CS, medium in IS and high in AS. The value of access to output parameters remains at medium (i.e. possible) in all systems as there are no general differences in the CS and rotation as such.

Access to inputs: no limitation in CS and IS but in AS limited due to the electron treatment of seeds and the information required for the choice and levels of pesticide treatment.

Access to knowledge: In the CS the access to knowledge is high (i.e. easy accessible) and no particular additional requirements exist for the grower, external support (3/3) and advice for the strategy (3/3) are easily available. In IS, the requirements on the knowledge of the grower increase because more skills are required in the decision making process and adaptation of treatments to the given situation as well as the use of the available tools. Access to external support (2/3) and advice for the strategy (2/3) on the individual farm level situation are less available. In AS the requirements to the farmer knowledge is higher than in IS and the access to external support (2/3) and advice for the strategy (2/3) are more difficult. The parameter system complexity increases from low in CS to medium in IS and high in AS. This represents a certain constraint for the farmer and therefore the sustainability decreases.

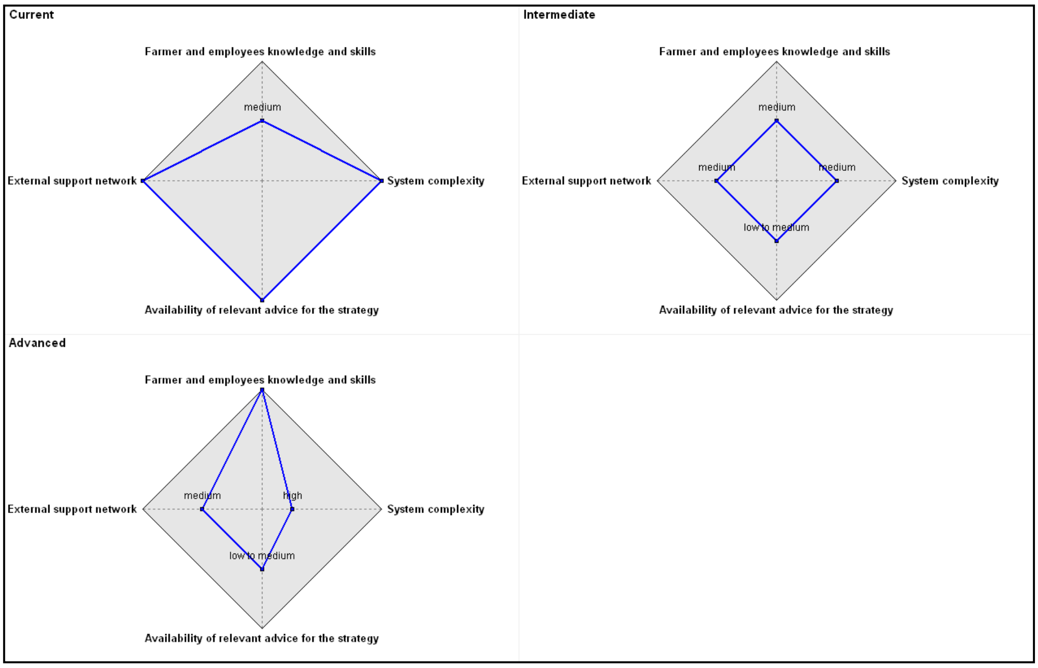


Figure 28: Access to knowledge 2012-14

The **interaction with society**, i.e. acceptance and recognition by the society, increases from medium in CS (3/5) to high in IS (4/5) and very high (5/5) in AS. The criteria which influence the increase are better contribution to employment (2; 3; 4/4) and increasing societal valuation of the landscape (2; 3; 3/3) from CS to AS respectively and an increased acceptability of the strategy (i.e. reduced ppp use) by the society in AS.

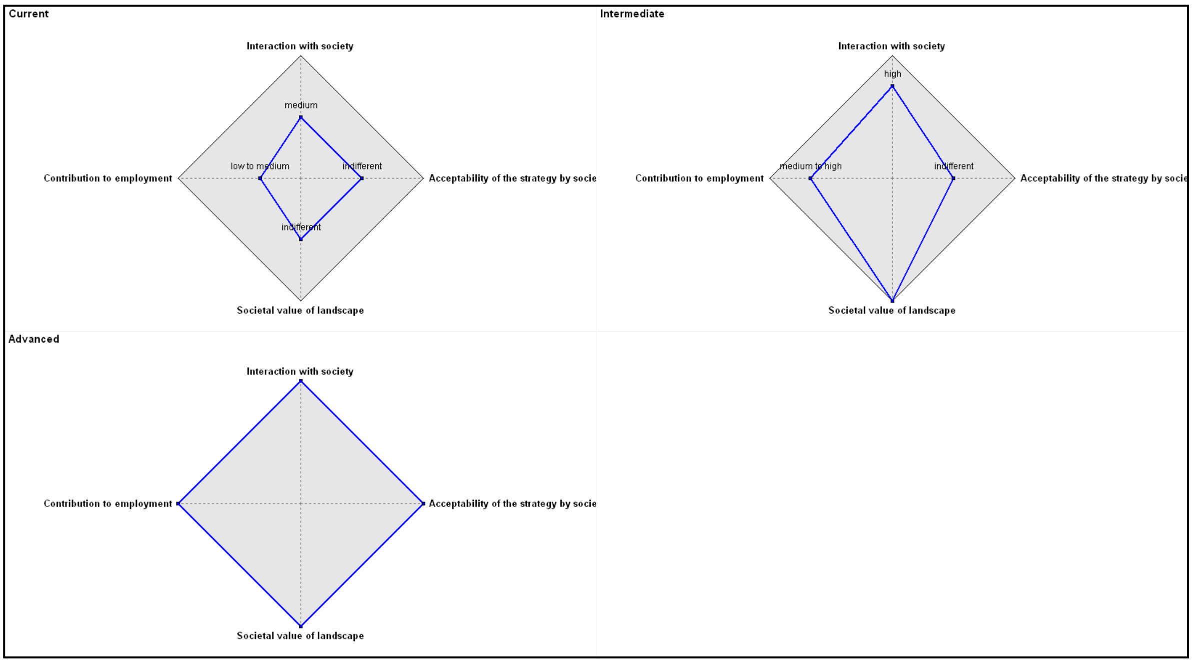


Figure 29: Interaction with society 2012-14

4.2.2.4. Environmental sustainability

According to the assessment results, environmental sustainability increases from low (CS) to medium (IS) and high (AS). These values result from the combination of the assessments of the sustainability of resource use which is low in CS and IS and medium (3/5) in AS. The environmental quality also increases from low in CS to medium in IS and high in AS and biodiversity levels increase from low in CS to medium in IS and high in AS.

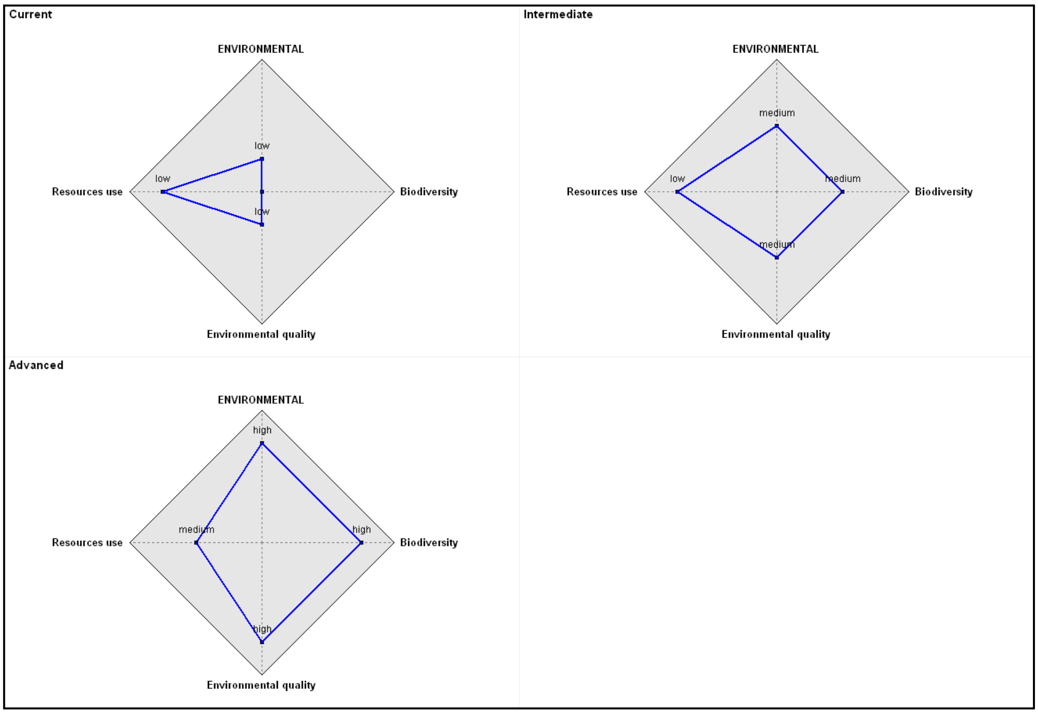


Figure 30: Environmental sustainability 2012-14

The **resource use** assesses the consumption of renewable and non-renewable resources, i.e. water use, land use, energy use and use of mineral fertilizer. The energy use is scored high to medium, the land use is medium to low in both CS and IS and high to medium in AS due to the lower yields. The sustainability of water use is high, because there is no irrigation used, and the sustainability of fertilizer use (stable fertilizer use across the systems) is low in all systems.

Environmental quality is the impact of the cropping system on the local environment and determined by **water and soil quality and air emissions** (figure 31).

For the **water quality,** no change across the systems can be observed. The overall water and ground water quality is judged very high, the eutrophication potential low and the aquatic ecotoxicity medium to low.

Ground water quality is very high across all systems. Zooming into the determinants it can be observed that the potential pesticide leaching is very low in AS and medium to low in CS and IS. The differences can be explained by a low potential risk of single active substances in CS and IS compared to a very low risk potential in AS (figure 32).

The increase from low (CS) to high (AS) is due to increasing **soil quality** from low (1/4) in CS to low-medium (2/4) in IS and medium – high (3/4) in AS. The increase is based on the improvement of physical (CS: 1/4, IS: 3/4, AS: 4/4) and biological (CS: 1/4, IS and AS: 2/4) soil quality (figure 33) due to the undersowing of *Festuca sp.* in maize.

The improvement, i.e. reduction of **air emissions**, can be explained by the reduced pesticide use expressed by the parameter pesticide volatilisation which is a function of total pesticide TFI and risk of pesticide drift (figure 34).

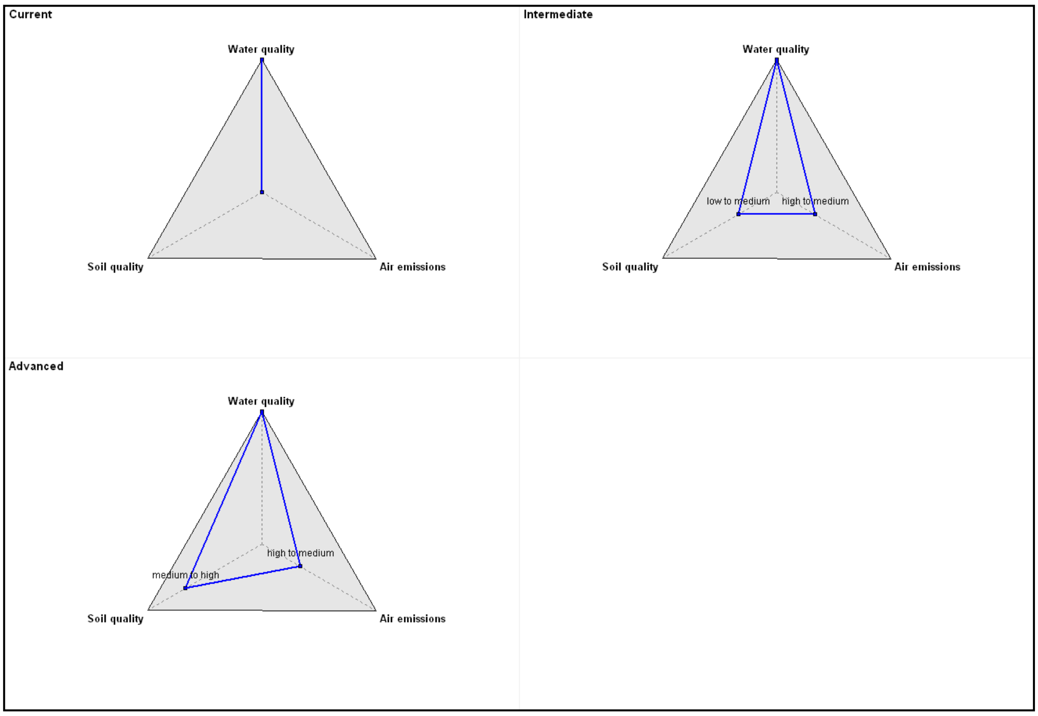


Figure 31: Environmental quality 2012-14

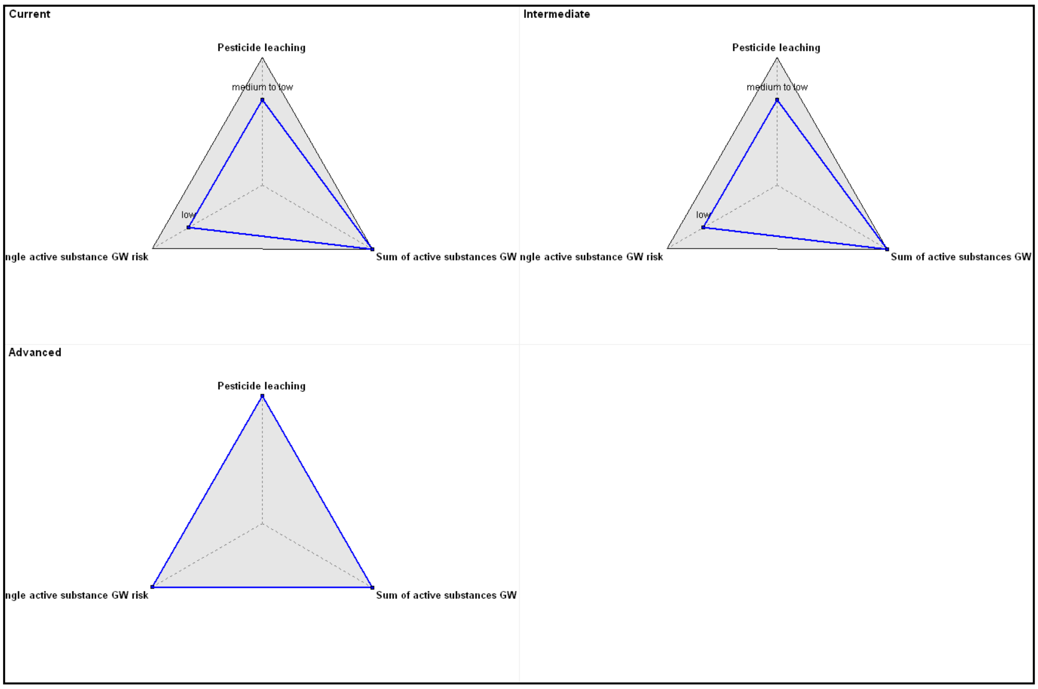


Figure 32: Potential risk of pesticide leaching into groundwater 2012-14

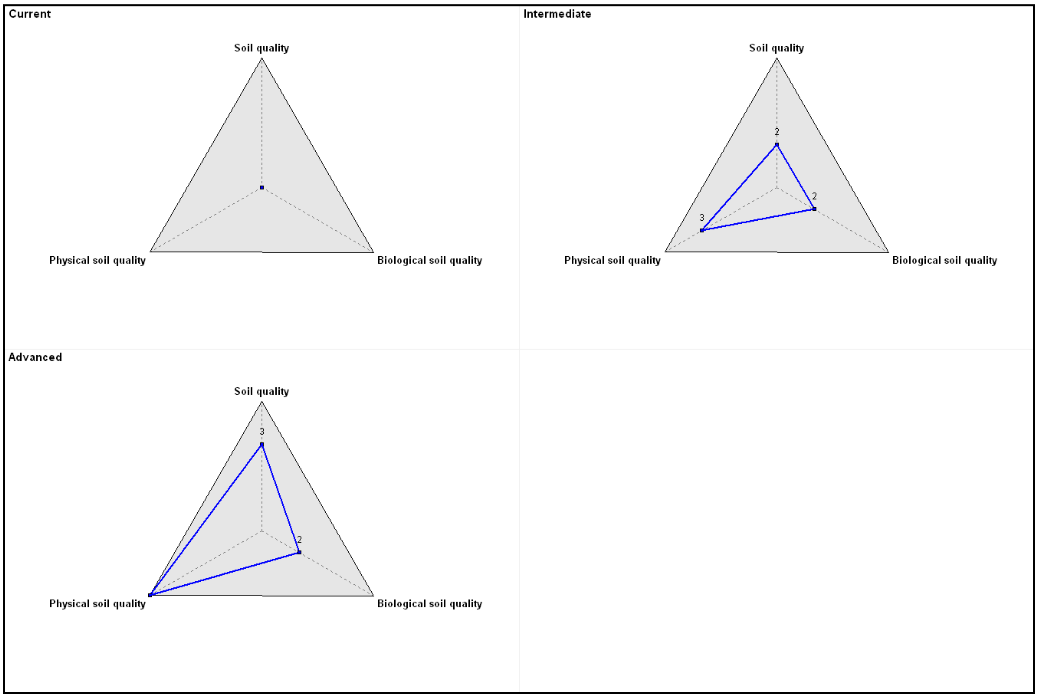


Figure 33: Soil quality 2012-14

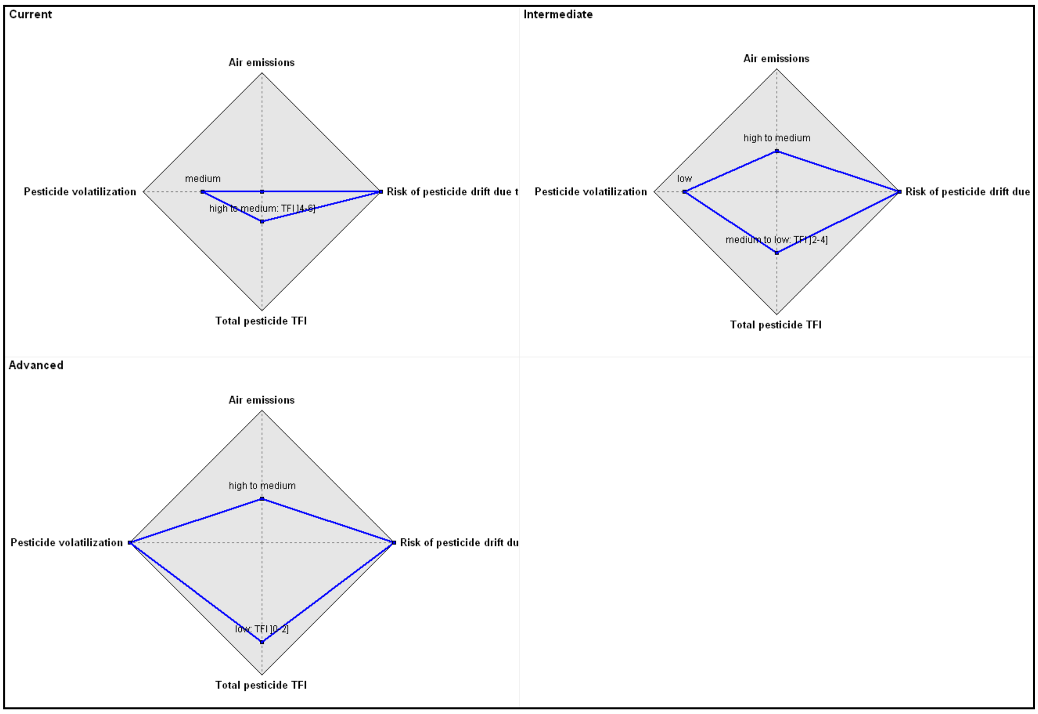


Figure 34: Air emission 2012-14

The biodiversity improves in the assessments from very low in CS to medium in IS and high in AS. The increase is explained by the positive impacts both systems IS and AS have on fauna (the corresponding score improves from very low in CS to low-medium in IS and medium-high in AS) and flora (the corresponding score increases form very low in CS to medium-high in IS and AS; figure 35).

The value **Fauna** is the assessment of diversity and abundance of species groups affected by crop protection. The changes in cropping systems had no effects on the diversity and abundance of soil natural enemies which is assessed as low. The levels for flying natural enemies increased slightly from low –medium in the CS to medium-high in IS and AS due to the improvement of flora in the latter systems. The parameter of the abundance and diversity of pollinators increased from low-medium in CS to medium-high in IS and very high in AS. The change is due to the improvement of flora (CS: 1/4) to IS and AS (3/4) and to the improvement of crop effects in AS (3/4 vs. 2/4 in CS and IS). Although the choice of pesticides was not driven by their ex-ante assessment of potential risks the pesticide pressure on pollinators was low across all systems.

The values for **Flora** have improved from CS, very low, to medium-high in IS and AS, which was caused by the increase of the diversity (CS: 1/4; IS and AS: 2/4) and abundance (CS and IS: 2/4 and AS: 3/4) of weeds due to reduced herbicide dose rates and mechanical weeding.

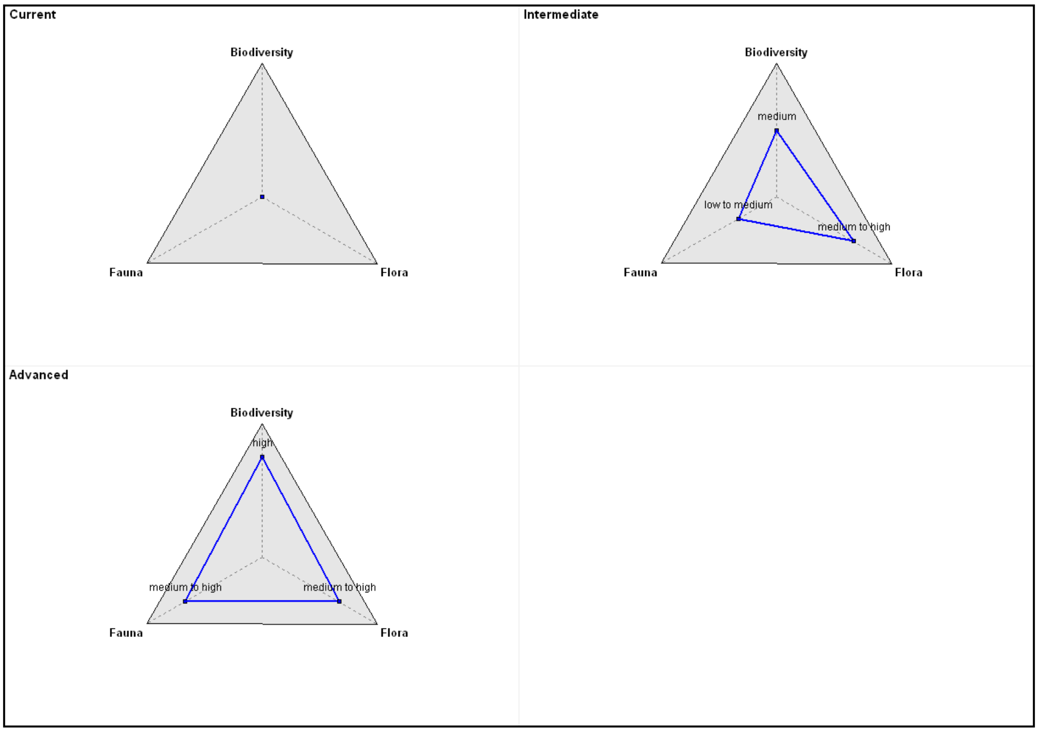


Figure 35: Biodiversity 2012-14

4.2.3. SYNOPS results

The assessment of the potential risk did not indicate major differences between the systems. The potential acute and chronic risks for aquatic organism of the rotation range from medium to low exposure toxicity ratios.

Table 5: SYNOPS results for aquatic risk

		Acute risk						Chronic risk					
2012-14		Aquatic	Algae	Daphnia	Fish	Lemna	Chironomus	Aquatic	Algae	Daphnia	Fish	Lemna	Chironomus
CS	AVG	0,135777	0,11235733	0,00012733	0,00035967	0,05966233	0,00058033	0,63050733	0,32874867	0,00203767	0,003051	0,50593867	0,00056233
	MAX	0,241541	0,241541	0,000252	0,000604	0,093639	0,001716	1,042084	0,678663	0,003538	0,003807	1,042084	0,001597
IS	AVG	0,09684833	0,08333	0,00872233	0,002184	0,086081	0,001064	0,886457	0,59620567	0,074693	0,07637033	0,72555633	0,001154
	MAX	0,133257	0,131374	0,025914	0,004859	0,133257	0,003192	1,288411	1,155771	0,214257	0,215189	1,288411	0,003462
AS	AVG	0,12154367	0,10599067	0,00084444	0,00082689	0,06195489	0,00263444	0,64206478	0,35174011	0,17649289	0,00674133	0,41100056	0,00239378
	MAX	0,320882	0,320882	0,003246	0,001781	0,119414	0,016718	1,663361	1,663361	1,501834	0,017735	1,042084	0,015018

The higher risk potentials for pesticide leaching to ground water in the IS and AS are due to different herbicide the strategies in maize due to the undersowing of *Festuca sp.*.

Table 6: SYNOPS results for risk to groundwater

		Pesticide Leaching Risk	
2012-14		single a. i.	sum a. i.
CS	AVG	0,00519133	0,001038
	MAX	0,008675	0,001735
IS	AVG	0,43797633	0,08759533
	MAX	1,312113	0,262423
AS	AVG	0,02561089	0,00512211
	MAX	0,214478	0,042896

Table 7: SYNOPS results concerning the risk for terrestrial organisms

		Acute risk			Chronic risk		
2012-14		Terrestrial	Earthworm	Bee	Terrestrial	Earthworm	Bee
CS	AVG	0,00104567	0,00104567	0,00024367	0,016193	0,016193	0,00186567
	MAX	0,001538	0,001538	0,000543	0,028397	0,028397	0,00485
IS	AVG	0,006377	0,00152733	0,00581833	0,050598	0,025307	0,045068
	MAX	0,011791	0,002596	0,011791	0,076556	0,057912	0,076556
AS	AVG	0,00153133	0,00150911	0,00038689	0,01817111	0,01778356	0,00410133
	MAX	0,004993	0,004993	0,000844	0,050434	0,050434	0,009925

4.2.4. CBA results

In the on-station experimentation in Germany, the gross margin of the CS and IS are not significantly different. Whereas, in the AS the gross margin is significantly lower due to lower yields which are not compensated by significantly reduced pesticide costs. Costs for monitoring and field observations are not calculated into the cost model but present an additional cost factor.

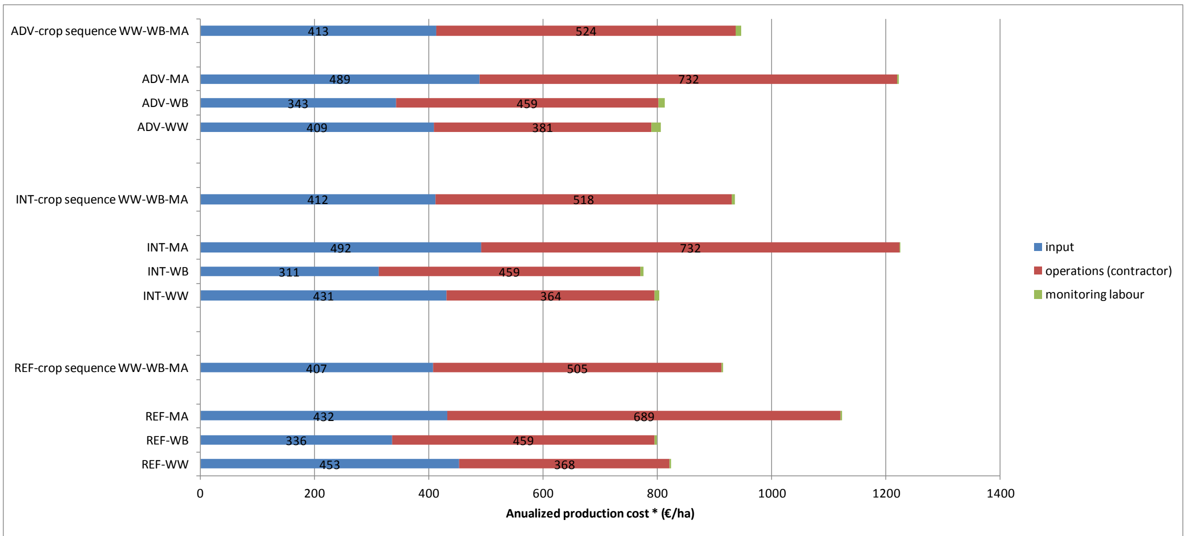


Figure 36: Annualized production costs 2012-14

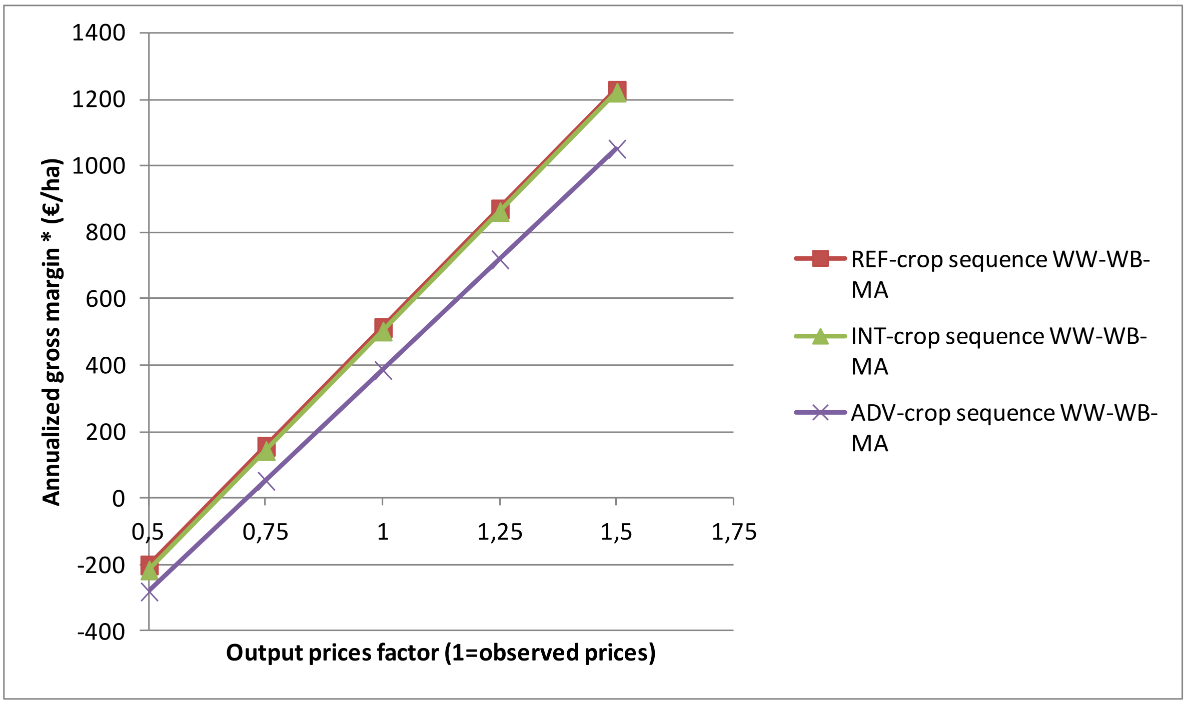


Figure 37: Annualized gross margin 2012-14

4.3. South Region – France

4.3.1. Description of location and systems

Context

Site: Grignon, France, Ile de France
Soil and climate: silt soil, deep soil, high hydric reserve, low erosion risk
Regional context: main crop: cereal - intensive production

Cropping systems

Current system (CS):

Crop sequence: winter wheat (WW) - winter oilseed rape (WOSR) – winter wheat – spring pea (SP)
Tillage: inversion tillage every year.
Pesticide use: high-to-medium (mean TFI=4.76) compared to the French standards.

- WW (both): 1 herbicide application, resistant cultivar + 3 fungicides, 1 insecticide and 1 PGR. Expected yield: 9.5 t/ha.
- WOSR: 1 herbicide application, resistant cultivar + 1 fungicide, 1 insecticide and 2 PGR. Expected yield: 4.6 t/ha.
- SP: 2 herbicide applications, resistant cultivar + 1 fungicide and 1 insecticide. Expected yield: 3.6 t/ha.

Intermediate system (IS):

Crop sequence: winter faba bean (WFB), winter wheat, winter oilseed rape, winter wheat, (mustard as intermediate crop) – spring barley (SB).
Tillage: inversion tillage less than one out of five years.

Pesticide use: medium-to-low (mean TFI=2.09) compared to the French standards.
IPM tools:

- Diversifying crops and shifting sowing dates, thresholds for insect pests and diseases, reducing the frequency of deep tillage against slugs.
- WFB: 1 mechanical weeding + 1 herbicide application, cultivar resistant to disease and lodging + 1 fungicide (if needed), no insecticide, no PGR. Expected yield: 3.4 t/ha.
- WW (both): 1 mechanical weeding + 1 herbicide application, cultivar resistant to disease and lodging + 1 fungicide and 1 insecticide (both if needed), no PGR. Expected yield: 7.9 t/ha.
- WOSR: early sowing (against weeds, Phoma and some autumn insects) of mixture of cultivars with high light competition and resistant to diseases and lodging. Mechanical weeding, no herbicide, 1 fungicide and 1 insecticide (both if needed), no PGR. Expected yield: 3.1 t/ha.
- SB: 1 herbicide application, cultivar resistant to disease and lodging + 1 fungicide (if needed), no insecticide, no PGR. Expected yield: 6.2 t/ha.

Advanced system (AS):

Crop sequence: (mustard species mixture as intermediate crop) – spring faba bean (SFB), winter wheat, (mustard species mixture as intermediate crop) – hemp (H), triticale (T), (mustard species mixture as intermediate crop) –maize (M), winter wheat.
Tillage: deep tillage one year out of two, before each spring crop.
Pesticide use: zero pesticide.
IPM tools:

- Diversifying the crop sequence introducing high competitive species (hemp, triticale) and cultivars against weeds.
- Diversifying sowing periods with 3 spring and 3 winter crops and shifting sowing dates (early/late sowing dates) in order to reduce the specialization of the weeds and the autumn weeds' seed-bank.
- Mechanical weeding for all the crops.
- Diversifying the species and shifting sowing dates (early/late) against insect pests and diseases.
- No deep ploughing before each spring crop and between maize and wheat to limit slugs and favour soil natural enemies.
- SFB: cultivar resistant to diseases and lodging, wide row spacing to allow mechanical weeding. Expected yield: 4.7 t/ha.
- WW (both): wide row spacing for mechanical weeding, late sowing to reduce the sensitivity to disease, autumn insects and slugs and to allow more false seedbed. High seed density to compensate losses (hoeing, late sowing). Cultivar mixture including varieties with high light competiveness. Expected yield: 5.5 t/ha.
- H: high seed density for quick soil cover (weed competiveness). Expected yield: 10 t dry matter/ha.
- T: wide row spacing for mechanical weeding, Cultivar mixture including varieties with high light competiveness. Expected yield: 4.2 t/ha.
- M: row spacing for mechanical weeding. If necessary, biological control against *Diabrotica*. Expected yield: 7.3 t/ha

4.3.2. DEXiPM

4.3.2.1. Overall sustainability

After one complete rotation **the three cropping systems achieved a high score (4/5) in term of overall sustainability**. Nevertheless, this result is obtained by very different combinations of performances on the three sustainability pillars. Indeed, the current cropping system (CS) shows very-high and medium performances in terms of economic and environmental sustainability while the environmental sustainability is judged low. The latter has increased in intermediate (IS) and advanced (AS) cropping systems obtaining respectively high and very-high values, while the economic performances have decreased (high in both IS and AS). Finally, the social sustainability has remained medium for all systems.

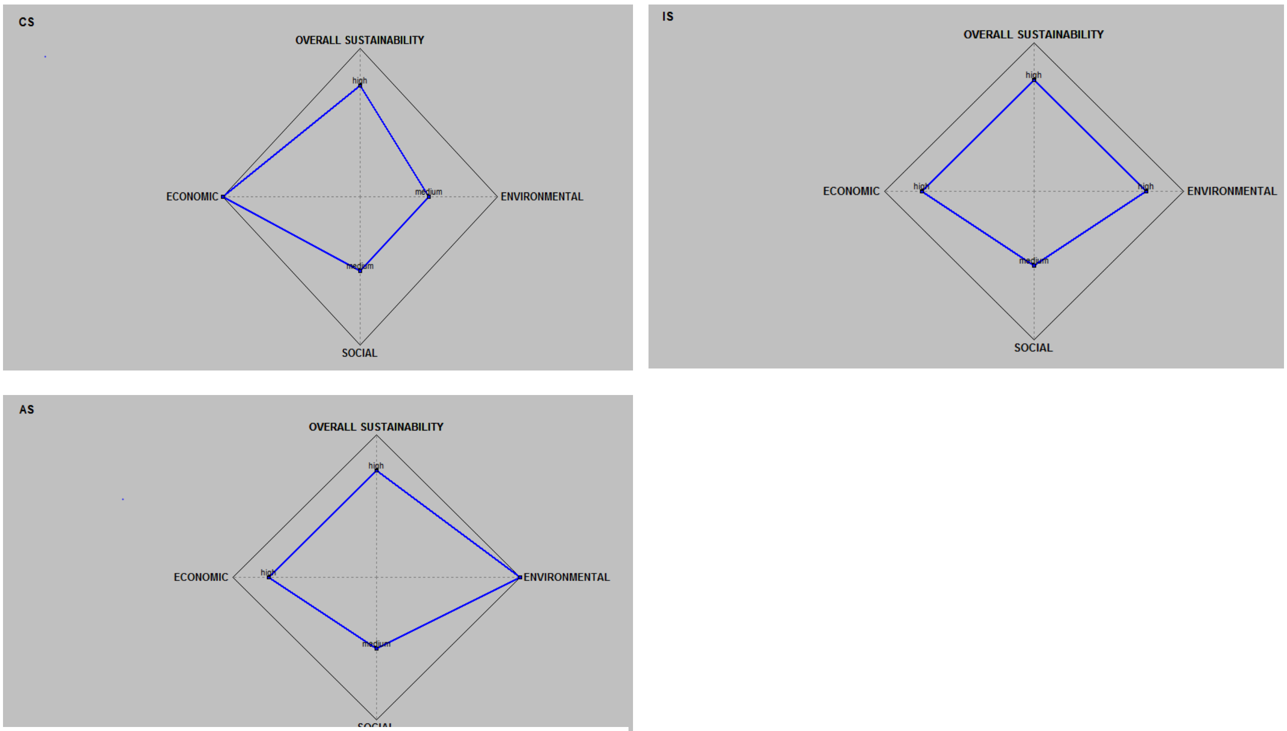
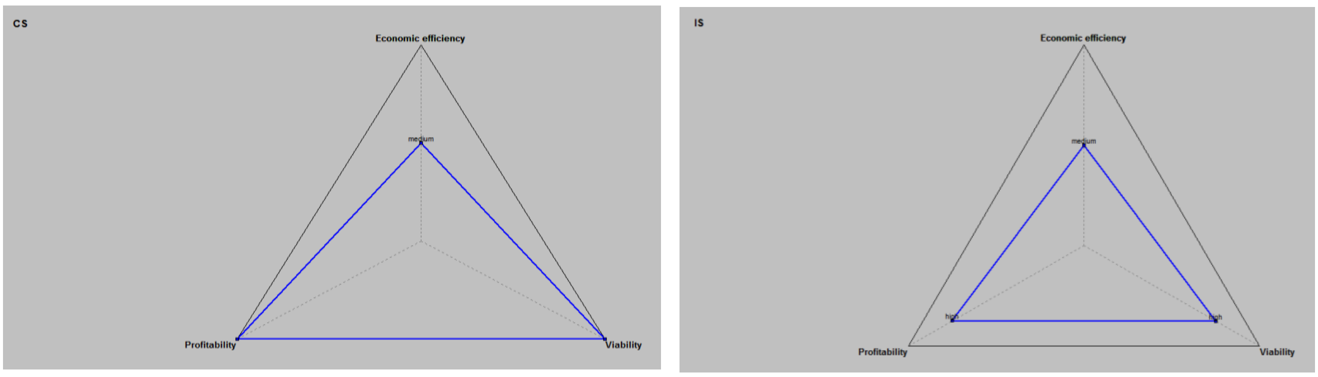


Figure 38: Overall sustainability 2012-14

4.3.2.2. Economic sustainability

Economic sustainability has been judged very-high for the CS, while it is high for IS and AS. This situation results from the combination of different values for real profitability and viability which are both very high in CS and high in IS and AS.



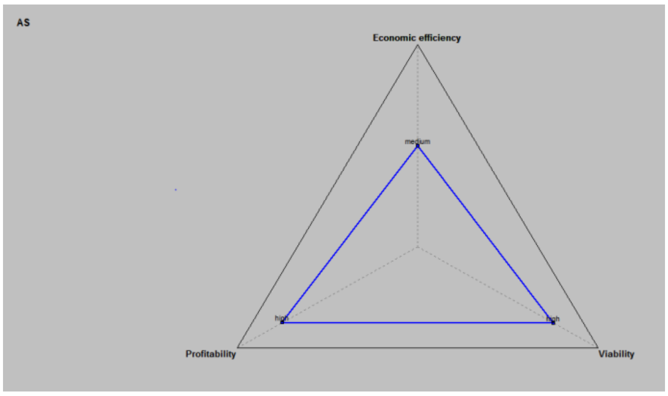


Figure 39: Economic sustainability 2012-14

Production risk: low in CS and IS, high in AS. The total absence of pesticide use enhance the risk of high pest attacks in AS. However, there were low pest pressures during these last years (specifically in 2009, 2010, and 2011).

Labour cost: very-low in CS, very-high in IS, medium-to-low in AS.
Considering a medium hourly wage, the difference is due to the number of working hours needed to implement the systems. Systematic pesticide treatments in CS are not time-consuming, while in IS the need for intensive monitoring before use pesticides need much more time, finally in AS monitoring is needed only for mechanical weeding.

Production value: very-high in CS, high in IS and AS.
This attribute is the result of the aggregation of yield and selling price. The first one is very high in CS and high in IS and in AS, because there is no decrease of yields with a reduce (IS) or without (AS) pesticide use (linked to the low pest pressures during these last years, specifically in 2009, 2010, 2011).

Economic efficiency: medium in CS, in IS and AS.
This attribute is the result of the aggregation of selling price and pesticides prices. The first one is very high in CS and high in IS and in AS, and the second one is very high in AS, high in IS and medium in AS.

Investment capacity: high in CS and medium in IS and AS,
Capacity of investment is different according to the system: high in CS and medium in IS and AS, due to difficulties to by mechanical weeding materials.

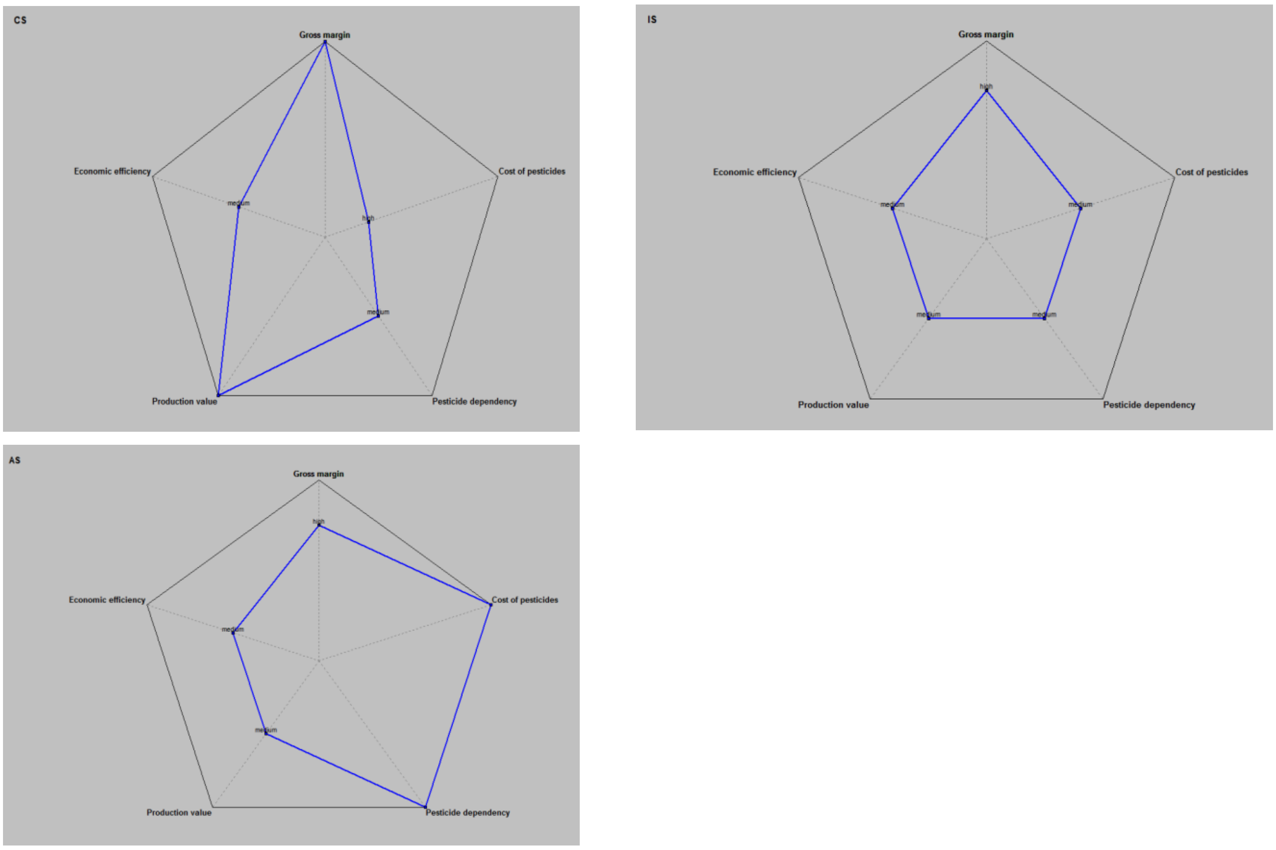


Figure 40: Economic efficiency 2012-14

4.3.2.3. Social sustainability

The social sustainability has been judged as medium in all systems (CS, Is and AS). This results from the combination of different values of the production chain level (very-high for CS, high for IS, medium for AS), the farmer (low for CS and IS, medium for AS) and the interaction with the society (very-low for CS, very-high for IS, high for AS).
Regarding the feasibility at the **production chain** level, there is no limit in accessing to inputs, knowledge and output market in CS while the access to inputs is limited gradually in IS and AS.

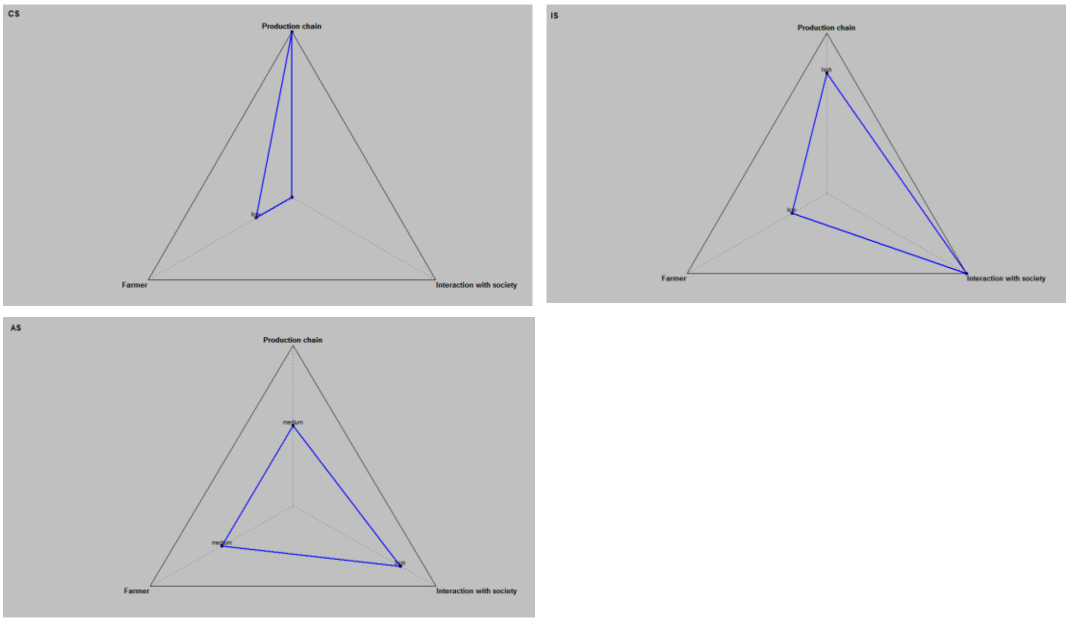


Figure 41: Social sustainability 2012-14

Access to inputs: easy in CS and IS, limited in AS. In AS this is limited because of hemp and the use of cultivar mixtures

Access to knowledge: high in all the systems. The farmers considered have high skills, especially regarding the capability of transmitting information. Moreover, even without an existing network of farms, the knowledge needed for implementing the system is considered commonly available because it is mostly about standard and efficient pesticide use, and mechanical weeding, which is currently widespread among advisers.

The low **farmer** sustainability of CS and IS results from a combination of low job gratification (fixed for all the systems because of the general context in arable crops), low-to-medium operational difficulties in CS and high to medium in IS, and very low health risks in CS and high in IS. AS scored a higher value medium because of the consistent improvement of the situation from the health point of view (low risks).
Differences in operational difficulties are due to differences in system complexity (low in CS, medium in IS and AS) and evenness of workload distribution (medium in CS and IS, high in AS).

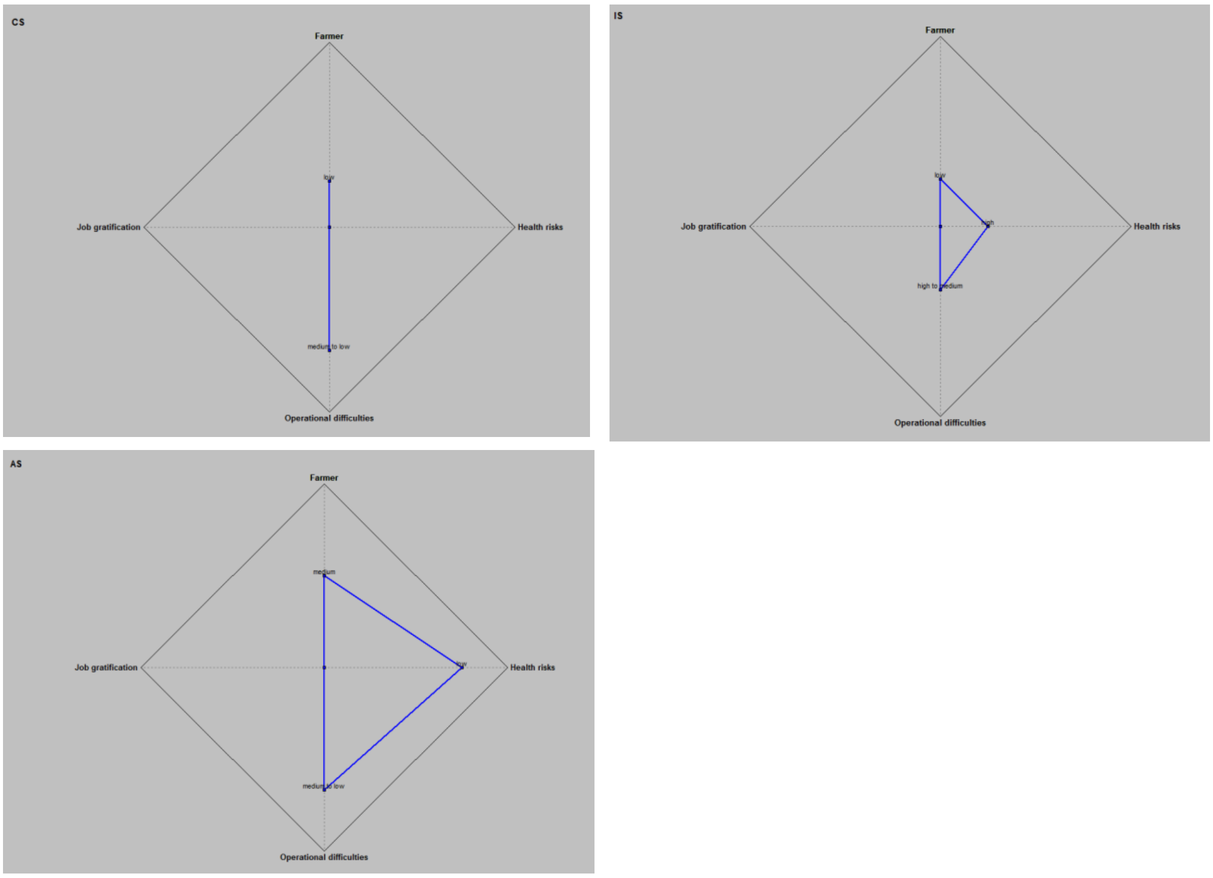


Figure 42: Farmer sustainability 2012-14

The health risk is considered very-high and high in CS and IS and low in AS mainly because of a high use of dangerous pesticides (TFI are respectively 4.7, 1.8 and 0), while the physical risk is medium for the three systems.

Lastly, the **interaction with society** has been judged as very-low in CS. This is due to a very-low contribution to employment, a bad societal value of the landscape, a high accessibility of the product and the low acceptability of the strategy. In AS the contribution to employment is slightly higher, while it is considerably higher in IS, and in both systems landscape and the strategy have been considered as more acceptable, while the product would probably be less accessible.

4.3.2.4. Environmental sustainability

According to the assessment results, environmental sustainability increases passing from CS (medium) to IS and AS (very-high). These values result from the combination of the assessments in terms of resource use (high in CS and very-high in IS and AS), environmental quality (from medium in CS, to very-high in IS and AS), and aerial and above-soil biodiversity (from very-low in CS and low in IS to very-high in AS).

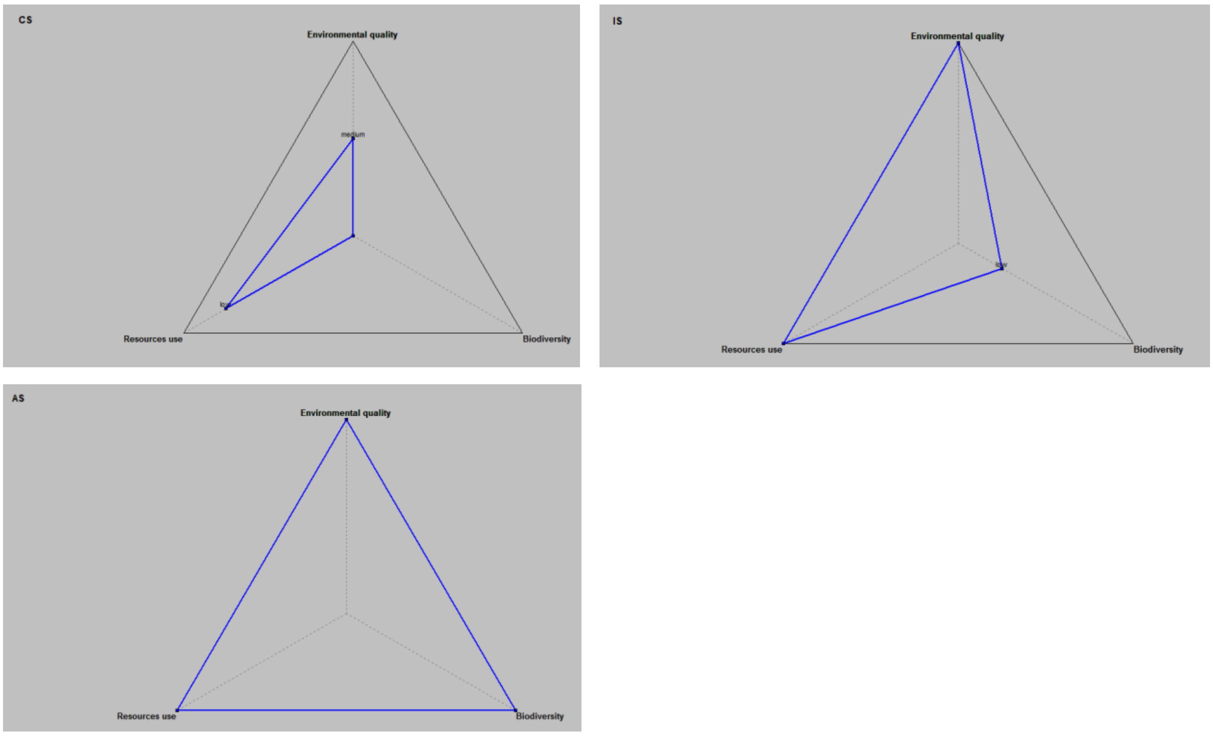


Figure 43: Environmental quality 2012-14

Concerning the **resource use**, CS scored a low value while in IS and AS are evaluated as very-low.

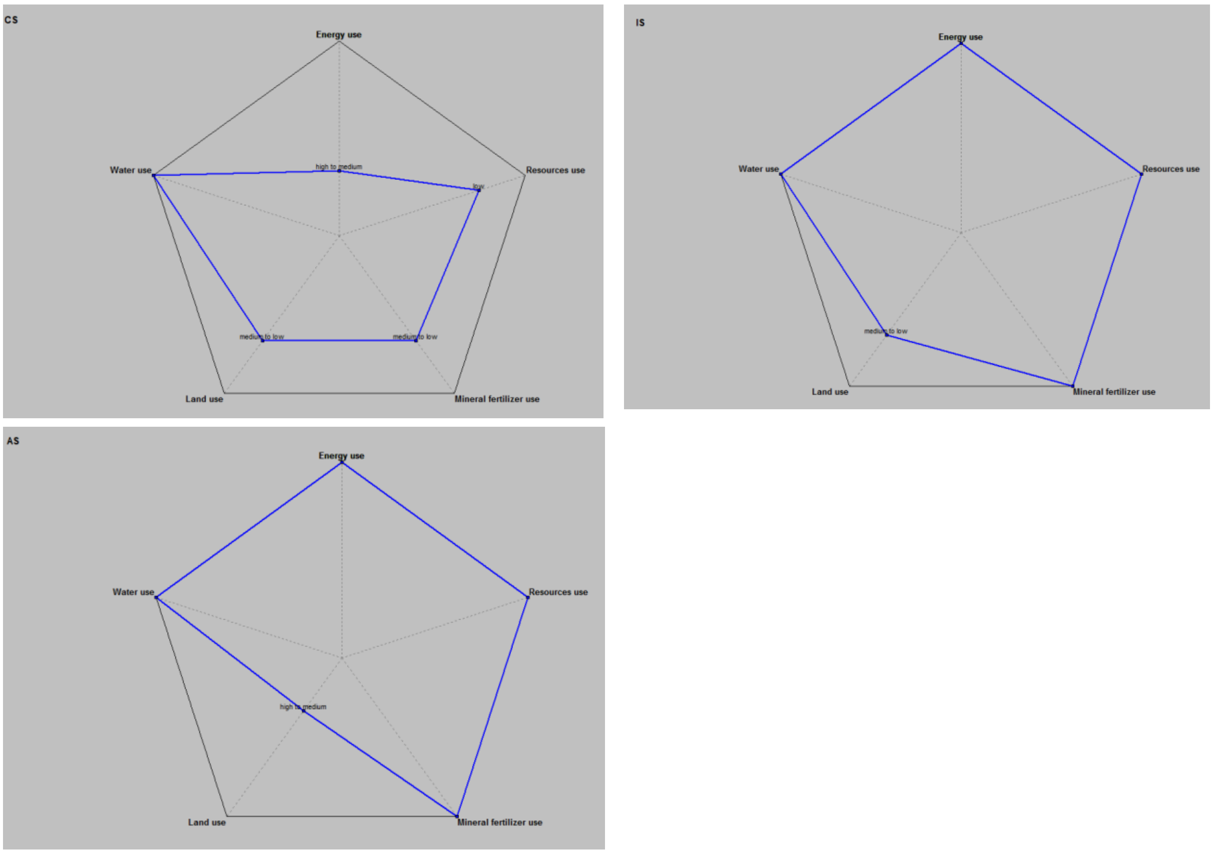


Figure 44: Resource use 2012-14

In CS, high value results from the combination of a very low **water use,** a low to medium **P-K fertilizer use** and in **land use** and a high to medium **energy use.** In IS, **water use, P-K fertilizer use** and **energy use** are very low, while **land use** is low to medium. In AS, **water use, P-K fertilizer use** and **energy use** are very low while **land use** is high to medium.
The differences in the energy attribute are due to lower energy consumption in AS and in IS (very-low) compared to CS (medium to high) which essentially are derived by a difference in indirect energy consumption (fertilizer and pesticide). Nevertheless it should be pointed out that IS energy consumption can be considered lower than CS because of the lower N use (lower yield objectives) and fuel machinery use (lower deep tillage frequency and spraying machine use).

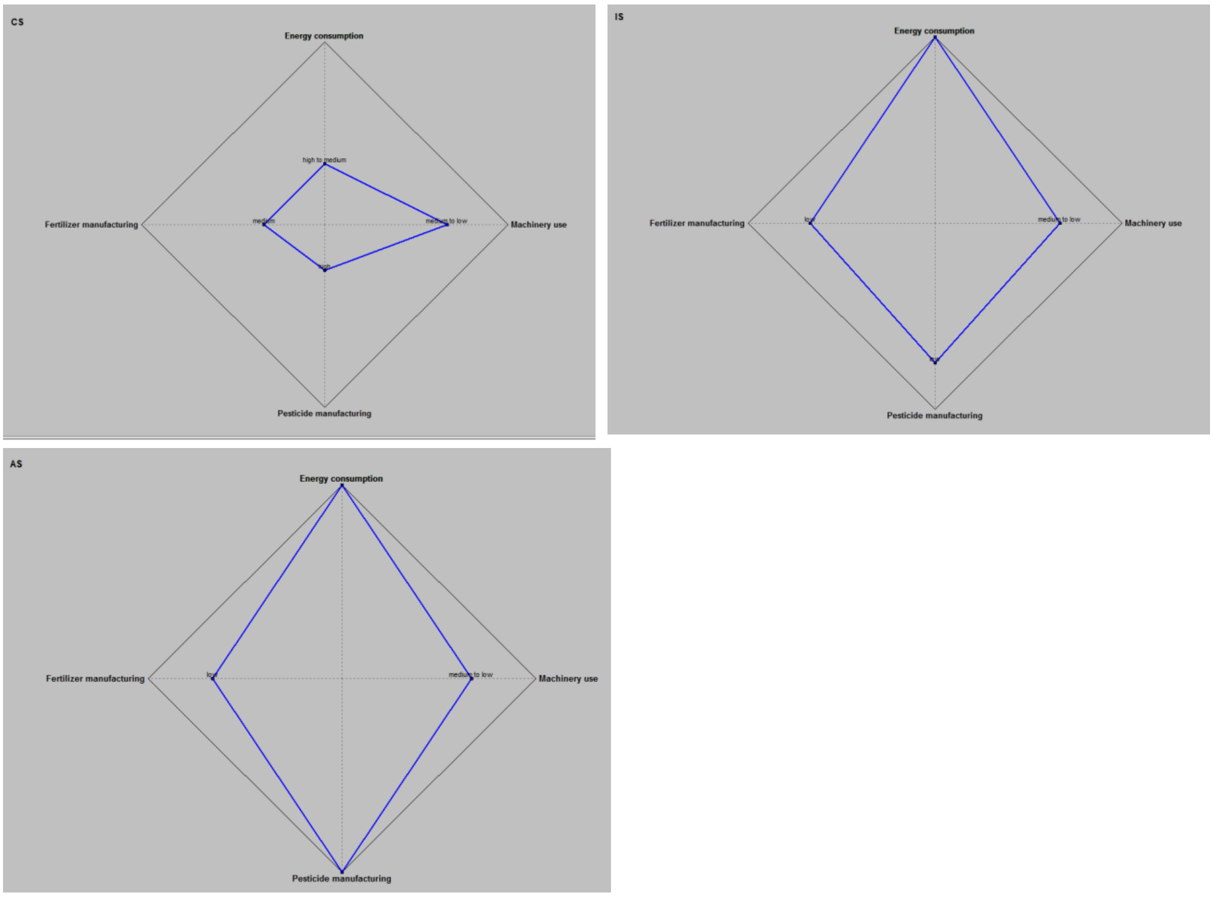


Figure 45: Energy consumption 2012-14

From the **biodiversity** point of view an expressive improvement can be observed for the alternative systems (AS) compared to the current ones (CS and IS). This attribute passes from very low for CS, low to medium in IS, to very high in AS. In these three systems both flora and fauna are also classified as very low, low to medium and very high respectively.

Zoom on the determinants

Natural and semi-natural **flora** is very low in CS and in IS, while it is one class higher in AS. Weeds biodiversity increases regularly from very low in CS, low to medium in IS to very high in AS. This value influences directly the upper level (**flora**) but also the fauna attribute (as a habitat factor).

> **Natural/semi-natural flora:** very low in CS and IS, medium to low in AS.
> No particular landscape management practice is implemented, but the non-use of herbicide in AS favours the development of spontaneous flora on non-productive areas.
>
> **Weeds:** very low in CS, low to medium in IS, very high in AS.
> This attribute is estimated by the combination of the diversity and abundance of weeds. Weed diversity is very low in CS, low to medium in IS and medium to high in AS, because of the important differences in herbicide use and the diversity of crops grown (two types in CS and IS, three types in AS). Weed abundance is low to medium in CS and in IS and medium to high in AS, because the weed management of the

latest one has different objectives compared to CS and IS. Indeed, a higher occurrence of weeds is tolerated in this system (AS).

CS **fauna** is characterized by very low levels of soil natural enemies and flying natural enemies, and low to medium of pollinators. Each of these attributes increases in the two alternative systems: soil natural enemies scored low to medium (IS and AS), pollinators obtained a medium to high and very high scores respectively in IS and AS, and flying natural enemies low to medium (IS) and very high (AS).

Soil natural enemies: very low in CS, low to medium in IS and AS.
The lack of a favourable habitat network is partly compensated by a reduced pesticide use and a reduced deep tillage frequency. It is also important to point out that ploughing in AS will not be performed as deep as in CS in order to have a less negative impact on soil beneficial.

Pollinators: low to medium in CS, medium to high in IS, very high in AS.
This is due, on one hand, to the pesticide use (insecticides and, to a lesser extent, fungicides) and, on the other hand, to the vegetal habitat: flora and crop effect on pollinators (more favourable in the alternative systems because of the introduction of mustard as cover crop and faba bean).

From the **environmental quality** point of view, we can observe the same strong improvement than in biodiversity, passing from a medium quality in CS to a very high quality in both IS and AS.
In the first system a medium to high water quality is combined to a low to medium soil quality and medium to low air emissions. In the two alternative systems (IS and AS) the quality of the three environmental compartments is improved: water quality reaches a very high level in both systems, soil quality is increased of two classes in IS, and is the same in AS (low to medium), and air emissions is very low in both IS and AS.

Water quality
Water quality is medium to high in CS and very high in IS and AS. In these three systems, eutrophication potential is judged very low (phosphorus, nitrate and pesticide leaching are not different in these three systems) and groundwater quality very high according to the characteristics of the soil and the distance to the nearest river. Differences appear in the aquatic ecotoxicity characteristics: high to medium, medium to low and very low respectively in CS, IS and AS. In IS and in AS there are a consistent reduction of pesticide uses (i.e. pesticide pressure: TFI are 4.7, 1.8 and 0 respectively for CS, IS and AS).

Aquatic ecotoxicity: high to medium in CS, medium to low in IS and very low in AS. As aquatic organisms in surface water are the objects of the analysis, runoff risk (medium to low in CS and AS, very low in IS) is coupled to the pesticide profile risk (ecotoxicity and TFI) (high to medium, medium to low and very low).

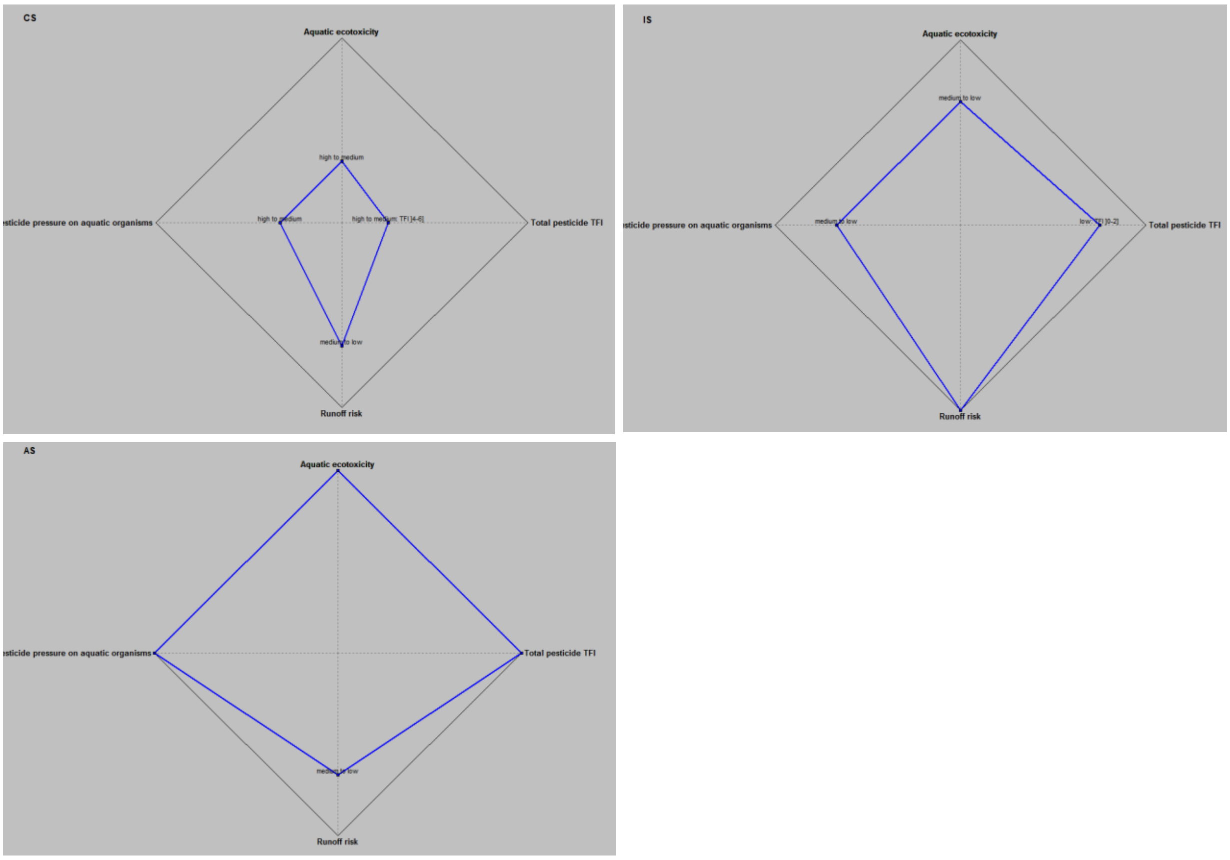


Figure 45: Environmental quality 2012-14

Soil quality is low to medium in CS and in AS, and very high in IS. It results to a combination of the physical, chemical and biological qualities.

The physical quality is very high for the CS and IS, while it is medium to low in AS. For CS and IS, the very high value of physical quality is obtained by the combination of very low compaction risk and an erosion risk going from medium to low (CS) to very low (IS). For AS the medium to low value of physical quality results in high to medium compaction risk and a medium to low erosion risk.

Erosion risk: medium to low in CS and AS, very-low in IS diversity of crops grown (two types in CS and IS, three types in AS).

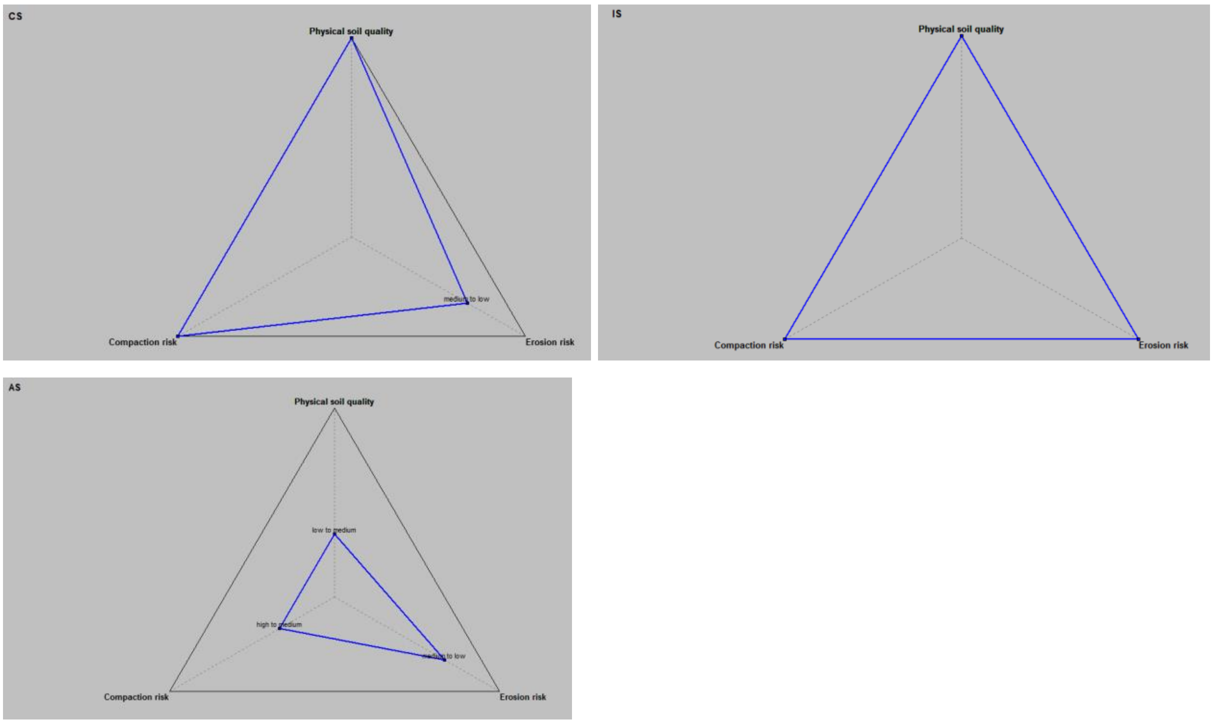


Figure 46: Soil quality 2012-14

<u>The chemical quality</u> is very low in CS and AS and low to medium in IS.

Chemical soil quality is very low because of the poor values in term of organic matter (very low in CS and AS, low to medium in IS). These differences are mainly due to the lower frequency of deep tillage of IS, which has a strong positive impact on the runoff risk (and on field erosion risk) and on organic matter degradation. It is also important to remind that ploughing in AS will not be performed as deep as in CS in order to have a less negative impact on soil beneficial.

<u>The biological quality</u> passes from the value of CS (very low) to the highest value of IS and AS (very high).

All categories of disturbances are reduced: pesticide use, mineral fertilization (both at the lowest values in IS and in AS) and deep tillage (less frequent in IS).

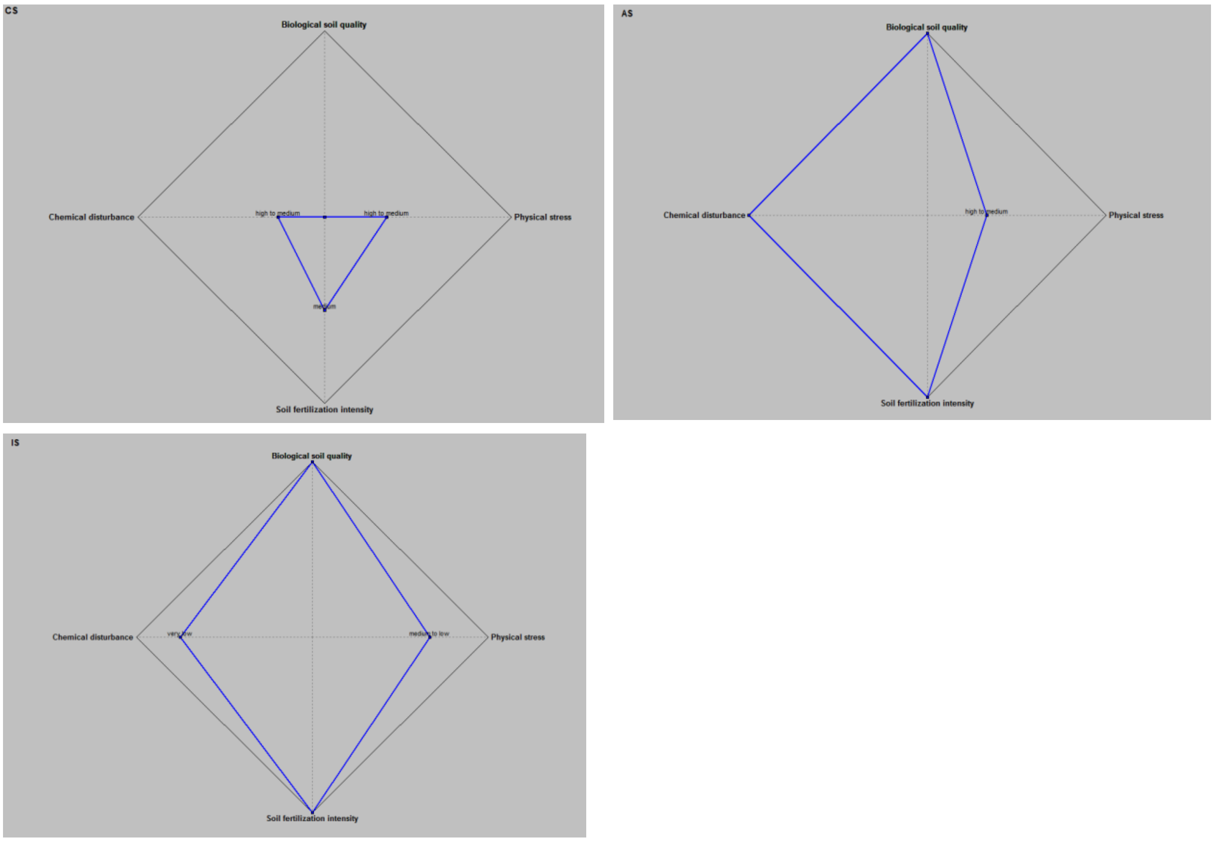


Figure 47: Biological quality 2012-14

Air quality

Air emissions are considered medium to low in CS, and very low in both IS and AS.

For the first system the situation is caused by high to medium greenhouse gases (CO_2) and NH_3, and a medium pesticide volatilization. In the alternative systems all these attributes are improved: very low in both IS and AS.

In AS, N_2O is very low and NH_3 medium to low, the lowest values obtained by these systems.

NH_3 N_2O: Both attributes are closely linked to the amount of N applied and the non-hydromorphic nature of the soil (N_2O).

CO_2: high to medium in CS, and very low in IS and AS. See *energy consumption*.

Pesticide volatilization: medium in CS, and very low in IS and in AS, because of systems TFI and low risk of drift.

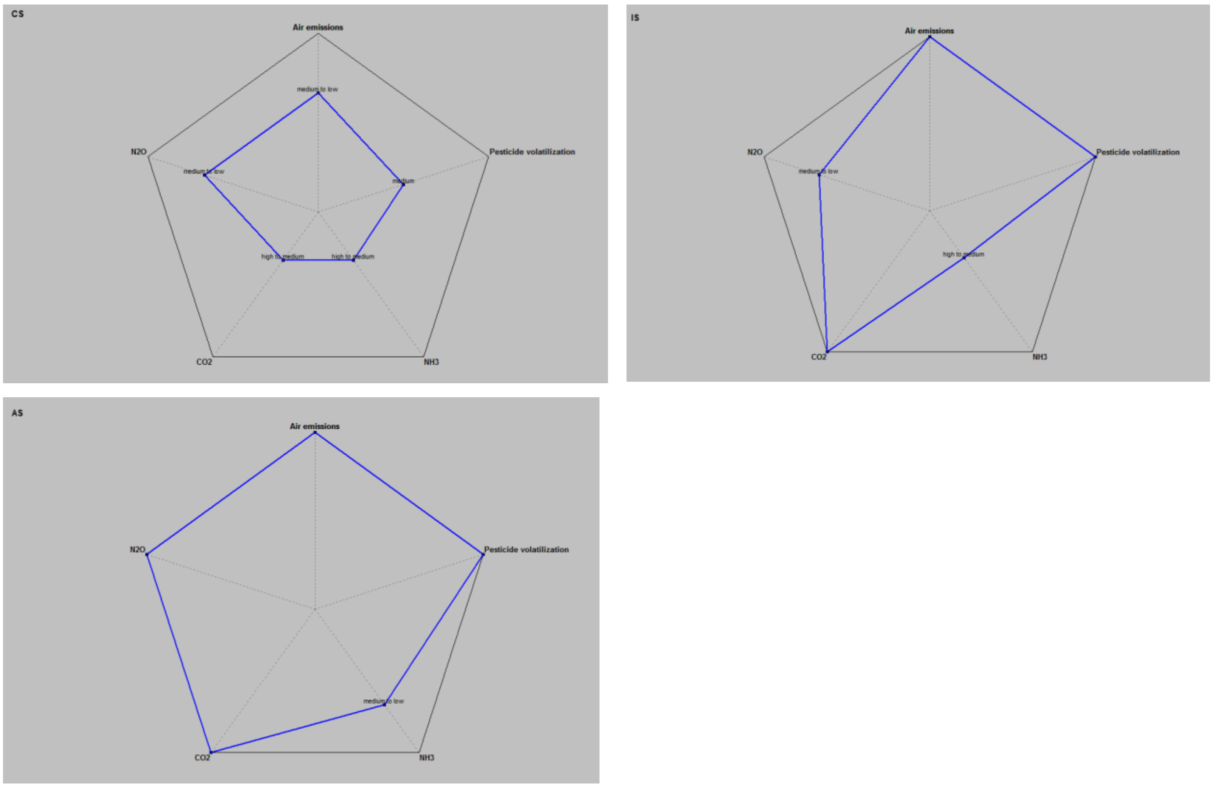


Figure 49: Air quality 2012-14

4.3.3. SYNOPS

The risk assessment with SYNOPS was conducted for the French experiment for the current, intermediate and advanced system. In the advanced system no pesticides were used and accordingly no risk assessment was done.

Three different results correspond to:

- 1. the mean of the two/three replications (according to the cropping system) over one crop sequence
- 2. the mean expressed per year (because cropping systems have different crop sequence durations)
- 3. the max observed in a plot for the cropping system, whatever the plot is

Table 8: Results: effects of the cropping systems for groundwater

Current system	**acute**	**chronic**
	Groundwater	Groundwater
mean / 4 replications (total over one crop sequence)	0.10157925	0.020316
mean / 4 replications / year	0.02539481	0.005079
max / 4 replications	0.205675	0.041135

Intermediate system	**acute**	**chronic**
	Groundwater	Groundwater
mean / 3 replications (total over one crop sequence)	0.08535567	0.01707167
mean / 3 replications / year	0.01707113	0.00341433
max / 3 replications	0.12555	0.02511

When risk is expressed in chronic data, the current and the intermediate systems present very low risk.
When risk is expressed in acute data, the current system presents a higher risk for groundwater than the intermediate system.
The main risk in the current system is provided by the use of "imazamox" active ingredient, included in the herbicide produce Nirvana, and sprayed on spring pea regularly.
The main risk in the intermediate system is provided by the use of "clopyralid" active ingredient, included in the herbicide produce Bofix, and sprayed on cereals (winter wheat, spring barley...) regularly.

Table 9: Results: effects of the cropping systems for aquatic organisms

Current system	**acute**	**chronic**
	Aquatic	Aquatic
mean / 4 replications (total over one crop sequence)	0.7630885	4.63677425
mean / 4 replications / year	0.19077213	1.15919356
max / 4 replications	0.28704	1.914353
Intermediate system		
mean / 3 replications (total over one crop sequence)	0.21508367	2.53225267
mean / 3 replications / year	0.04301673	0.50645053
max / 3 replications	0.227816	2.357416

Table 10: Results: effects of the cropping systems for terrestrial organisms

Current system	**acute**	**chronic**
	Terrestrial	Terrestrial
mean / 4 replications (total over one crop sequence)	0.0724325	1.466455
mean / 4 replications / year	0.01810813	0.36661375
max / 4 replications	0.065934	0.791923
Intermediate system		
mean / 3 replications (total over one crop sequence)	0.078558	0.94331567
mean / 3 replications / year	0.0157116	0.18866313
max / 3 replications	0.065934	0.821766

In the current system, there are low risks for terrestrial organisms, earthworms and bees (acute data) while medium risks appear in chronic data for both terrestrial organisms and earthworms.

4.3.4. CBA results

The results of the cost-benefit analyses show lower operation and input cost in the intermediate and advanced system respectively. However, over the three year project period the gross margin results of the CS were higher than those of the IS and AS.

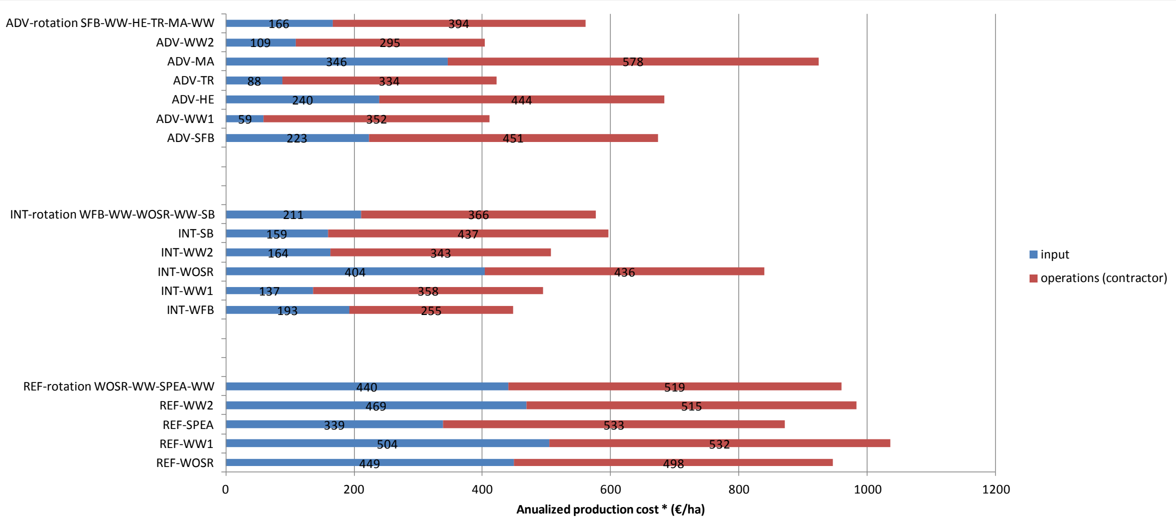


Figure 50: Annualized production cost 2012-14

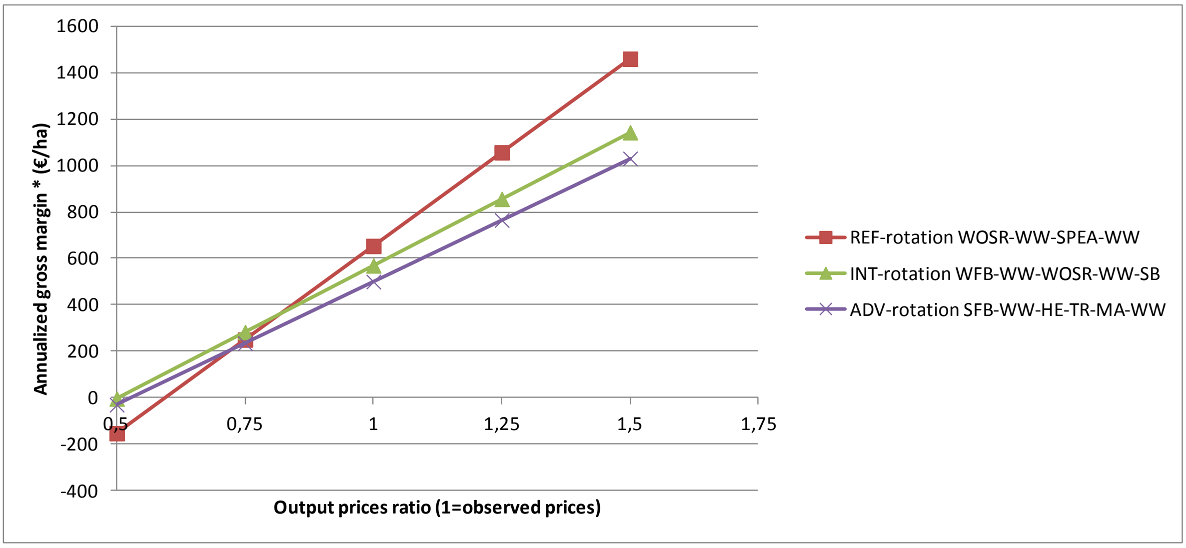


Figure 51: Annualized gross margin 2012-14

5. Conclusion

The improvement and further advancement of IPM systems was tested in on-station experiments by comparison with current systems and the sustainability of each protection system was assessed using the DEXiPM, SYNOPS tools and a cost-benefit-analysis. The overall sustainability did not change across the systems and location. The environmental sustainability could be improved from the current to the intermediate and to the advanced systems at all locations. The social sustainability remained unchanged for all systems at the location in France. In the UK experiments, it decreased from a high level in the current and intermediate system to a medium level in the advanced system in the UK. In Germany, it decreased from a high level in the CS to medium levels in the IS and AS. An explanation for the decrease in Germany and the UK is the change from current well adopted practices in an optimized system which is supported by easily accessible knowledge and efficient advisory support to the intermediate and advanced systems where the knowledge system and advisory support is not as well established and the requirements to the farmer are higher.

The assessment of the economic sustainability showed a decrease from the CS to the IS and AS at all locations; the same results were obtained by the cost-benefit-analysis, as shown on the figure below.

The observations of the experiments indicate that intermediate IPM systems seem to be an attainable production system at the tested locations. Further agronomic improvements and optimisation as well as improvement of knowledge and support would allow better economic and social performance and lead to higher overall sustainability.

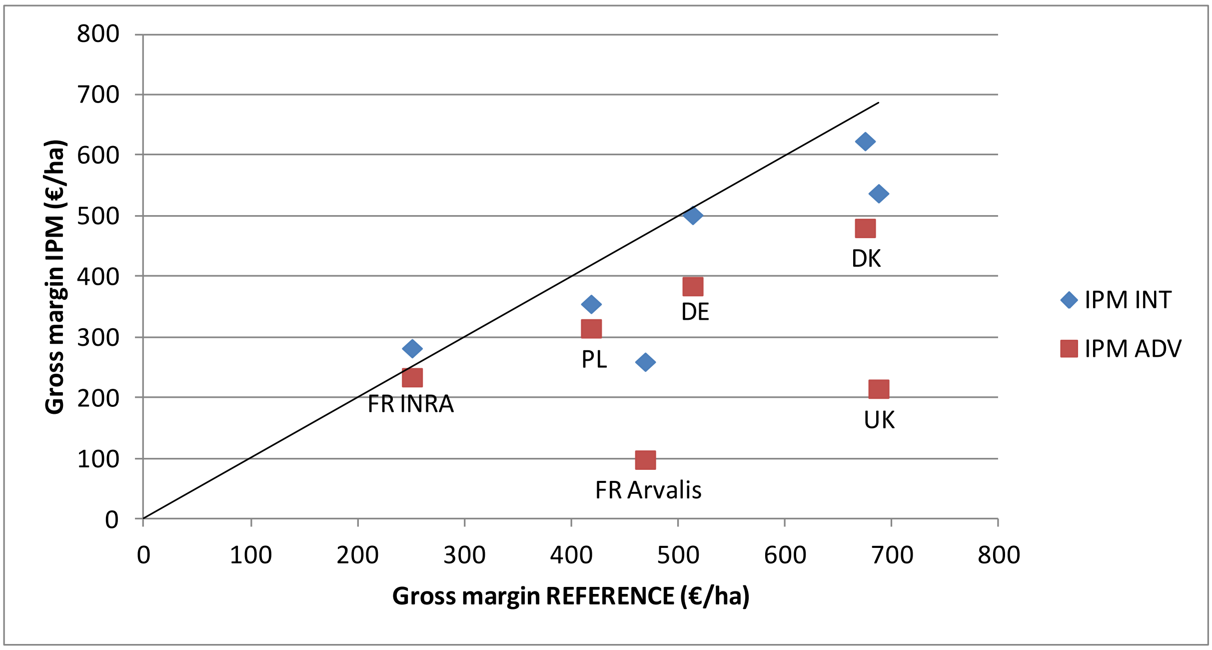


Figure 52: Gross margin on-station experiments 2012-14