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Economic consequences of abandoning the use of chemical plant protection products

Expert opinion commissioned by the German Farmers' Association

Prof. Dr. Friedrich Kerkhof

MSc. Claudia Wiese

MSc. Jan Berglar

University of Applied Sciences

Südwestfalen Faculty of Agricultural

Economics Lübecker Ring 2

59494 Soest

Mail:

Kerkhof.friedrich@fh-swf.de

Wiese.claudia@fh-swf.de

Berglar.jan-frederik@fh-swf.de

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List of abbreviations

ABK	Cultivation concentration
Akh	Man hours
DAL	Direct and labour cost free performance
DB	Contribution margin
DG	Permanent grassland
FF	Crop rotation
HF	Holstein Friesian
AL	Agriculturally used area
LP	Linear programming
PPP	Plant protection products
SUR	Sustainable Use Regulation
UKB	Weed control
WFD	Water Framework Directive
GR	Growth regulator

1 Introduction

The use of chemical plant protection products (PPP) is causing social and political debates. The EU Commission is planning significant restrictions on the use of chemical PPPs and has therefore presented a draft regulation on the sustainable use of plant protection products (SUR - Sustainable Use Regulation). The draft regulation aims to achieve a general reduction of PPP, particularly a 50% reduction in more hazardous plant protection products by 2030. Chemical plant protection products are planned to be completely banned in sensitive areas. These sensitive areas include protected areas as defined by the Water Framework Directive (WFD), drinking water sources, medicinal springs, natural habitats, bird and wildlife conservation areas, and national parks. The regulation is intended to fulfill the goals for reducing plant protection products outlined in the 'Farm to Fork' strategy.

Joint projections by the Leibniz Institute for Ecological Spatial Research and the Technical University of Kaiserslautern-Landau in Rhineland-Palatinate show that the regulation could potentially affect 38,018 km² of arable land and an additional 696 km² of orchards and vineyards. In terms of the total arable land in Germany, this would correspond to a share of 31%, including landscape protection areas. In fruit growing and viticulture, the ordinance could impact 36% of the cultivated areas. The majority of these areas are located within landscape protection areas, accounting for approximately 19% of German arable land and 25% of orchard and vineyard areas. Without considering the landscape protection areas, 17% of arable land and 16% of orchards and vineyards in Germany would still be affected by a ban of PPP, with significant regional variations. For example, without the landscape conservation areas, the proportion of arable land subject to a pesticide ban would reach 37% in Baden-Württemberg and 45% in Hesse (HENSEL 2023).

The economic consequences of renunciation of chemical plant protection products were examined in the following calculations. This was done for arable, fodder, and vegetable farming operations. For fodder production, the focus was on a dairy farm with heifer rearing in a low mountain region characterized by a significant proportion of permanent grassland. Variation calculations were performed, considering different levels of scarcity in the the available land for roughage production. The vegetable farming operation represented locations with a moderate yield level and the cultivation of the most important vegetable species in Germany. Arable farms were analysed for sites with high yield potential as well as sites with low yield potential. For the farms, that are situated in weak arable farming locations, larger farm sizes with an average field size of 40 hectares were assumed.

Farms that are located on good arable farming locations operated with an average field size of 5 hectares. The economic impacts were calculated using the performance measure of direct and labour-cost-free performance (DAL), which includes fixed labour completion costs. The costs associated with foregoing chemical plant protection were determined for the model farms using linear programming and Activity-Based Costing (ABC or LKR) as methodologies.

2 Methodical approach

2.1 Model farms and choice of fruit

The effects of the European Union's *Sustainable Use Regulation (SUR)* have been investigated for various locations with different natural growing conditions and yield expectations as well as types of operation:

- Arable farm/ Cash Crop Farm - medium soils with high yield potential
- Arable farm/ Cash Crop Farm - light soils with low yield potential
- Fodder farm - medium yield potential in a low mountain region
- Vegetable farm - medium soils with medium yield potential

The relevant crops for the respective locations were determined in two steps. First, the relevant fruits were selected with regard to their importance for cultivation. For this purpose, the cultivation conditions in regions typical for the yield level were evaluated, based on the statistics of the state offices as well as our own experience. The applied crop rotation respectively the specific cultivation ratio was optimised on the basis of the economic advantageousness and the specified cultivation restrictions.

The arable site with its high yield potential and medium-sized fields is oriented towards the cultivation conditions in favourable regions such as the Soester Börde. The following fruits were included in the optimisation for cultivation:

Grain: winter wheat, winter barley, winter rye, oats, spring barley

Maize: silage maize, grain maize

Oil Crops: Winter oilseed rape

Root crops: sugar beet, table potatoes, starch potatoes

Legumes: Field beans

Analogous to the site with high yield potential and medium-sized fields, a site with low yield potential but larger-sized arable fields should be examined to represent the conditions in Eastern German arable regions such as Brandenburg.

In order to narrow down the relevant crops, the cultivation conditions in the state of Brandenburg were evaluated based on data from the Office for Statistics Berlin-Brandenburg. The data from land use in 2022 were used for this purpose (OFFICE FOR STATISTICS BERLIN-BRANDENBURG 2023). Consideration for the calculation was given to the crops that make up at least 5% of the arable land area (see Fig. 1 for comparison).

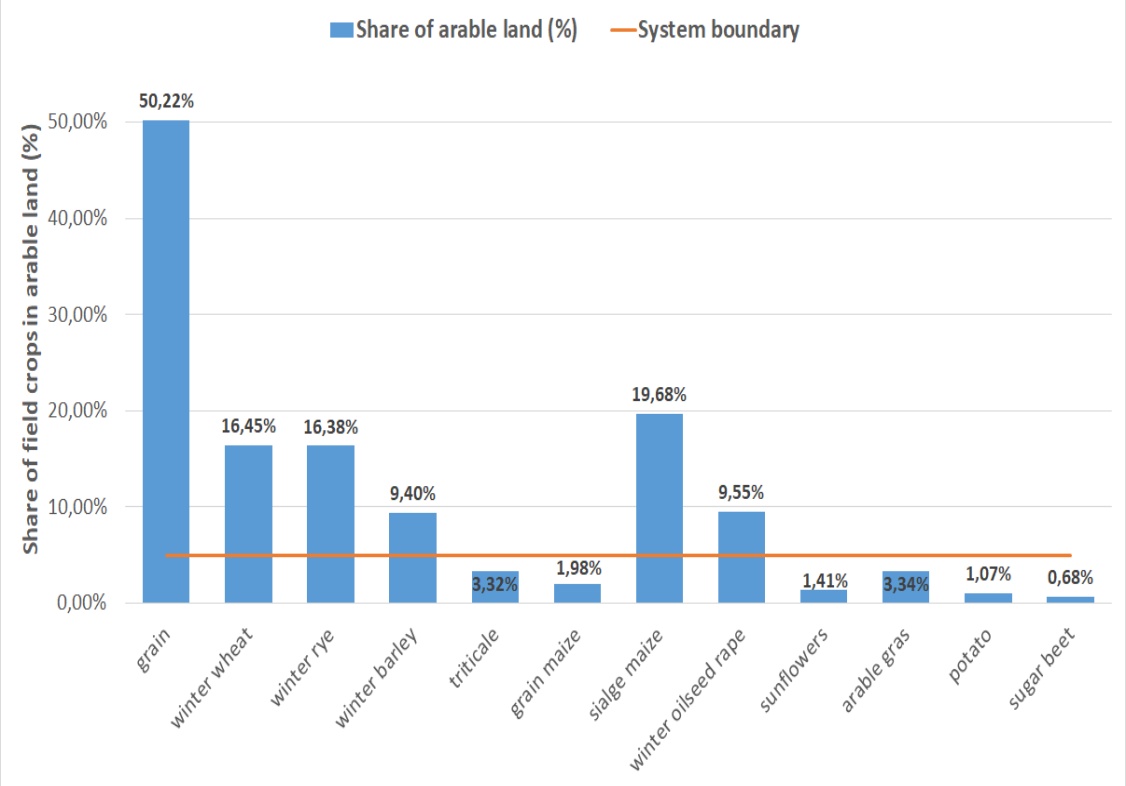


***Figure 1**: Cultivation importance of selected agricultural crop types in the federal state of Brandenburg on average from 2017 to 2022 in % of AF*

Source: OFFICE FOR STATISTICS BERLIN-BRANDENBURG 2023

For the arable site with low yield potential and large fields, the following fruits were included in the optimisation, supplemented by the crop forage pea, in order to be able to consider a legume in the cultivation programme if necessary:

Grain: winter wheat, winter barley, winter rye

Maize: Silage maize

Oil Crops: Winter oilseed rape

Grain legumes: Fodder peas

With the assumed price and cost ratios, which are based on the KTBL data (2023), the direct and labour cost-free benefits of the fruits on this site are comparatively low and partly negative. The fixed special costs cannot always be fully covered by the contribution margins. Without the single farm payment, profitable arable farming is difficult to realise under the given assumptions. As a modification, therefore, a **light site with a 20% higher yield level has** also been calculated.

In principle, for the model farms of the arable farming type, an owner-occupied area of 100 ha of arable land is assumed, as well as the option of leasing an additional 20 ha. The rent level is based on the conditions on the land market in the regions mentioned (see Fig. 2).

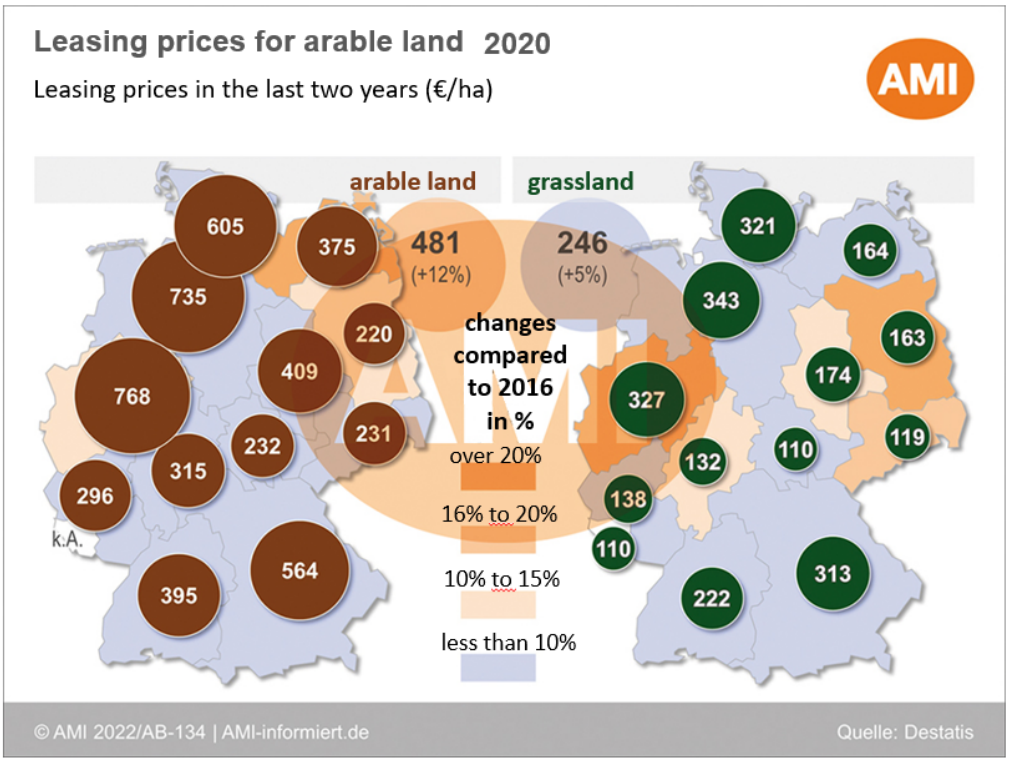


Figure 2: *Lease prices for new leases in Germany in €/ha.*

Source: DBV 2022 p.93

For the location with low yield potential and larger fields, the effects of different farm structures - under otherwise identical conditions - were investigated. The model calculations were carried out for farms with 1,000 ha and
2,000 ha of ownership and different shares of leased land. If the average field size and mechanisation remain the same, the level of adjustment costs for the larger farms does not change. Therefore, the model farms could always be calculated with an area of 100 ha owned plus 20 ha leased.

For the conceptual design of a model of the farm type "fodder production", at least two thirds of the farm's standard output must come from the production of milk, beef, the rearing of cattle, the keeping of grazing livestock and/or grassland management. The focus was placed in advance on a dairy farm with heifer rearing. It is assumed that the model farm has a high proportion of permanent grassland (75 percent) on its utilised agricultural area (UAA). This corresponds approximately to the average share of permanent grassland in selected low mountain regions in North Rhine-Westphalia (see Fig. 3).

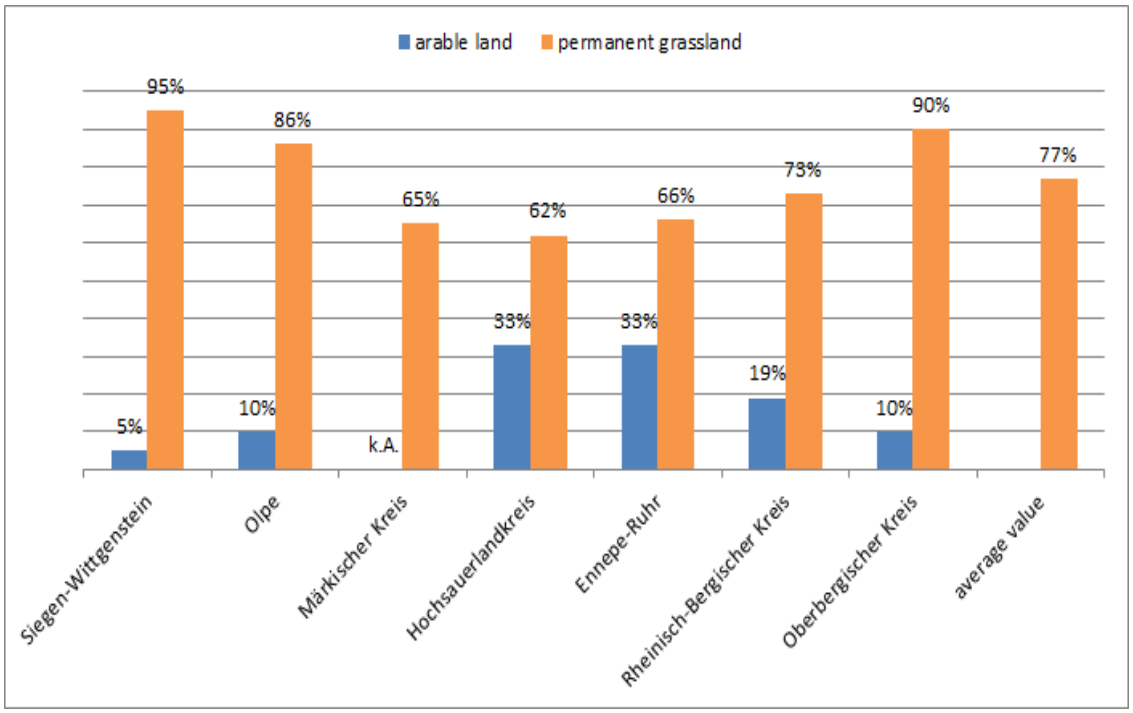


***Figure 3**: Land use of selected regions in North Rhine-Westphalia*

Source: LANDESBETRIEB INFORMATION UND TECHNIK NRW 2020

With regard to further specifications, the yield potential of the farm, both for grassland and for arable land, is oriented towards a location with medium-heavy soils and a medium yield level. While the acreage is based on an average field size of five hectares and a farm-to-field distance of two kilometres, the mechanisation is based on a tractor size of 120 kW.

On the arable land, the following production methods have been taken into account for the **fodder farm:**

Grain: winter wheat, winter barley

Arable fodder production: silage maize, arable grass

Permanent grassland: Grass silage and/or hay in the cultivation system chopper or bale.

The arable farming practices have been designed with turning tillage. For permanent pasture management, it should be noted that the option of post-grazing of permanent pasture is not provided for.

For the production method dairy cow husbandry with own heifer rearing, a herd size of 100 dairy cows is assumed, which exceeds the average herd size per farm in selected fodder-growing regions in North Rhine-Westphalia (compare Fig. 4).

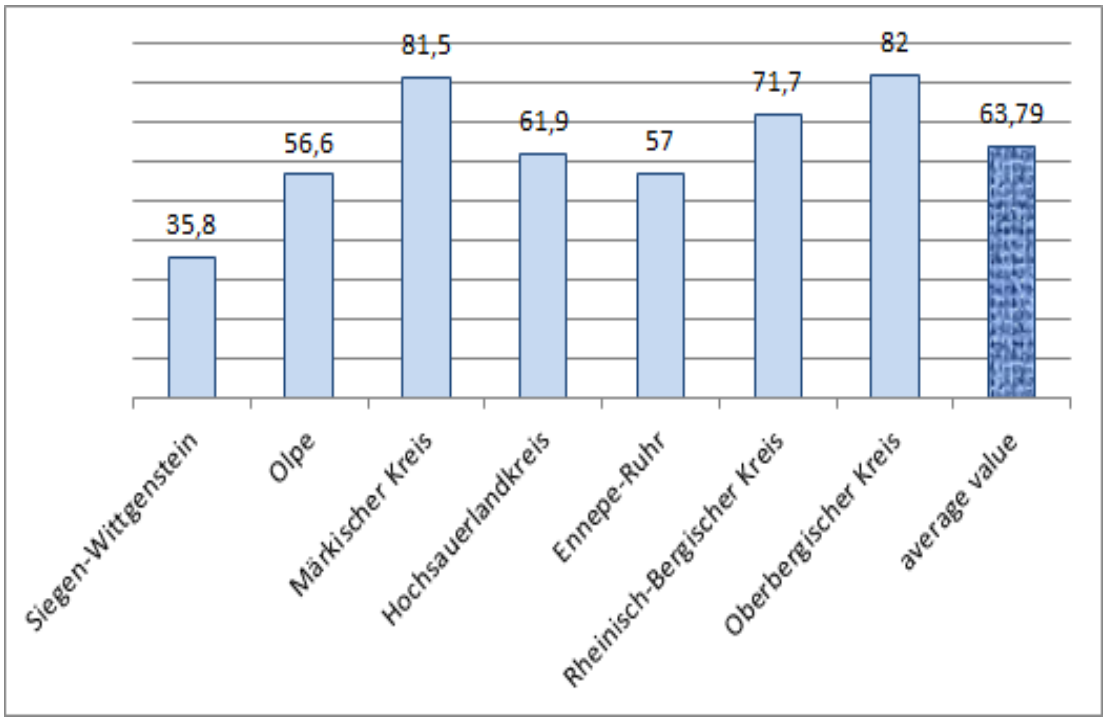


Figure 4: *Average number of dairy cows per farm*

Source: LANDESBETRIEB INFORMATION UND TECHNIK NRW 2020

This assumption is intended to illustrate the intensive specialisation and optimisation of the model farm in this sector. The production factors labour and land can be considered limited and scarce, respectively. The amount of agricultural land available is 80 (100) hectares. Based on the average nutrient excretions in dairy cow husbandry and heifer rearing, this represents the minimum area required for the utilisation of the manure accumulation.

Both the dairy cows and the heifers are kept in a box pen with a flow-mist system (see Table 1). The livestock consists exclusively of
"Holstein Friesian" dairy cows with a performance level of 10,000 kg milk per cow and year. The remounting rate in the dairy herd is 32 percent. The heifer rearing period is 27 months.

***Table 1**: Definition of dairy farming for the model farm "fodder production"*

Definition of dairy farming	
dairy farming	• **animal housing capacity**: 100 cow places • **breed:** Holstein-Friesian cattle • **keeping system**: free stall barn with liquid manure • **milking system**: herringbone milking parlour • **milk yield**: 10.000 kg/cow/a • **replacement rate**: 32%
heifer rearing	• **keeping system**: free stall barn with liquid manure • **duration of rearing**: 27 month

The crops silage maize, grass silage (permanent grassland or field grass) and hay primarily serve as basic fodder for dairy cow husbandry and heifer rearing. In addition, there is an option to sell crops such as winter wheat and winter barley, but also silage maize, field grass, hay and grass silage.

In vegetable cultivation, a location with medium-heavy soils and a medium yield level is considered. In Germany, vegetables are mainly grown outdoors. Cultivation in greenhouses accounts for only about one percent of the total vegetable cultivation area in Germany. In the following, only the situation with outdoor vegetables is considered. According to the Federal Statistical Office, outdoor vegetables were cultivated on an area of 125,184 ha in 2022. Cultivation is concentrated in North Rhine-Westphalia (28,707 ha), Lower Saxony (21,912 ha) and Rhineland-Palatinate (15,996 ha), but also in Bavaria (15,784 ha) and Baden-Württemberg (11,328 ha). The vegetables studied were selected on the basis of their cultivation importance in Germany (STATISTISCHES BUNDESAMT (DESTATIS) 2023).

***Table 2**: Cultivation importance of important vegetable species in Germany*

Open field cultivation of selected vegetables	open field vegetables 2022					
	number of farms	share of farms in %	area under cultivation in ha	share area relatively (%)	yield (dt/ha)	harvested quantity DE (tons)
	5.916		**125.184,40**			
asparagus	1.465	25%	21.267,60	16,99%	51,90	110.300,30
onion	1.651	28%	15.068,10	12,04%	383,70	578.180,50
carrots	1.852	31%	13.607,30	10,87%	573,60	780.489,40
white cabbage	1.748	30%	5.425,00	4,33%	709,10	384.660,70
edible pumpkins	2.004	34%	4.820,20	3,85%	192,20	92.663,20
bush bean	1.138	19%	4.397,90	3,51%	96,40	42.390,00
pea	271	5%	4.397,90	3,51%	96,40	42.390,00
iceberg lettuce	699	12%	3.825,20	3,06%	363,00	13.887,80
spinach	915	15%	3.263,00	2,61%	203,50	66.407,40
broccoli	1.089	18%	3.047,90	2,43%	144,00	43.883,70
cauliflower	1.178	20%	2.960,90	2,37%	295,40	87.452,20
radish	595	10%	2.831,30	2,26%	266,40	75.435,60
lamb's lettuce	802	14%	2.289,30	1,83%	49,40	11.423,10

Source: Federal Statistical Office (DESTATIS) 2023

Table 2 shows the 13 most important vegetable species in terms of cultivation. Of these, 8 vegetable species were selected for the study. The selection was made on the basis of the importance of cultivation in Germany and the distribution among the groups of cabbage vegetables, leafy and stem vegetables, root and tuber vegetables, fruit vegetables and legumes. Vegetable species that are of great importance in organic farming, such as carrots as the most important vegetable and edible onions, have also been included. The suitability of the vegetable species for cultivation without the use of chemical pesticides can partly be deduced from their cultivation importance in organic farming.

The following **crop types have** been included in the investigation **for the model farm "vegetable production"** (highlighted in blue in the table):

Vegetables: asparagus, onion, carrot, bean, pea, iceberg lettuce, cauliflower and lamb's lettuce.

These represent the most important crop groups. The crop groups cover approx. 75 % of German vegetable production and each individual crop group at least 10 %. Vegetable cultivation areas are found in particular where the climatic and other natural conditions are good. Vegetables have high demands on the supply of water and on the soil. Vegetables are therefore cultivated in particular in fertile regions on

medium-heavy soils (LFL BAYERN 2005). For the vegetables and the model farm, a location with medium-heavy soils and medium yield expectations has been assumed.

The four model farms described are summarised and compared with their essential characteristics in Table 3.

Table 3: *Overview of the main characteristics of the model farms*

farm	**Cash Crop Farm**	**Cash Crop Farm**	**vegetable farm**	**fodder crops farm**
location	**good arable farming locations (e.g. Soester Börde)**	**weak arable farming locations (e.g. Brandenburg)**	**favourable regions**	**low mountain range region**
cultivation system	conventional			
soil cultivation	turning soil cultivation, seedbed preparation, seeding	non-turning soil cultivation, rotary harrow for seedbed preparation and seeding	turning soil cultivation	turning soil cultivation, seedbed preparation, seeding
field size	5 ha	40 ha	2 ha	5 ha
yield potential	high	low (variant + 20%)[1]	medium	medium
Type of soil	medium soil	light soil	medium soil	medium soil
mechanisation in kW (Power of the strongest tractor used in the production process)	120-kW	200-kW	120-kW	120-kW
distance between field and farmstead	2 km	4 km	2 km	2 km
Farm size in hectare				
Arable land (owned)	100 ha	100 ha	100 ha	20 ha or 25 ha[2]
Arable land (leased)	20 ha (768 €/ha)	20 ha (220 €/ha)		
grassland (owned)				60 ha or 75 ha

In principle, the benefit of the use of plant protection products results primarily from higher and more stable yields (NOLEPPA and VON WITZKE 2013). The use of mycotoxins can also have a positive effect on product quality. However, risks for the environment, the consumer and the user can arise, especially in the case of application errors (JKI o.J. a, JKI o.J. b).

In cereal farming, successful weed management is described as one of the most important technical production measures, which, depending on the site-specific weed situation, can be associated with yield protection of 20% to

[1] In addition, a variation with medium yields was calculated for the weak arable site (yield: +20%).
[2] For the fodder farm, two different land configurations (80 ha UAA and 100 ha) with a constant grassland share of 75% were investigated.

30% (GEHRING 2003). The individual competitiveness of the crop type, the field-specific weed pressure and their temporal occurrence play an important role. Further influencing factors result from the weather pattern and fertiliser management. Overall, the negative yield effects in summer cereals are less pronounced than in winter cereals due to the competition with the accompanying field vegetation (BVL 2019). The use of herbicides is particularly effective and inexpensive, but mechanical control strategies and the combination of both approaches are also gaining in importance (GEHRING 2003; LALLF 2023 p. 30).

In the following, the yield effects of dispensing with plant protection products are explained and summarised in Table 4 for arable farming.

Table 4: *Effects of changes in plant protection product use on the individual fruits of the arable farms*

crop	yield reduction due to the renunciation of plant protection products ...				
	Herbicide	Fungizide	Insecticide	GR*	total
winter wheat	16%	13%	1%	0%	30%
winter barley	14%	14%	1%	0%	29%
winter rye	14%	14%	1%	0%	29%
oats	5%	5%	1%	0%	11%
spring barley	7%	5%	1%	0%	13%
silage maize	12%	0%	0%	0%	12%
grain maize	12%	0%	0%	0%	12%
winter oil seed rape	12%	6%	16%	5%	39%
sugar beet	12%	5%	6%		23%
table potato	10%	22%	6%		38%
starch potato	10%	22%	6%		38%
field bean	2%	5%	6%		13%
forage peas					

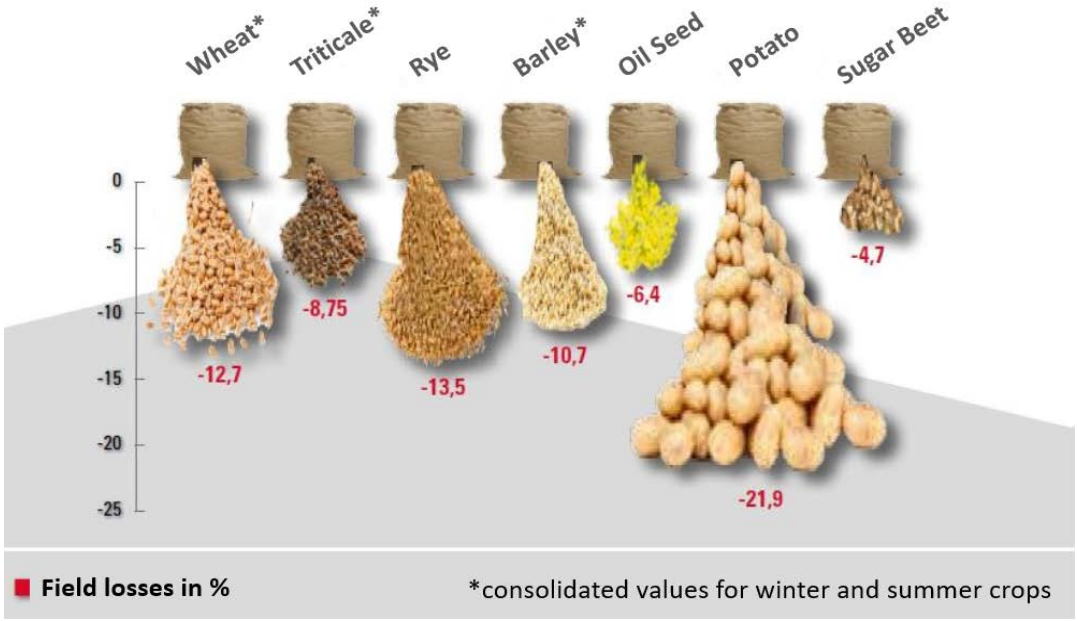
Source: NOLEPPA u. VON WITZKE 2013; GEHRING 2003; BVL 2019; LALLF 2023; LM MV 2019; OERKE 2005; LALLF 2023; WERNER u. BRAUER-SIEBRECHT 2015; HABERLAH-KORR 2022.

For wheat, the yield loss when abandoning herbicides and simultaneously switching to mechanical weed control is derived from a long-term trial conducted by the Mecklenburg-Western Pomerania State Office for Agriculture, Food Safety and Fisheries. Here, different methods of weed control were investigated for a cultivation period of four years. On average over the years, the "chemical weed control" variant achieved an additional yield of around 16% in comaparison with the mechanical control method.

The use of growth regulators was described to have a negative impact on the yield of winter wheat and winter barley (LALLF 2023 p.26, 31). Overall, no yield effect is assumed for the cereal species in the "growth regulator" field of action. The contribution of insecticides to yield generation is given as an additional percentage point for winter wheat (LM MV 2019). Corresponding ten- dencies can be read from the evaluation of the LALLF for the winter crops barley and wheat (LALLF 2023 p. 26). In the following, a yield effect of insecticides of one percent is assumed for all cereal species considered.

The yield effects resulting from the use of fungicides were largely derived from a study by NOLEPPA and VON WITZEK (2013) (cf. Fig. 5). The study is based on the evaluation of more than 13,000 trial series on the subject of variety trials, covering various locations throughout Germany. Furthermore, more than 250 publications of the public state institutes and chambers on this issue were evaluated (NOLEPPA and VON WITZKE 2013).

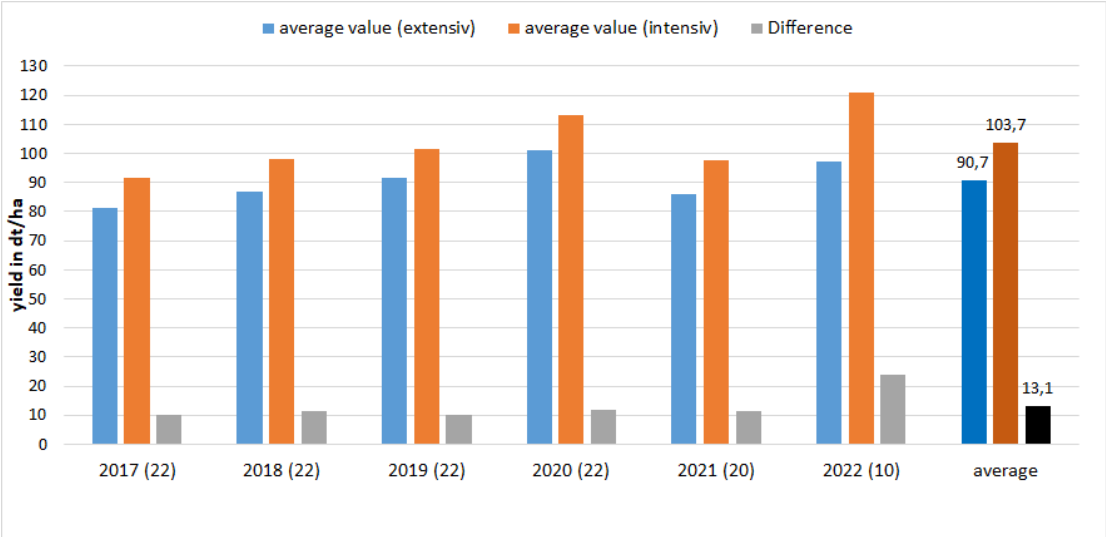
Figure 5: *Yield losses in % by not using fungicides*



Source: NOLEPPA u. VON WITZKE 2013

For the crops winter wheat and winter barley, additional trial data on the benefit of fungicides from the university's own experimental farm "Merklingsen" were evaluated. For the wheat crop, the influence of fungicides on the hectare yield in the years 2017 to 2022 was investigated (compare Fig. 6). On average over the years, not using foliar fungicides results in a yield disadvantage of 13.1 dt/ha or 12.5%. Accordingly, yield effects of 13% for fungicides were assumed for the further calculations in winter wheat.

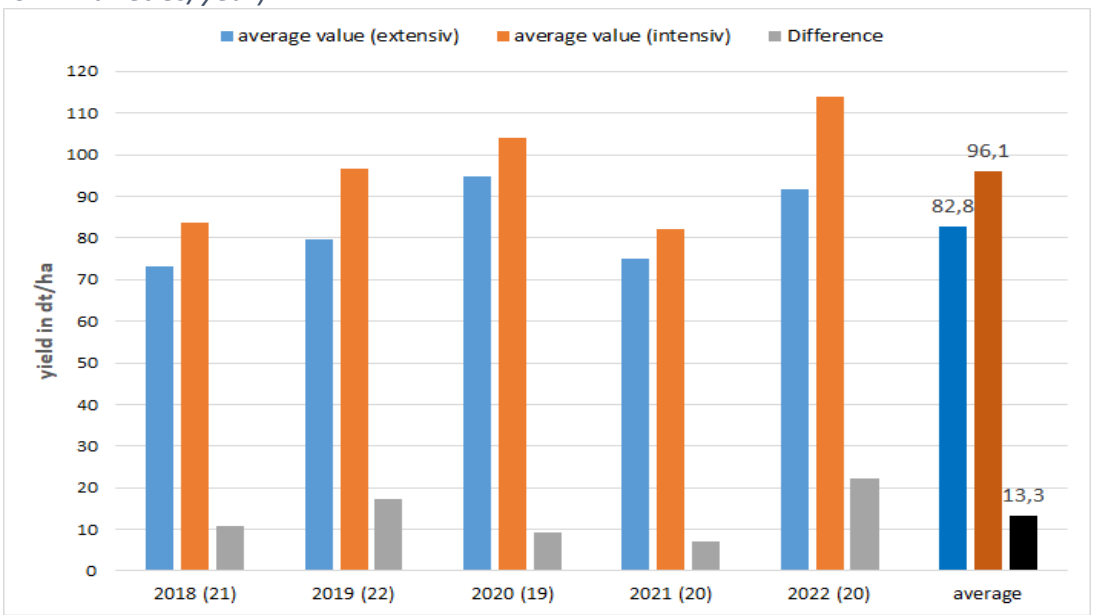
***Figure 6**: Yield (dt/ha) of winter wheat with/without foliar fungicides (2017-2022, 10-22 varieties/year)*



Source: HABERLAH-KORR 2022

Evaluations of the trial plot with regard to winter barley show a yield difference between the variant with fungicides and the "untreated variant" of 13.3 dt/ha (cf. Fig. 7). This corresponds to a yield difference of 13.8%. Accordingly, this value is assumed for the further calculations. The study by NOLEPPA and VON WITZEK (2013) shows a lower value of 10.7%, but the percentage is a consolidated value that applies equally to spring barley and winter barley.

***Figure 7**: Yield (dt/ha) of winter barley with/without foliar fungicides (2018-2022, 10-22 varieties/year)*



Source: HABERLAH-KORR 2022

Compared to winter wheat, winter barley has a significantly higher competitive power against weeds. Accordingly, it was assumed that not using herbicides would result in a 14% drop in yield. The use of fungicidal active substances is significantly more important for yield formation in winter barley (LALLF 2023 p. 26, 32).

Winter rye is generally regarded as a vigorous cereal with good weed suppression. The fact that it roots comparatively shallowly and therefore reacts sensitively to mechanical weed control is problematic (DLG 2022 p. 11). Accordingly, it is assumed that the situation in winter rye will be similar to winter barley if herbicides are not used.

As already described, summer tillage has lower yield losses than winter tillage when herbicides are not used. Accordingly, a comparatively low yield loss of 8% is reported for spring cereals in the literature (BVL 2019 p. 4; DLG 2022 p. 11). In general, oats and spring barley are described as being relatively tolerant of weeding, with their vigour being particularly conducive to weed suppression. In the case of oats, the habit, over the plant length, is significant for the competitive strength of the crop. Consequently, a yield reduction of 5% was assumed for the crop oats and 7% for spring barley in the "herbicide" field of action.

The yield effects resulting from the use of fungicides in summer cereals were calculated on the basis of the economic damage threshold (see Tab. 5), as the source situation for these crops is comparatively low. For hafer, the use of a fungicide makes sense if at least 3 to 4 % additional yield can be generated. For spring barley, at least 5 to 8% would be necessary due to the significantly higher PPP costs. Based on this calculation, yield effects of 5% were assumed for spring cereals.

***Table 5**: Necessary additional yield (dt/ha) to amortise the PPP measure (economic damage threshold)*

Crops	Oats	Spring barley
Fungicide costs (€/ha)	22,32 €	86,25 €
Machine costs PP application (€/ha)	17,23 €	17,23 €
Total costs fungicide application (€/ha)	**39,55 €**	**103,48 €**
Producer price in €/dt (LfL)	21,49 €	28,24 €
Producer price in €/dt (KTB)	16,30 €	18,80 €
Yield level in the production (dt/ha)	59,20	69,00
Necessary additional yield in dt/ha		
according to producer price (LfL)	1,84	3,66
According to producer price (KTB)	2,43	5,50
Damage threshold (LfL) in %.	**3,11%**	**5,31%**
Damage threshold (KTBL) in %.	**4,10%**	**7,98%**

In maize cultivation, sufficient weed control is of decisive importance, as the crop is comparatively slow in its youth development and is quickly overgrown by weeds. The complete omission of weed control measures is associated with high yield depressions, which can extend to total failure. OERKE (2005) estimates a yield loss of 40.3% for maize (BVL 2019; Oerke 2005). Taking into account the achievable effectiveness of mechanical weed control methods, a yield difference of 12% is assumed compared to herbicide use.

For winter rape cultivation, the result from the report by NOLEPPA and VON WITZKE (2013) of 6% was assumed with regard to fungicide use. In rapeseed cultivation, the benefit of insecticide use depends strongly on the population dyna- mics of important pests such as rapeseed flea, rapeseed lance beetle and cabbage pod weevil. While in some years there may be a mass occurrence of insect pests, there are also years with lower pest pressure. Accordingly, the yield effect of insecticide application varies greatly between years. In a series of trials conducted by LALLF over several years, a yield effect for insecticides in rape of 16% could be derived. The necessity of the measures as well as their intensity are secured in integrated plant protection with the help of damage thresholds and stand controls. Further LALLF trial results show a yield loss of 24% if weed control measures are completely dispensed with (LALLF 2022). However, as mechanical weed control (2 x hoeing) is carried out in the cultivation methods, the efficiency of the hoe must also be taken into account. An efficiency of 50% was assumed for the calculations. Accordingly, the yield effect of the herbicides is assessed at 12%.

The benefit of growth regulators for the stability of winter oilseed rape was investigated with the help of trial results from the Lower Saxony Chamber of Agriculture. However, the stability of winter oilseed rape depends on many factors such as sowing time, weather and nitrogen fertilisation. In addition, the evaluations show a strong influence of the variety. Although high effects are achieved in some cases, the choice of variety can be used as a countermeasure. For the further calculations, a yield effect of 5% is assumed for the growth regulator according to the trial results (WERNER and BRAUER-SIEBRECHT 2015).

In sugar beet cultivation, NOLEPPA and VON WITZKE (2013) confirm an advantage of fungicide use of around 5%. In the field of weed management, it should be noted that technical developments have made considerable progress in the field of hoeing equipment and that the equipment can also work within the row. As a result, a negative yield effect of 12% was assumed. After the discontinuation of neonicotinoids in the dressing, the major effect on sugar beet yields did not occur, despite initial fears. Based on this finding, an effect of 6% is assumed for the insecticides.

With a total of 38%, potato cultivation shows the highest relative yield reduction due to the abandonment of chemical plant protection products. According to NOLEPPA and VON WITZKE (2013), 21.9% of this can be attributed to not using fungicides. Based on expert estimates in their Delphi study, AMMANN ET AL. (2021) put the yield effectiveness due to the elimination of herbicides at about 10%. According to OERKE (2005), the impact of insecticides, especially with regard to the transmission of virus diseases, ranges between 5 and 9%. At its own discretion, this value has been set at 6%.

In the area of legumes, own observations of the research farm "Merklingsen" show a practicable crop management without the use of herbicides. Accordingly, a low yield effect of 2% has been included in the calculations. Due to the limited availability of literature, the influence of the other areas of effect on yield has also been based on observations and evaluations of the experimental crop.

Fodder production

The changes in the use of plant protection products have an effect not only on the achievable yields in arable farming, but also in permanent grassland. For the fodder farms, a different assumption was made for winter wheat cultivation. Here, in addition to the already described yield reduction (30%) due to the renunciation of plant protection products, a surcharge of five per cent was applied to take into account the growth of previously cultivated arable grass. This increases the amount of the relative yield reduction to 35%.

As arable grass can be grown with double-cutting as an "intercrop", for example between a winter and summer crop, or as an annual crop in the initial variant without chemical plant protection, the yield or performance of this method has not been further adjusted.

In the management of permanent grassland by the fodder farm, the effects of not using plant protection products on the fresh mass yield of all growth are illustrated using two scenarios:

- **Scenario I** assumes a **medium intensity level for the use of chemical plant protection products.** Consequently, not using chemical pesticides results in a 5% decrease in yield in terms of fresh mass (quantitative) and energy content (qualitative).
- **In scenario II,** a **high intensity level for the use of chemical plant protection products is** assumed, in which a reduction in yield of 10% is caused by not using plant protection products.

Not using plant protection can also lead to a lower silage quality of the grassland. The result is not only a lower energy density, but also a less palatable fodder, so that the basic fodder intake (kg dry matter) decreases. Compensation with concentrated feed may then be necessary.

The assumptions made in the scenarios are intended to reflect the assessments made in expert discussions, in which a ban on chemical plant protection products is considered to be more important for farms with a high intensity of plant protection products than for farms with a lower intensity or no use of plant protection products at all.

On permanent grassland, which is used for the production of grass silage and hay, two scenarios are mapped, which are intended to reflect current practice in grassland management in discussions with the agricultural intensive advisory service:

In the variant with "high pesticide intensity", it is assumed that a chemical pesticide measure is carried out annually on the grassland in order to control problem weeds and to avoid negative yield effects. In the "medium pesticide intensity" variant, this takes place only once in two years due to better management. While a yield reduction of ten percent is assumed in the "high pesticide intensity" scenario, this amounts to five percent in the "medium pesticide intensity" scenario. Along with the fresh mass yield, the energy yield per hectare has also been adjusted by the aforementioned yield reductions (LWK NRW 2023).

In both scenarios, an additional pass with the harrow and an increase in the reseeding quantity by five kilograms of seed per hectare, with a simultaneous increase in the labour input by one and 0.5 Akh per hectare respectively, based on BUHK ET AL. 2021 p. 74 ff. are assumed as a mechanical adaptation strategy.

***Table 6**: Effects of changes in plant protection product use on the individual fruits of the fodder farm*

crops	yield reduction due to the renunciation of plant protection products ...						mechanical weed control
	Herbicide	Fungizide	Insecticide	GR*	other*	total	amount of treatments
winter wheat	16%	13%	1%	0%	5%	35%	3 x harrowing
winter barley	14%	14%	1%	0%		29%	2 x harrowing
arable grass	0%	0%	0%	0%		0%	
silage maize	12%	0%	0%	0%		12%	1 x harrowing 2 x hoeing
permanent grassland with high PPP itensity	10%	0%	0%	0%		10%	1 x harrowing
permanent grassland with medium PPP intensity	5%	0%	0%	0%		5%	1 x harrowing
hay with high PPP intensity	10%	0%	0%	0%		10%	1 x harrowing
hay with medium PPP intensity	5%	0%	0%	0%		5%	1 x harrowing

* **GR** = growth regulator

* **other** = 5% surcharge for volunteer plants from previously grown arable grass

Vegetable Production

The yield reductions due to the abandonment of chemical crop protection have been estimated on the basis of expert discussions, in particular by the Dienstleistungszentrum Ländlicher Raum Rheinland-Pfalz (DLR) (LAUN 2023, ZIEGLER 2023) and literature findings, and are intended to represent an average year (see Tab. 7).

***Table 7**: Reductions in vegetable yields due to the abandonment of chemical crop protection*

Culture	Rel. reduction in yield due to renunciation of …				Total
	Herbicide	Fungicid e	Insecticide	Growth regulator	
Asparagus	20%	30%	30%	0%	**80%**
Onion	20%	30%	10%	0%	**60%**
Carrots	10%	20%	10%	0%	**40%**
Cauliflower	0%	10%	20%	0%	**30%**
Iceberg lettuce	10%	20%	30%	0%	**60%**
Bush bean	20%	20%	10%	0%	**50%**
Radish	0%	50%	50%	0%	**100%**
Pea	15%	10%	10%	0%	**35%**
Lamb's lettuce	20%	10%	0%	0%	**30%**

Source: LAUN 2023, ZIEGLER 2023

The estimates are subject to uncertainties, as the occurrence of diseases and pests varies greatly from year to year. The occurrence of certain pests and critical, wet weather conditions can also lead to total failure if chemical plant protection products are not used. This is particularly economically relevant in the case of one crop per harvest year, e.g. onions and asparagus (LFL BAY- ERN 2019, DLR and LTZ 2023).

If chemical crop protection is abandoned, alternative methods are needed. These are generally available for herbicides, but there are only a few options for dispensing with fungicides and insecticides.

If chemical plant protection is not used, the following preventive measures and alternative plant protection measures must be taken in addition to the choice of variety, crop rotation, soil cultivation and the promotion of beneficial organisms:

- suitable site selection: Alone locations and open field locations
- weed control by hoeing, harrowing, mounding/ earthing up and flaming
- Hand weeding and use of hand hoe for weed control

- false seedbed with the use of a harrow and soil cultivator before sowing, typically resulting in a shift in the sowing timing.
- Use of crop protection nets
- Use of mulch films/ foil-covered beds
- (if applicable, authorised plant protection products in organic farming, such as Bacillus thuringensis preparations as insecticides).

Depending on the type of crop, the herbicides can be replaced to varying degrees. This is more possible for seed crops, e.g. lettuce and cabbage, than for seed crops, e.g. onions and carrots. For the cultivation of carrots and onions, manual weed control is associated with a larger volume of man-hours, which must be available in short periods of time (work peaks). Ultimately, an infrastructure for the employment of seasonal labour is necessary on the farms and the corresponding labour must be available in the first place. Mechanical weed control is inadequate during prolonged rainy periods, so that the risk of cultivation increases. The wrong sowing and planting bed method leads to a two to four week reduction in growth time, depending on the crop and the time of year, and cannot be placed in front of all crops in the year.

There are hardly any alternative measures for fungicides and insecticides. In the area of fungicides, only the chemical agents used in organic farming, such as copper and sulphur preparations, are available. If these are not used either, the cultivation risk increases significantly. Especially in the case of lettuce, fungal diseases can quickly lead to total loss. As a rule, the infestation of pests is only reduced and not completely prevented. Individual pests such as the carrot fly or the bean fly can quickly lead to the total loss of the harvest in the corresponding crops if insecticides are not used.

Beneficial insects are sometimes very effective against pests, but can only be controlled to a very limited extent. A high number of beneficial insects on the crop can lead to rejection of the product. If weather conditions are favourable, insecticides can be dispensed with. The use of crop protection nets leads to additional labour costs due to covering and uncovering. In addition, there is a risk of insect pests flying in during the chopping work.

The alternative methods for the vegetable species investigated were derived from interviews with experts (LAUN 2023, ZIEGLER 2023, and MEISE 2023) and the measures used in organic farming. The results of the expert interviews and organic farming methods (KTBL methods) are presented in Table 8.

Table 8: *Alternative measures for dispensing with plant protection products according to KTBL and expert interviews*

	mechanical weed control			measures to replace chemical crop protection
crop	hand-weeding (hour/ha)	hoeing and earthing up (number)	harrowing (number)	
asparagus	40	4 x	0 x	standalone location, winter mounding, raising the beds, foil-covered asparagus bed
onion	100	3 x	2 x	stale seedbed
carrots	100	2 x	2 x	open fields, stale seedbed
cauliflower	40	3 x	1 x	cultivation protection nets, stale seedbed
iceberg lettuce	40	2 x	2 x	open fields, stale seedbed
bush bean	40	2 x	2 x	open fields, stale seedbed
radish	0	0 x	2 x	cultivation protection nets, stale seedbed
pea	40	1 x	2 x	open fields, stale seedbed
lamb's lettuce	40	0 x	3 x	open fields, stale seedbed
organic vegetabel farming according to KTBL				
	mechanical weed control			**additional measures to replace chemical crop protection**
crop	hand-weeding (hour/ha)	hoeing and earthing up (number)	harrowing (number)	
onion	450	5 x	0 x	1x flaming
carrots	210	5 x	0 x	biological insecticides, 1x flaming
cauliflower	31	2 x	0 x	cultivation protection nets
bush bean	60	2 x	3 x	PPP Coniothyrium minitans
pea	3	0 x	2 x	
lamb's lettuce	40	0 x	3 x	open fields, stale seedbed

Source: KTBL 2023, LAUN 2023, ZIEGLER 2023

For the selected fruits, the following alternative plant protection measures were used in the calculations (see Tab. 9).

***Table 9**: Alternative measures for vegetables in the procedures without chemical plant protection products*

mechanical weed control					additional measures to replace chemical crop protection
crop	hand-weeding (hour/ha)	flaming (number)	hoeing and earthing up (number)	harrowing (number)	
asparagus	40		4	0	winter mounding, raising the beds, foil-covered asparagus bed
onion	327	1	5	0	stale seedbed
carrots	210	2	5	0	stale seedbed
cauliflower	40		3	1	cultivation protection nets, stale seedbed
iceberg lettuce	40		2	2	stale seedbed
bush bean	33		2	3	stale seedbed
pea	3		0	2	stale seedbed
lamb's lettuce	40		0	3	stale seedbed

Source: KTBL 2023, LAUN 2023, ZIEGLER 2023

2.3 Crop production design of the production methods

The selected production methods are based on the web application "*Leistungs-Kostenrechnung Pflanzenbau/ Activity-based costing for plant cultivation*" of the Kuratorium für Technik und Bauwesen in der Landwirtschaft (KTBL). The application allows the cultivation methods to be adapted to the operational conditions. Thus, field size, soil type (light, medium and heavy soils) as well as the yield level (low, medium, high) can be varied. Other important influencing variables, such as the farm-specific mechanisation (indicates the power of the strongest tractor used in the production process in kW) or the farm-to-field distance, can also be adjusted (KTBL 2023). Table 10 visualises the assumptions made for the model farms.

Table 10: *Assumptions on the plant cultivation design of the investigated sites*

farm	Cash Crop Farm	Cash Crop Farm	vegetable farm	fodder crops farm
location	**good arable farming locations (e.g. Soester Börde)**	**weak arable farming locations (e.g. Brandenburg)**	**favourable regions**	**low mountain range region**
cultivation system	conventional			
soil cultivation	turning soil cultivation, seedbed preparation, seeding	non-turning soil cultivation, rotary harrow for seedbed preparation and seeding	turning soil cultivation	turning soil cultivation, seedbed preparation, seeding
field size	5 ha	40 ha	2 ha	5 ha
yield potential	high	low (variant + 20%)[1]	medium	medium
Type of soil	medium soil	light soil	medium soil	medium soil
mechanisation in kW (Power of the strongest tractor used in the production process)	120-kW	200-kW	120-kW	120-kW
distance between field and farmstead	2 km	4 km	2 km	2 km

Modifications within the crop production methods refer to the assumed producer prices for the harvested products and the assumed prices for diesel and fertiliser. The calculation data used in this work can be found in chapter 2.4.

Arable farms

Further adjustments concern the silage maize procedure. Instead of selling silage maize from the silo, it is sold as standing crop directly from the field. This procedure meets the operational requirements better, especially for farms without their own cattle or biogas production. The labour costs were reduced by the harvesting work. In addition, costs for hail insurance were taken into account.

The plant cultivation design of the calculated cultivation methods also deviates from the "Leistungs-Kostenrechnung Pflanzenbau/ Activity-based costing for plant cultivation" of the KTBL with regard to fertiliser use. The nitrogen fertiliser requirement was calculated according to the specifications of the official advice (see Fig. 8). The nutrients phosphorus and potassium are supplied to the cultivation methods according to the withdrawals. It should be noted that harvest residues such as straw or beet leaves remain on the land, so only the nutrient removal by the main harvest product has to be compensated. In this way

[3] In addition, a variation with medium yields was calculated for the weak arable site (yield level of the site +20%).

the applied fertiliser quantities and the associated costs can be adjusted to the yield effects by dispensing with plant protection products.

Düngebedarfsermittlung und Dokumentation der Düngung
für Ackerbau - Stickstoff

Landwirtschaftskammer Nordrhein-Westfalen

Düngejahr		Schlag/ Bewirtschaftungseinheit		Vorjahreskultur	
Betriebsnr.		Feldblocknr.		Zwischenfrucht	
Betrieb		Schlaggröße (ha)			

Düngebedarfsermittlung Stickstoff

Datum	Kultur	Ertrag laut DüV	Ertrag 5 Jahre Ø Betrieb	N-Bedarfswert	Zu-/Abschlag Ertrags-differenz	Abschlag Nmin-Probe/ Richtwert	Abschlag Standort/ Humus	Abschlag Organische Düngung Vorjahr	Abschlag Vor-/ Zwischen-frucht	N-Düngebedarf
		dt/ha	dt/ha	kg N/ha	kg N/ha	kg N/ha	kg N/ha	kg N/ha	kg N/ha	kg N/ha

Dokumentation der Stickstoffdüngung | Summe DBE N/Jahr

***Figure 8**: Calculation of nitrogen demand according to official advice*

Source: LWK NRW 2021

Liming of the arable land is carried out, analogous to the assumptions in the respective KTBL cultivation procedures, taking into account the modified fertiliser prices (see chapter 2.4).

Cultivation methods without the use of plant protection products (arable farms)

In contrast to the calculation of the crop production methods in a system with integrated crop protection (*initial situation*), the individual operations and inputs used in the respective crop production methods were modified in order to be able to assess the consequences of dispensing with chemical crop protection. The assumptions made can be found in Table 11.

***Table 11**: Yield effects and crop management when crop protection is dispensed with*

crop	yield reduction due to the renunciation of plant protection products ...					mechanical weed control
	Herbicide	fungizide	insecticide	GR*	total	amount of treatments
winter wheat	16%	13%	1%	0%	30%	2-3 x harrowing
winter barley	14%	14%	1%	0%	29%	2 x harrowing
winter rye	14%	14%	1%	0%	29%	1 x harrowing
oats	5%	5%	1%	0%	11%	1 x harrowing
spring barley	7%	5%	1%	0%	13%	2 x harrowing
silage maize	12%	0%	0%	0%	12%	1 x harrowing, 2 x hoeing
grain maize	12%	0%	0%	0%	12%	1 x harrowing, 2 x hoeing
winter oil seed rape	12%	6%	16%	5%	39%	2 x hoeing
sugar beet	12%	5%	6%		23%	4 x hoeing
table potato	10%	22%	6%		38%	3 x harrowing und hoeing, mechanical haulm removal
starch potato	10%	22%	6%		38%	3 x harrowing und hoeing, mechanical haulm removal
field bean	2%	5%	6%		13%	1 x harrowing, 1 x hoeing
forage peas	2%	5%	6%		13%	1 x harrowing, 1 x hoeing

The **benefits** for the cultivation of the crops are made up of the yield achieved multiplied by the net sales price generated. The yield losses due to not using plant protection products are shown in Table 11, depending on the respective areas of action (herbicides, fungicides, insecticides, growth regulators).

The changes in **operating funds** are as follows:

The costs for the seed used are reduced by the dressing costs for cereals and maize, based on the standard value contributions of the Lower Saxony Chamber of Agriculture (2022). In the case of seed costs for maize, the share of dressing costs in the seed price was calculated. For this purpose, the share of dressing costs in the grain types shown was determined and the arithmetic mean was formed. The percentage determined in this way (15.79%) describes the share of dressing costs in the purchase price for maize seed. The sowing rate for maize and cereals was increased by 10% to compensate for losses due to the use of the harrow (DLG 2022 p.7).

For the crop production methods, mechanical weed control (hoe and/or harrow) was assumed as a matter of principle, as this represents a customary adaptation reaction when dispensing with the use of herbicides. The number of passes for mechanical weed control is based on the assumed crop management of the organic crop production methods within the web application "Leistungs-Kostenrechnung Pflanzenbau/ Activity-based costing for plant cultivation" of the KTBL (cf. Table 11).

An adjustment of fertiliser costs results from the reduced yield level compared to the initial situation. Further modifications concern the labour costs. In this context, the changed crop management affects the machines used (use of hoe and/or harrow instead of crop protection sprayer), as well as the required labour time and diesel fuel.

Vegetable cultivation

In principle, the profitability of integrated vegetable production has been calculated with KTBL data. For example, variable labour costs for weeding, hand hoeing or harvesting were set at 14.00 € per acre and fixed labour costs at 21.50 € per acre. Deviating from the KTBL, the fertiliser prices have been updated (see Table 13) and a diesel price of 1.70 € per litre has been included in the calculations. In comparison to the "integrated vegetable production methods", the following modifications were taken into account in the methods "without chemical plant protection":

- Chemical plant protection has been replaced by alternative methods (see Table 9). As a result, the labour costs for machinery and labour have been recalculated.
- For individual vegetable species, it has also been assumed that the amount of seed/planting material is increased. Plant losses due to mechanical measures should thus be compensated or a denser stand leads to stronger weed suppression.
- The costs for fertiliser, hail insurance and, if applicable, marketing costs were adjusted to the yield reductions.

2.4 Price and cost ratios

As already explained, the economic evaluation of the crop production methods is based on the KTBL web application "*Leistungs-Kostenrechnung Pflanzenbau/ Activity-based costing for plant cultivation*". The prices for products and inputs used in the calculations basically correspond to the assumptions of the KTBL in 2023 and have been checked for plausibility. Assumptions regarding producer prices have been made. Therefore, the planned data for the 2023 harvest from the Bavarian State Research Center for Agriculture, which were derived from the "LfL Contribution Margins and Calculation Data" tool, were used.

The producer prices assumed in the tool also reflect the expected price level in the long term (see Table 12).

Table 12: *Producer prices in €/dt without VAT*

Crops in arable farming		Producer prices without VAT in €/dt
Cereals	Winter wheat	25,20 €
	Winter barley	21,55 €
	Winter rye	22,29 €
	Oats	21,49 €
	Spring barley	28,24 €
Maize	Silage maize (ex field)	3,97 €
	Grain maize	25,77 €
Oil fruits	Rapeseed	52,03 €
Root crops	Sugar beet	4,81 €
	Table potatoes	13,41 €
	Starch potatoes	8,75 €
Legumes	Field bean	25,10 €
	Forage pea	24,06 €

Source: LFL BAYERN 2023

Further adjustments concern the costs for the production inputs fertiliser and diesel, which were subject to strong fluctuations as a result of the Ukraine crisis. The assumed prices for the fertilisers used are based on the price level of February 2023. As with producer prices, it is assumed that the price peaks of the past months will not be reached again in the long term. On the other hand, it is not assumed that the prices will be reduced to the level before the Ukraine war in the foreseeable future. The selected prices take a middle position here. Costs of 1.70 €/l were assumed for the diesel fuel used; the assumed fertiliser prices can be taken from the table below (see Tab. 13). Based on the listed fertilisers and their market prices, the fertiliser costs for the nutrients (nitrogen, phosphorus and potassium) per kilogram of pure nutrient were determined. The fertiliser costs in the procedure are therefore the product of the factors nutrient requirement and factor price per kilogram of pure nutrient. Deviations from this procedure refer to the model livestock farm in the low mountain region and are described separately.

***Table 13**: Prices for fertilisers in €/dt without VAT.*

mineral fertiliser	Nutirents (kg/dt)					prices February 2023
Fertiliser	N	P_2O_5	K_2O	MgO	CaO	€/dt (free yard)
calcium ammonium nitrate	27,00	0,00	0,00	0,00	13,00	46,00 €
Urea ammonium nitrate solution	28,00	0,00	0,00	0,00	0,00	49,40 €
ammonium sulphate nitrate	26,00	0,00	0,00	0,00	0,00	54,20 €
diammonium phosphate	18,00	46,00	0,00	0,00	0,00	77,60 €
triple superphosphate	0,00	46,00	0,00	0,00	0,00	69,70 €
grain potash w. 6% MgO	0,00	0,00	40,00	6,00	0,00	59,30 €
potash fertilizer			30,00	10,00		72,50 €
carbonate of lime				5,00	80,00	3,80 €

Source: AMI in AGRARHEUTE 2023

In all calculations of this study, net prices have been used for product and equipment prices. Since the VAT/pre-tax is an income/expense for flat-rate farms, these farms should calculate with gross prices in their business calculations. It can therefore be assumed that flat-rate farms have somewhat higher adjustment costs for the measures examined than shown in the results.

Vegetable farm

Depending on the market situation, producer prices for vegetables fluctuate relatively strongly depending on the year and season. Prices for many types of vegetables have risen and are currently stabilising at a high level. It is difficult to predict at which price level producer prices will remain in the coming years. The prices for the calculations were estimated from KTBL 2023 data with average prices of the past three years (data according to KOCH 2023 and experts such as LAUN 2023, ZIEGLER 2023 and MEISE 2023). Table 14 shows the producer prices used.

***Table 14**: Producer prices for the vegetable species studied*

Culture	Producer prices		
	Price AMI, March 2023, Experts	Price KTBL March 2023	**Price used**
Asparagus, all Grades	5,07 €/kg		**5,64 €/kg**
Edible onion, Sowing onion	27 €/dt	25 €/dt	**27,00 €/dt**
Carrots, fresh market produce,			**70,00 €/dt**
	39 €/dt	28 €/dt	**39,00 €/dt***
Bush bean, Processed goods	Fresh market: 1,37 €/kg Industry: 23,00 €/dt	18,50 €/dt	**18,50 €/dt**
Iceberg lettuce, fresh market produce, Summer cultivation	0,46 €/piece	0,46 €/piece	**0,46 €/piece**
Cauliflower, Fresh market produce, summer cultivation	0,86 €/piece	0,74 €/piece	**0,86 €/piece**
Peas, processed goods	Fresh market: 13.7 €/dt Industry: 23,00 €/dt	25,70 €/dt	**25,70 €/dt**
Lamb's lettuce, fresh market produce Autumn cultivation	3,97 €/kg	4,32 €/kg	**3,97 €/kg**
* additional assumption: low price level for carrot cultivation			

Source: KTBL 2023, KOCH 2023, LAUN 2023, ZIEGLER 2023, MEISE 2023

Especially in the case of carrots and onions, an estimation of future producer prices is associated with greater uncertainties. The present report was ultimately based on the estimates of the experts for vegetables.

2.5 Requirements for crop rotation in linear programming

After defining and calculating the individual cultivation methods, the crop rotation is optimised with the help of linear programming. Since linear programming aims to maximise the target function (overall farm DAL), cultivation restrictions must be formulated to take account of both economic considerations and crop production requirements.

The crop restrictions for the two arable sites can be found in Table 15. In principle, it is assumed that the model farms are

choose at least a three crop rotation cycle. Thus, the maximum cultivation concentration (MC) of each crop cannot exceed one third of the arable land. In this way, the agricultural policy requirement for crop rotation (e.g., no crop in self rotation) is implemented, but phytosanitary concerns are also taken into account. In an integrated cultivation system, for example, it is recommended that winter rape be cultivated for at least three years. Test evaluations show that the increased pest pressure in narrow crop rotations cannot be countered economically with additional pesticide use (GRAF et al. 2008; LWK NRW 2015). Another influencing factor in the planning of crop rotation results from the marketing opportunities of the cultivated crops on the farm. Accordingly, restrictions have been formulated for the fruits brewing barley, sugar beet and potato. The agricultural policy requirements also include the implementation of fallow on 4% of the arable land in order to meet the requirements of conditionality.

***Table 15**: restrictions for linear programming*

requirements for the crop rotation - maximum share per crop	with PPP 3 crop rotation cycle maximum share per culture: 33%	without PPP 5 crop rotation cycle maximum share per culture: 20%
oats	25%	20%
spring barley	10%	10%
sugar beet	15%	15%
potato	15%	15%
field bean	20%	20%
forage pea	17%	17%
fallow land	4%	4%

If the use of plant protection products is dispensed with in crop management, it makes sense to choose a wider crop rotation in order to counteract the increasing weed and pest pressure. Accordingly, in the "without crop protection" system, a five-unit crop rotation is selected and the maximum cultivation concentration is set at a maximum of 20%.

The linear optimisation of the fodder farm takes into account two scenarios with different plant protection intensity levels (high/medium) for the permanent grassland as well as a variation of the available agriculatural land (80 ha UAA and 100 ha UAA) with a constant grassland share of 75 percent.

In addition to the arable crops (winter wheat, winter barley, silage maize and field grass), the grass silage and hay production methods have been defined for grassland management. The model farm is supplemented by the livestock farming method

"Dairy cow husbandry including rearing of heifers. The winter cereals are considered as market fruit and are sold. The fodder (silage maize, grass silage and hay) can be used internally (feeding) in animal husbandry or sold.

With regard to the restrictions, it was assumed that winter cereals and arable grass can each occupy a maximum share of 33 percent of the arable land (see Table 16), while silage maize can occupy a maximum share of 66.67 percent (crop rotation on the land at least once in three years), e.g. in the case of a fodder shortage on grassland, according to GAEC 7 of the CAP reform 2023.

***Table 16**: Restrictions for crop rotation in linear programming*

requirements for the crop rotation - maximum share per crop	with PPP per crop	without PPP per crop
silage maize	67%	67%
winter wheat	33%	33%
winter barley	33%	33%
arable gras	33%	33%

The maximum herd size in dairy cow husbandry is limited to 100 stalls. With regard to feeding, the focus is primarily on supplying the animals with an energy requirement from basic feed, which guarantees a basic feed output of 30,810 MJ NEL per dairy cow and year and 7,744 MJ ME for the proportionate heifer rearing per dairy cow and year. Furthermore, a raw fibre requirement of 803 kg per cow and year, including pro rata heifer rearing, has been established.

2.6 Planning methods

Linear programming

The crop rotations in the model farms were determined using linear programming, which is a frequently used method for the strategic planning of production processes in agriculture. In this method, the crop rotation is optimised according to economic advantageousness while adhering to predefined cultivation restrictions. The linear planning calculation was carried out using Microsoft Excel, which offers an instrument for linear programming of model farms with the add-in "Excel Solver".

In order to calculate the business effects for the model farms, the direct and labour cost-free performance (DAL) was used.

The DAL is calculated by deducting the direct costs and the fixed and variable labour completion costs from the revenues (cf. Tab. 17). In contrast to the contribution margin (DB), the DAL also includes the fixed labour completion costs (salaries for permanent employees, the imputed salery rate for the farm managers) and the fixed machine costs in the calculation. Since only the variable costs are taken into account in the contribution margin, it mainly reflects the short-term adjustment costs of the measures. In contrast, the DAL should be used to consider the medium-term adjustment costs.

Table 17: *Calculation scheme of the performance measures contribution margin (DB) and direct and labour cost-free performance (DAL).*

	revenue	sales from selling of products
–	direct costs	material costs (seeds, fertiliser, plant protection products), interest costs for the deployed capital
–	variable labour completion costs	variable machine costs (fuel and lubricants, repairs), services provided by agricultural contractors
=	**contribution margin (DB)**	
–	fixed labour completion costs	fixed machine costs (depreciation, interest costs, insurance premiums, equipment storage costs) salaries for permanent employees imputed salary rate
=	**direct and labour-cost-free performance**	

In order to determine the adjustment costs caused by the renunciation of PPP a comparison with a baseline situation or a reference system is required. The reference system is based on the current agricultural policy framework conditions such as ecological conditionalities (4 % fallow land, no continous cropping, ...). The adjustment costs can be derived from the changed costs compared to the initial situation.

Activity-based costing (ABC / LKR)

The adjustment costs of further measures were calculated using a benefit-cost calculation called Activity-based costing (ABC / LKR) . This method takes into account the respective outputs of the production processes (e.g. from the sale of harvested products) and the costs that are directly attributable to the production process. Moreover, the direct and labour cost-free performance (DAL) was used to measure success. Activity-based costing is used in two places in this study. Firstly, it is used for the economic presentation of the crop production methods (see appendix). Secondly, the method was used for

the vegetable crops in the 4th model farm, in order to compare two cultivation situations "with plant protection" and "without plant protection (without PPP)".

3 Results on the abandonment of chemical plant protection

3.1 Model farm 1: "good arable farming site

The economic effects for the model farm can be derived on the one hand from the DAL achieved for the individual cultivation methods. On the other hand, the realised crop rotation is decisive, which determines the importance of the individual crops for the farm by means of the cultivation volumes.

Table 18 shows an economic evaluation of the crop production methods considered for the good arable site. Here, the assumed yield reductions due to not using plant protection products (herbicide, fungicide, insecticide and growth regulator) are described, as well as the adapted crop management. Mechanical weed control is assumed as an alternative. The operational effects are compared via the generated yields in kind (dt/ha) and the achieved direct and labour cost-free performance (DAL in €/ha) for the two farming systems "conventional/integrated" and "without crop protection". At the end of the table the calculated differences between the two farming systems are shown. The difference in the direct and labour-free benefits lie between 29 €/ha and 2,047 €/ha. It is noticeable that the spring cereals react with comparatively low yield losses and reduced DAL to the abandonment of plant protection products. The DAL losses are more significant for economically strong crops such as wheat, rape and sugar beet. The most significant effects, however, are for potato cultivation. In addition, it should be noted that the economic attractiveness and the associated cultivation attractiveness depend to a large extent on the producer price situation.

As a consequence of not using plant protection products, the cultivation risk also increases. Especially in the case of rape, sugar beet and potatoes, the high cultivation risk can lead to total failure. Besides potatoes, the cultivation of rape without chemical crop protection is also fundamentally problematic. In years without heavy pest infestation, cultivation works, but in other years there can be total failure. Weed control by hoeing is also not easy, especially grasses can hardly be controlled by hoeing. Due to the assumed average yield reductions when chemical plant protection is dispensed with and the comparatively good economic efficiency in integrated cultivation, rape remains economically viable even without the use of chemical plant protection products in the expert opinion. In practice, however, the high cultivation risk may mean that in some cases no more rape is cultivated.

***Table 18**: Definition of crop production methods at the good arable site*

Cash Crop Farm - good arable farming locations with high yield potencial												
crop	**yield reduction due to the renunciation of plant protection products ...**					**mechanical weed control**	**yields and earnings**				**difference**	
							with PPP		**without PPP**			
	Herbicide	**fungizide**	**insecticide**	**GR***	**total**	amount of treatments	dt/ha	DAL in €/ha	dt/ha	DAL in €/ha	(dt/ha)	DAL in €/ha
winter wheat	16%	13%	1%	0%	30%	3 x harrowing	98,60	806,00 €	69,02	446,67 €	-29,58	- 359,33 €
winter barley	14%	14%	1%	0%	29%	2 x harrowing	78,80	204,69 €	55,95	48,14 €	-22,85	- 156,55 €
winter rye	14%	14%	1%	0%	29%	1 x harrowing	78,80	451,54 €	55,95	245,48 €	-22,85	- 206,06 €
oats	5%	5%	1%	0%	11%	1 x harrowing	59,20	140,06 €	52,69	111,10 €	-6,51	- 28,96 €
spring barley	7%	5%	1%	0%	13%	2 x harrowing	69,00	714,11 €	60,03	636,55 €	-8,97	- 77,56 €
silage maize	12%	0%	0%	0%	12%	1 x harrowing, 2 x hoeing	528,00	523,47 €	464,64	467,01 €	-63,36	- 56,46 €
grain maize	12%	0%	0%	0%	12%	1 x harrowing, 2 x hoeing	114,00	692,93 €	100,32	522,02 €	-13,68	- 170,91 €
winter oil seed rape	12%	6%	16%	5%	39%	2 x hoeing	44,10	731,62 €	27,03	305,07 €	-17,07	- 426,55 €
sugar beet	12%	5%	6%		23%	4 x hoeing	700,00	1.360,43 €	539,00	1.015,83 €	-161,00	- 344,60 €
table potato	10%	22%	6%		38%	3 x harrowing und hoeing, mechanical haulm removal	550,00	1.131,13 €	341,00	- 915,41 €	-209,00	- 2.046,54 €
starch potato	10%	22%	6%		38%	3 x harrowing und hoeing, mechanical haulm removal	650,00	1.372,52 €	403,00	6,95 €	-247,00	- 1.365,57 €
field bean	2%	5%	6%		13%	1 x harrowing, 1 x hoeing	49,30	223,17 €	42,89	141,26 €	-6,41	- 81,91 €
* GR = growth regulator; PPP = plant protection products												

In addition to the economic assessment of foregoing crop protection for the individual crops, the operational effects for crop rotation were determined using linear programming. As in practice, the farm manager can adjust his crop rotation based on the changed yield expectations and the economic advantages of the crops. Accordingly, linear programming optimises the crop rotation for a cultivation system "with crop protection", which serves as a reference system. Subsequently, the cultivation programme is optimised for a system "without crop protection". The economic consequences for the farm result from the comparison of the two crop rotations and the direct and labour-free outputs achieved.

***Table 19**: Results for the good arable farming location - Soester Börde*

Cash Crop Farm - good arable farming locations with high yield potencial					
crop	**reference system**		**without PPP**		**Difference**
	ha	**%**	**ha**	**%**	**%**
winter wheat	38,40	33%	19,20	20%	-13%
winter rye			14,40	15%	15%
spring barles	3,84	3%	9,60	10%	7%
grain maize			19,20	20%	20%
winter oil seed rape	38,40	33%	19,20	20%	-13%
sugar beet	17,28	15%	14,40	15%	0%
table potato	17,28	15%			-15%
fallow land	4,80		4,00		
total	**120,00**	**100%**	**100**	**100%**	
leased land	**yes**		**no**		
DAL in €	**93.391,53 €**		**48.512,74 €**		
Difference in €/farm	**-**		**44.878,79 €**		
Differece in €/ha	**-**		**448,79 €**		

In the reference system (see Table 19), the farm operates conventionally/integrated and establishes the following crops in its crop rotation, taking into account the formulated cultivation restrictions: 33% wheat, 33% winter rape, 15% sugar beet, 15% starch potatoes and 3% spring barley. Furthermore, 4% of the available arable land is set aside to comply with the conditionality requirements. The model farm generates € 93,391.53 through the cultivation programme described above.

If the farm is now required not to use plant protection products in arable farming due to the SUR regulation, the yields in kind decrease and the crop management changes. A five-unit crop rotation is assumed in order to reduce weed and pest pressure. Accordingly, on the one hand, the maximum possible cropping rates in the crop rotation change from 33% to 20%. On the other hand, the suitability of the respective crops for cultivation changes (compare Table 18). Without the use of crop protection products, potatoes in particular lose

economic attractiveness and fall out of the cultivation plan. On the other hand, crops such as grain maize and winter rye are gaining in cultivability and are now included in the crop rotation. If one considers the rent price level in the region of 768 €/ha in comparison to the generated DAL of the crops, it becomes clear that a lease at this price level can no longer be re- alised. In total, the farm generates DAL of € 48,512.74 through the modified cultivation programme.

Compared to the initial situation/reference system, there is a reduction in the farm DAL of € 44,878.79. Applied to a cultivated area of 100 ha, this results in a DAL loss of 448.79 €/ha compared to the reference system.

3.2 Model farm 2: "weak arable farming site

The second arable site is characterised by large-structured plots (40 ha) with light soils and a weaker yield level. It should be noted that for the model farm in the reference system a non-applied tillage was assumed. In the case of no pesticides, however, the assumption was made that turning the soil reduces weed pressure and the influence of pests on the crop. For this reason, the crop management in the "without plant protection" scenario was changed accordingly to turning tillage.

With the assumed price and cost ratios, the direct and labour cost-free benefits of the fruits at this location are comparatively low and partly negative. The fixed special costs cannot always be fully covered by the contribution margins. Without the single farm payment, profitable arable farming is difficult to realise under the given assumptions. As a modification, therefore, a **light site with a 20% higher yield level has** also been cal- culated. An overview of the crop production methods is shown in Table 20. The crop production methods at the Brandenburg site and the variation "**yields in kind +20%**" are visualised.

***Table 20**: Definition of crop production methods at the weak arable site*

Cash Crop Farm - weak arable farming locations with low yield potencial												
crop	yield reduction due to the renunciation of plant protection products ...					mechanical weed control	yields and earnings				difference	
							with PPP		without PPP			
	Herbicide	fungizide	insecticide	GR*	total	amount of treatments	dt/ha	DAL in €/ha	dt/ha	DAL in €/ha	(dt/ha)	DAL in €/ha
winter wheat	16%	13%	1%	0%	30%	2 x harrowing	59,20	342,29 €	41,44	62,75 €	-17,76	- 279,54 €
winter barley	14%	14%	1%	0%	29%	2 x harrowing	54,20	61,20 €	38,48	- 107,10 €	-15,72	- 168,30 €
winter rye	14%	14%	1%	0%	29%	1 x harrowing	39,40	- 21,50 €	27,97	- 174,78 €	-11,43	- 153,28 €
silage maize	12%	0%	0%	0%	12%	1 x harrowing, 2 x hoeing	352,00	191,44 €	309,76	124,89 €	-42,24	- 66,55 €
winter oil seed rape	12%	6%	16%	5%	39%	2 x hoeing	29,40	465,15 €	17,93	37,14 €	-11,47	- 428,01 €
forage peas	2%	5%	6%		13%	2 x harrowing	24,70	- 214,00 €	21,49	- 220,98 €	-3,21	- 6,98 €
Cash Crop Farm - weak arable farming locations with medium yield potencial (variation: +20%)												
crop	yield reduction due to the renunciation of plant protection products ...					mechanical weed control	yields and earnings				difference	
							with PPP		without PPP			
	Herbicide	fungizide	insecticide	GR*	total	amount of treatments	dt/ha	DAL in €/ha	dt/ha	DAL in €/ha	(dt/ha)	DAL in €/ha
winter wheat	16%	13%	1%	0%	30%	2 x harrowing	71,04	587,53 €	49,73	234,36 €	-21,31	- 353,17 €
winter barley	14%	14%	1%	0%	29%	2 x harrowing	65,04	246,45 €	46,18	24,37 €	-18,86	- 222,08 €
winter rye	14%	14%	1%	0%	29%	1 x harrowing	47,28	118,97 €	33,57	- 75,09 €	-13,71	- 194,06 €
silage maize	12%	0%	0%	0%	12%	1 x harrowing, 2 x hoeing	422,40	364,02 €	371,71	276,73 €	-50,69	- 87,29 €
winter oil seed rape	12%	6%	16%	5%	39%	2 x hoeing	35,28	713,57 €	21,52	188,65 €	-13,76	- 524,92 €
forage peas	2%	5%	6%		13%	2 x harrowing	29,64	- 113,27 €	25,79	- 133,26 €	-3,85	- 19,99 €

* GR = growth regulator; PPP = plant protection products

Table 21 shows the result of linear programming for this location. In the reference system, the farm has a three-part crop rotation consisting of one third each of wheat - rape - silage maize. The farm leases 20 ha of arable land and fulfils the conditionality requirements with 4% fallow. The farm earns € 33,693.95 DAL through the cultivation programme.

***Table 21**: Results for the weak arable site*

Cash Crop Farm - weak arable farming locations with low yield potencial				
crop	**reference system**		**without PPP**	
	ha	**%**	**ha**	**%**
winter wheat	38,40	33%	19,20	
winter barley				
winter rye				
silage maize	38,40	33%	19,20	
winter oil seed rape	38,40	33%	19,20	
forage peas				
fallow land	4,80		4,00	
total	**120,00**		**61,60**	
leased land	**yes**		**no**	
DAL in €	**33.693,95 €**		**4.096,58 €**	
Difference in €/farm	**-**		**29.597,37 €**	
Differece in €/ha	**economically unfeasible**			

Looking at Table 20, it becomes clear why linear programming does not design an alternative cultivation programme for the model farm without PPPs. With the exception of winter wheat, winter oilseed rape and silage maize, negative DALs result for all crop production methods - at this location and under the assumptions made. Accordingly, the optimisation only selects 20% each of winter wheat, winter rape and silage maize in the cultivation programme and no other crop.

As a variation, it was investigated how the results for a light site with large-scale management units change when the natural yields assume a medium level. Accordingly, under otherwise identical assumptions, the yields per hectare were increased by 20%. Table 22 visualises the results of linear programming.

Table 22: *Results for the weak arable site (variation yield +20%)*

Cash Crop Farm - weak arable farming locations with medium yield potencial (variation: +20%)						
Fruchtfolge	3 crop rotation cycle		**5 crop rotation cycle**		**3 crop rotation cycle**	
crop	**reference system**		**without PPP**		**without PPP**	
	ha	**%**	**ha**	**%**	**ha**	**%**
winter wheat	38,40	33%	19,20		38,40	33%
winter barley			19,20			
winter rye						
silage maize	38,40	33%	19,20		38,40	33%
winter oil seed rape	38,40	33%	19,20		38,40	33%
forage peas						
fallow land	4,80		4,00		4,80	
total	**120,00**	**100%**	**80,80**		**120,00**	**100%**
leased land	**ja**		**nein**		**nein**	
DAL in €	**59.277,57 €**		**13.683,71 €**		**22.206,98 €**	
Difference in €/farm	-		**45.593,86 €**		-	**37.070,59 €**
Difference in €/ha			economically unfeasible		-	**308,92 €**

The crop rotation in the baseline situation remains unchanged with one third each of wheat, rape and silage maize. However, the higher yields in kind (+20%) lead to a higher output of the crop production methods. The farm achieves direct and labour cost-free benefits in the amount of 59,277.57 € in cultivation. In the case of a renunciation of plant protection products, the yields of the crops are reduced (see Table 20). Only the crops wheat, barley, winter rape and silage maize still achieve positive DAL under these conditions. As a consequence, linear programming selects these crops for cultivation, but cannot expand the cultivation volumes for the required five-unit crop rotation beyond 20% per crop. Consequently, only 80.80 ha including 4 ha of fallow are cultivated (compare Table 22).

If the requirements for crop rotation were reduced from a five-member to a three-member crop rotation, the three crops with the highest DAL would each be able to utilise a share of one third of the arable land and thus the entire available arable land could be cultivated.

3.3 Model farm 3: "Fodder production"

In order to determine the adaptation costs arising from the abandonment of chemical-synthetic plant protection products in the fodder farming business as a whole, the reference situation (reference system) should also be established on the basis of the direct and labour cost-free performance (DAL).

Scenario: 80 ha, high PPP intensity Permanent grassland

In the scenario "80 hectares of land and high pesticide intensity on permanent grassland", the reference system (conventional/integrated type of farming) shows a direct and labour cost-free performance of the total farm amounting to 161,161.22 Euros. This results from the cultivation of 13.40 hectares of silage maize (695.66 Euros DAL per hectare) and 6.60 hectares of field grass (560.02 Euros DAL per hectare) on the arable land, as well as a grass silage production of 47.48 hectares (388.08 Euros DAL per hectare) and a hay production of 12.52 hectares (533.35 Euros DAL per hectare) on the permanent grassland. In addition, 100 dairy cows (1,594.53 Euro DAL per cow and year) including heifer rearing are kept. Since the yield situation of the "initial situation" sufficiently ensures the basic fodder supply, mainly by not cultivating winter cereals on the arable land, part of the grassland growth, about 29.87 tonnes of hay, can be sold for an average of 168.50 euros per tonne.

In the procedure "without chemical plant protection", the direct and labour cost-free performance of the total farm is reduced by 24,414.56 Euros to a total of 136,746.66 Euros, which corresponds to 308.92 €/ha. Due to the assumed yield reductions caused by the renunciation of chemical plant protection, a shortage of basic fodder occurs on the fodder farm, which the farm can only partially compensate for by increasing the silage use of the permanent grassland and renouncing the sale of hay. The silage maize cultivation was already fully exhausted in the reference system. The shortage of basic fodder causes the dairy herd, including heifer rearing, to be reduced by more than eleven dairy cows. Additional compensatory measures to mitigate the yield risks, e.g. through mechanical weed control, increasing the amount of reseeding on permanent grassland, etc., lead to an increase in the number of dairy cows. ..., lead to an increase in feed costs and also reduce the direct and labour cost-free performance per remaining dairy cow on the farm to 1,547.21 euros per cow and year.

***Table 23**: Linear optimisation of fodder farm (80 ha LN, high level of PPPs in permanent grassland)*

Crops	Reference system (high PPP intensity on permanent grassland)		without PPP		Change
	ha/places	%	ha	%	%
Winter wheat	0,00	0%	0,00	0%	0%
Winter barley	0,00	0%	0,00	0%	0%
Silage maize	13,40	17%	13,40	17%	0%
Arable grass	6,60	8%	6,60	8%	0%
Permanent grassland	47,48	59%	50,85	64%	4%
Hay	12,52	16%	9,15	11%	-4%
Dairy farming	100,00	100%	88,38	88%	-12%
Sum agricultural land	**80,00**	**100%**	**80,00**	**100%**	
Total cow places	**100,00**	**100%**			
DAL in €	**161.161,22 €**		**136.746,66 €**		
Difference in €/farm	**-24.414,56 €**				
Difference in €/ha	**-305,18 €**				

Scenario: 80 ha, medium PPP intensity Permanent grassland

In the scenario "80 hectares of land and medium pesticide intensity on permanent grassland", the reference system shows a direct and labour cost-free performance of the total farm of 165,383.37 euros. This results from the cultivation of 13.40 hectares of silage maize (695.66 Euros DAL per hectare) and 6.60 hectares of field grass (560.02 Euros DAL per hectare) on the arable land, as well as grass silage production of 47.48 hectares (471.39 Euros DAL per hectare) and hay production of 12.52 hectares (616.66 Euros per hectare) on the permanent grassland. In addition, 100 dairy cows and heifer rearing are kept. Since the yield situation of the "initial situation" sufficiently ensures the basic fodder supply, especially by not cultivating winter cereals on the arable land, part of the grassland growth, about 29.86 tonnes of hay, can be sold.

The difference to the direct and labour cost-free performance of the baseline situation in the "high PPP intensity" scenario is 4,222.15 euros and is due to a lower pesticide input on grassland, which in turn causes lower feed costs and a higher direct and labour cost-free performance in dairy cow husbandry.

In the procedure "without chemical plant protection", the direct and direct and labour cost-free performance of the entire farm is reduced by 16,397.54 euros to a total of 148,985.83 euros. Due to the assumed yield reductions through the renunciation of chemical plant protection, the fodder production farm again experiences a reduction in yields.

The farm can only partially compensate for this by increasing the use of permanent grassland for silage and not selling hay. The silage maize cultivation was again completely exhausted in the reference system. The shortage of basic fodder causes the dairy herd, including heifer rearing, to be reduced by just over six dairy cows. Additional compensatory measures to mitigate yield risks, e.g. through mechanical weed control, increasing the amount of reseeding on permanent grassland, etc., lead to an increase in the number of dairy cows. ..., lead to an increase in feed costs and also reduce the ddirect and labour cost-free performance per remaining dairy cow on the farm.

Since the yield decline in this scenario is only half as strong in grassland management as in the previous scenario with "high PPP intensity", the effects on dairy cow husbandry are not as massive in terms of herd reduction and changes in feed costs. Compared to the "high PPP intensity" scenario, the direct and labour cost-free performance of the entire farm in the "medium PPP intensity" variant without chemical plant protection is 12,239.17 euros higher.

***Table 24**: Linear optimisation of a fodder farm (80 ha LN, medium level of PPPs in permanent grassland)*

Crops	Reference system (medium PPP intensity on permanent grassland)		without PPP		Change
	ha/places	%	ha	%	%
Winter wheat	0,00	0%	0,00	0%	0%
Winter barley	0,00	0%	0,00	0%	0%
Silage maize	13,40	17%	13,40	17%	0%
Arable grass	6,60	8%	6,60	8%	0%
Permanent grassland	47,48	59%	50,82	64%	4%
Hay	12,52	16%	9,18	11%	-4%
Dairy farming	100,00	100%	93,63	94%	-6%
Sum agricultural land	**80,00**	**100%**	**80,00**	**100%**	
Total cow places	**100,00**	**100%**			
DAL in €	**165.383,37 €**		**148.985,83 €**		
Difference in €/farm	**-16.397,54 €**				
Difference in €/ha	**-204,97 €**				

Scenario: 100 ha, high PPP intensity Permanent grassland

By modifying or increasing the scarce factor "area" for the two existing scenarios, the model of the fodder farm can be extended by two more. This counteracts a possible shortage of fodder in advance by dispensing with chemical crop protection. Assuming a "high pesticide intensity", the reference system shows a direct and labour cost-free performance of the entire farm of 174,712.94 euros. This results from the cultivation of 16.75 hectares of silage maize (695.66 Euros DAL per hectare) and 8.25 hectares of field grass (560.02 Euros DAL per hectare) on the arable land, as well as grass silage production of 37.07 hectares (388.08 Euros DAL per hectare) and hay production of 37.93 hectares (533.35 Euros DAL per hectare) on the permanent grassland. In addition, 100 dairy cows (1,594.53 Euro DAL per dairy cow and year) including heifer rearing are kept. Since the income situation of the

In this scenario, a very large amount of grassland growth, about 266.67 tonnes of hay, can be sold for 168.50 euros per tonne if the "initial situation" in this scenario, compared to the scenario with 80 hectares of land, adequately ensures the basic fodder supply to a significantly higher extent.

In the procedure "without chemical plant protection", the direct and direct and labour cost-free performance of the entire farm is reduced by 13,564.04 euros to a total of 161,148.90 euros. Due to the assumed yield reductions caused by the renunciation of chemical plant protection, there is a shortage of basic fodder on the fodder farm, but the farm can completely compensate for this by increasing the use of permanent grassland and a conditional renunciation of the sale of hay (- 160.86 tonnes). The silage maize cultivation had already been completely exhausted in the reference system. In this situation, the dairy herd does not have to be reduced. Only the increased feed costs lead to a reduction in the direct and labour cost-free performance per dairy cow (1,547.21 euros per cow and year) on the farm.

***Table 25**: Linear optimisation of a fodder farm (100 ha LN, high level of PPPs in permanent grassland)*

Crops	Reference system (high PPP intensity on permanent grassland)		without PPP		Change
	ha/places	%	ha	%	%
Winter wheat	0,00	0%	0,00	0%	0%
Winter barley	0,00	0%	0,00	0%	0%
Silage maize	16,75	17%	16,75	17%	0%
Arable grass	8,25	8%	8,25	8%	0%
Permanent grassland	37,07	37%	52,04	52%	15%
Hay	37,93	38%	22,96	23%	-15%
Dairy farming	100,00	100%	100,00	100%	0%
Sum aricultural land	**100,00**	**100%**	**100,00**	**100%**	
Total cow places	**100,00**	**100%**			
DAL in €	**174.712,94 €**		**161.148,90 €**		
Difference in €/farm	**-13.564,04 €**				
Difference in €/ha	**-135,64 €**				

Scenario: 100 ha, medium PPP intensity Permanent grassland

In the scenario "100 hectares of land and medium pesticide intensity on permanent grassland", the reference system shows a direct and labour cost-free performance of the total farm of 181,052.07 euros and thus represents the highest objective function value within the variants considered. This results from the cultivation of 16.75 hectares of silage maize (695 Euros DAL per hectare) and 8.25 hectares of field grass (560.02 Euros DAL per hectare) on the arable land, as well as a grass silage production of 37.08 hectares (471.39 Euros per hectare) and a hay production of 37.92 hectares (616.66 Euros DAL per hectare) on the permanent grassland. In addition, 100 dairy cows (1,634.08 Euro DAL per hectare) including heifer rearing are kept. Since the yield situation of the "initial situation" sufficiently ensures the basic fodder supply, 266.67 tonnes of hay can also be sold.

In the procedure "without chemical plant protection", the direct and labour cost-free performance of the entire farm is reduced by 10,928.87 euros to a total of 170,123.20 euros. Due to the assumed yield reductions through the renunciation of chemical plant protection, a shortage of basic fodder occurs on the fodder farm, but the farm can completely compensate for this by an increase in the use of permanent grassland and a conditional renunciation of the sale of hay (-102.92 tonnes). The cultivation of silage maize was already in the reference system.

In this situation, the dairy herd does not have to be reduced. Only the increased feed costs lead to a reduction in the direct and labour cost-free performance per dairy cow (1,591.23 euros DAL per dairy cow and year) on the farm.

***Table 26**: Linear optimisation of fodder farms (100 ha LN, medium level of PPPs in permanent grassland)*

Crops	Reference system (medium PPP intensity on permanent grassland)		without PPP		Change
	ha/places	%	ha	%	%
Winter wheat	0,00	0%	0,00	0%	0%
Winter barley	0,00	0%	0,00	0%	0%
Silage maize	16,75	17%	16,75	17%	0%
Arable grass	8,25	8%	8,25	8%	0%
Permanent grassland	37,08	37%	46,70	47%	10%
Hay	37,92	38%	28,30	28%	-10%
Dairy cow farming	100,00	100%	100,00	100%	0%
Sum agricultural land	**100,00**	**100%**	**100,00**	**100%**	
Total cow places	**100,00**	**100%**			
DAL in €	**181.052,07 €**		**170.123,20 €**		
Difference in €/farm				**-10.928,87 €**	
Difference in €/ha				**-109,29 €**	

3.4 Model farm 4: "Vegetable production

First, the economic impacts on the selected vegetable species will be presented. The vegetable species selected are those that are of greater importance in Germany and represent the most important vegetable groups.

Compliance with quality parameters plays a major role in vegetable production. The harvested produce must be free of damage, contamination, diseases and pests for marketing. In some cases, the vegetables must not contain any weeds. If the quality parameters are not met, the crop cannot be marketed. Doing without chemical pesticides can therefore quickly lead to total failure. This results in a higher cultivation risk for cultivation without chemical pesticides. The ability to control pests, diseases and weeds is therefore crucial for economic success.

***Table 27**: Economic efficiency of vegetables without chemical plant protection*

Culture	Prices in €/unit		yields and earnings				Difference	
			with PPP		without PPP			
			dt/ha	DAL in €/ha	dt/ha	DAL in €/ha	(dt/ha)	DAL in €/ha
Asparagus	564,00 €	€/dt	70,00	3.338,00 €	14,00	- 12.778,00 €	- 56,00	- 16.116,00 €
Onion	27,00 €	€/dt	475,00	4.984,27 €	190,00	- 6.360,88 €	- 285,00	- 11.345,15 €
Carrots	70,00 €	€/dt	750,00	28.218,07 €	450,00	5.997,04 €	- 300,00	- 22.221,03 €
*Carrots	39,00 €	€/dt	750,00	7.676,63 €	450,00	- 6.327,82 €	- 300,00	- 14.004,45 €
Cauliflower	0,86 €	€/pc.	21.000,00	6.239,48 €	14.700,00	1.529,06 €	- 6.300,00	- 4.710,42 €
Iceberg lettuce	0,46 €	€/pc.	60.000,00	5.867,78 €	24.000,00	- 9.194,37 €	- 36.000,00	- 15.062,15 €
Bush bean	18,50 €	€/dt	120,00	243,62 €	60,00	- 1.010,89 €	- 60,00	- 1.254,51 €
Pea	25,70 €	€/dt	65,00	- 277,28 €	42,30	- 157,15 €	- 22,70	120,13 €
Lamb's lettuce	397,00 €	€/dt	68,00	10.855,60 €	47,60	3.693,04 €	- 20,40	- 7.162,56 €
*Variation: low producer price for carrots								

When it comes to the abandonment of herbicides, manual hand weeding and hoeing play a central role in the economic evaluation of cultivation methods. Time-consuming manual weeding or hoeing results in high costs, which are expected to increase significantly in the future due to rising wages. It is questionable whether vegetable farms specializing in a few crops can provide enough labor during the relevant time periods. In addition to labor availability, these farms also need to create the appropriate infrastructure for employment. Table 28 presents the costs of alternative measures for weed control and the additional expenses resulting from herbicide abandonment for selected vegetable crops.

***Table 28**: Additional expenditure due to herbicide avoidance for selected vegetable species*

culture		measures for weed control							
	stale seedbed	flaming	harrowing	rotary hoe	hand-weeding	increased need for seed	**costs of the action**	chemical PPP	**additional expenditure due to renunciation of herbicide**
Onion	1x	1x		5x	327 Akh			8x	
	60,00 €	169,00 €		581,00 €	4.578,00 €	129,00 €	**5.517,00 €**	682,98 €	**4.834,02 €**
Carrots	1x	2x		5x	210 Akh			6x	
	60,00 €	282,00 €		414,00 €	2.940,00 €	132,00 €	**3.828,00 €**	489,00 €	**3.339,00 €**
Cauliflower			1x	3x	40 Akh			7x	
			19,00 €	201,00 €	560,00 €		**780,00 €**	511,00 €	**269,00 €**
Iceberg lettuce	1x		2x	2x	40 Akh			2x	
	60,00 €		98,00 €	200,00 €	560,00 €		**918,00 €**	253,35 €	**664,65 €**
Bush bean	1x		3x	2x	33 Akh			5x	
	60,00 €		57,00 €	102,00 €	462,00 €	44,10 €	**725,10 €**	230,00 €	**495,10 €**
Lamb's lettuce	1x		3x		40 Akh			3x	
	60,00 €		147,00 €		560,00 €	169,00 €	**936,00 €**	503,00 €	**433,00 €**

Source: Own calculations, MEISE 2023, KTBL 2023

The avoidance of herbicides leads to high additional costs due to the high amount of manual labour. For carrots and onions, additional costs of 4,834 €/ha for onions and 3,339 €/ha for carrots can already be expected with a rather cautious estimate of the use of hand weeding and hand hoeing.

The calculations of the direct and labour cost-free output for the individual vegetable crops can be found in detail in the following tables in the appendix.

The group of **legumes** with bush beans and peas also have a low economic efficiency in integrated cultivation. A medium yield level hardly leads to economic cultivation. If yield reductions of 35 % for pea and 40 % for bean as well as hand weeding are added, cultivation of legumes without chemical plant protection is not economically viable.

Carrots (root vegetable group) and **onions (onion vegetable group)** play a central role in many vegetable-growing regions in Germany in terms of cultivation importance and profitability. For both types of vegetables, a high use of manual labour is to be expected due to the renunciation of herbicides. The price level for this is very high in March 2023 at 125 €/dt for carrots (1 kg unit prepaid) and onions at 80 - 90 €/dt (yellow onions in big bags ex station), combined with a high economic efficiency. In contrast, significantly lower average prices are to be expected in the future. In the calculations, a price of 70 €/dt has been calculated for carrots and 27 €/dt for onions. Due to the relatively high price level, the cultivation of carrots is economically viable even without chemical plant protection. This is provided that the quality parameters can be met and sufficient labour is available during peak periods. At a price level of 39
€/dt, the cultivation of carrots is not economically viable without chemical pesticides. The cultivation of onions is also not economically viable without chemical crop protection.

Asparagus (group of stem vegetables) is the most important vegetable in Germany in terms of area. In particular, not using insecticides and fungicides leads on average to relatively high yield losses, so that growing asparagus without chemical plant protection is not economically viable at a constant price level.

The cultivation of **cauliflower (critical species from the cabbage group)** without insecticides leads to relatively moderate yield reductions when using crop protection nets against pests. The additional expenditure for the use of crop protection nets is shown in Table 29. Avoiding insecticides leads to additional costs of about 1,900 € per ha and year. Mechanical weed control is well possible. The cultivation of cauliflower leads to income reductions of about 4,710 € per ha if no chemical crop protection is used.

***Table 29**: Additional expenditure for the use of crop protection nets in the cultivation of cauliflower*

Expenditure for crop protection nets (net)	**costs (€/ha)**
Capital costs (depreciation, interest costs) for crop protection nets	1.400 €
Calculatory costs (storage, spindles, net laying and lifting machine)	67 €
Installation of the nets	166 €
Covering/uncovering the nets for maintenance activities, 4 times	340 €
uncovering and retrieval of the nets	153 €
Total cost of crop protection nets	**2.126 €**
Cauliflower insecticide	137 €
Passes with the plant protection sprayer, 4 times	112 €
Additional cost due to insecticide avoidance	**1.877 €**

Source: Own calculations, KTBL 2023, MEISE 2023

Field and iceberg lettuce (group lettuce) can be grown economically successfully under current conditions with a DAL of 10,856 €/ha for field lettuce and 5,868 €/ha for iceberg lettuce. The cultivation of lamb's lettuce is clearly more economical. With hand weeding of 40 Akh/ha and moderate yield reductions of approx. 30 %, the renunciation of chemical plant protection leads to income losses of approx. 7,163 €/ha. The cultivation of iceberg lettuce is not profitable without chemical plant protection. The lettuces in particular are susceptible to fungal diseases due to the weather conditions. If the use of copper and sulphur pesticides must also be dispensed with, the cultivation risk rises very sharply.

Conclusion on the vegetables

Herbicides can be replaced by alternative methods to varying degrees depending on the type of crop. This is more practicable for plant crops such as cabbage and lettuce than for acid crops. In the case of bush beans, peas and asparagus, it would also be possible in principle to avoid herbicides. Especially for acid crops such as carrots and onions, a high number of manual weeding and hoeing is necessary. It seems questionable whether the corresponding labour force is available to the farms at all during peak work periods. Compared to herbicides, the alternative methods for weed control are also more dependent on weather conditions, which results in an increased cultivation risk.

Only a few alternative options are available for fungicides and insecticides. Non-chemical methods cannot completely prevent infestation with pests, for example. Under current market conditions, the corresponding goods cannot be marketed and lead to a total loss. Possible exceptions to this are vegetables such as washed carrots or onions, which can be

be marketed without foliage. It would hardly be possible to avoid the use of insecticides due to the lack of alternatives and the high cultivation risk. An exception to this is the use of crop protection nets, for example in the cultivation of cauliflower.

The cultivation of vegetables is usually not economically viable if chemical plant protection is dispensed with and producer prices remain the same. At very high price levels and for individual vegetable species, cultivation can be economically viable if sufficient labour is available and marketing is guaranteed due to quality requirements. In any case, the cultivation risk increases considerably. It is to be expected that if chemical plant protection is abandoned, the cultivation of most vegetable species in integrated cultivation will be discontinued.

In the following, the economic effects for a model farm with a cultivation of the five most important vegetable species are presented (see Table 30).

***Table 30**: Model farm vegetable production*

culture	reference system				without PPP				Difference
	ha	%	DAL/ha	DAL/culture	ha	%	DAL/ha	DAL/culture	%
asparagus	19,2	20%	3.338,00 €	**64.089,60 €**			-12.778,00 €	**- €**	-20%
onion	19,2	20%	4.984,27 €	**95.697,98 €**			- 6.360,88 €	**- €**	-20%
carrots	19,2	20%	28.218,07 €	**541.786,94 €**	19,2	20%	5.997,04 €	**115.143,17 €**	0%
cauliflower	19,2	20%	6.239,48 €	**119.798,02 €**	19,2	20%	1.529,06 €	**29.357,95 €**	0%
iceberg lettuce	19,2	20%	5.867,78 €	**112.661,38 €**			- 9.194,37 €	**- €**	-20%
bush bean			243,62 €	**- €**			- 1.010,89 €	**- €**	
pea			- 277,28 €	**- €**			- 157,15 €	**- €**	
lamb's lettuce			10.855,60 €	**- €**	19,2	20%	3.693,04 €	**70.906,37 €**	20%
sugar beet			1.360,42 €	**- €**	19,2	20%	1.015,69 €	**19.501,25 €**	20%
winter wheat			806,00 €	**- €**	19,2	20%	446,67 €	**8.576,06 €**	20%
fallow land	4,00	4%	- 193,42 €	**- 773,68 €**	4,00	4,0%	- 193,42 €	**- 773,68 €**	
total	**100,00**	**100%**		**933.260,24 €**	**100,00**	**100%**		**242.711,12 €**	
Difference in €/Betrieb	-							**690.549,12 €**	
Difference in €/ha	-							**6.905,49 €**	

*The cultivation areas of individual crops (in %) refer to the arable land excluding fallow land. (100 ha arable land - 4 ha fallow land = 96 ha) (96 ha = 100%)

The model farm represents the vegetable production of the most important crop groups. The selected crop groups cover 75 % of German vegetable production, each crop group at least 10 % of horticulture. Within the crop groups, the most important vegetable species in terms of cultivation volume have been selected. If chemical plant protection is not used, vegetable species that are still economically viable are cultivated. The cultivation of the remaining vegetable species is abandoned. In addition, the arable crops winter wheat and sugar beet are included in the crop rotation so that at least five crops can be grown. The renunciation of chemical plant protection results in profit reductions of about 6,900 €/ha in the model farm. The cultivation of vegetables would be partly replaced by arable crops.

4 Summary and Conclusions / Executive Summary

The EU Commission has presented a draft regulation on the sustainable use of plant protection products (SUR - Sustainable Use Regulation), which aims to reduce the use of plant protection products and the use of more hazardous plant protection products by 50% by 2030. A total ban on chemical plant protection products is planned for so-called sensitive areas.

With this study, the effects of the "*Sustainable Use Regulation (SUR)" of the* European Union were investigated for various locations with different natural cultivation conditions and yield expectations as well as for different types of farming:

- Arable farm/ Cash Crop Farm - medium soils with high yield potential
- Arable farm/ Cash Crop Farm - light soils with low yield potential
- Fodder farm - medium yield potential in a low mountain region
- Vegetable farm - medium soils with medium yield potential

The relevant crops for the respective locations were determined in two steps. First, the relevant fruits were selected whith regard to their importance for cultivation. For this purpose, the cultivation conditions in regions typical for the yield level were evaluated, based on the statistics of the state offices as well as our own experience. The applied crop rotation respectivly the specific cultivation ratio was optimised on the basis of the economic advantageousness and the specified cultivation restrictions.

The arable **farming location with a high yield potential** and medium-sized fields is oriented towards the cultivation conditions in favourable regions such as the Soester Börde. Analogous to the site with a high yield potential and medium-sized fields, an **arable site with a low yield potential** but larger fields should be investigated in order to reflect the conditions in the eastern German arable regions such as Brandenburg. With the assumed price and cost ratios, which are based on the KTBL data (2023), the direct and labour cost-free outputs of the fruits on this location are comparatively low and partly negative. The fixed special costs cannot always be fully covered by the contribution margins. Without the farm payment, profitable arable farming is difficult to realise under the given assumptions. As a modification, therefore, a **light site with a 20% higher yield level has** also been calculated.

In principle, an area of 100 ha of arable land is assumed for the model farms of the arable farming type, with the option of leasing a further 20 ha. The rent level is based on the conditions on the land market.

in the regions mentioned. For the location with low yield potential and larger fields, the effects of different farm structures under otherwise identical conditions have been investigated. The model calculations have been supplemented for farms with 1,000 ha and 2,000 ha of ownership and different proportions of leased land. If the average field size and mechanisation remain the same, the level of adjustment costs for the larger farms does not change. Therefore, the model farms could always be calculated with an area of 100 ha owned plus 20 ha leased.

In **fodder production, the** focus was placed on a dairy farm with heifer rearing. It is assumed that the model farm is characterised by a high proportion of permanent grassland. The yield potential of the farm for both grassland and arable land is oriented towards a location with medium soil and a medium yield level.

For the production method dairy cow husbandry with own heifer rearing, a herd size of 100 dairy cows is assumed. This assumption is intended to illustrate the intensive specialisation and optimisation of the model farm in this sector. The production factors labour and land can be considered limited and scarce, respectively.

In **vegetable cultivation,** a location with medium-heavy soils and a medium yield level is included. The vegetables studied were selected on the basis of their cultivation importance in Germany. The crop groups cover approx. 75 % of German vegetable production and each individual crop group at least 10 %. For the vegetables and the model farm, a location with medium-heavy soils and medium yield expectations was assumed.

The four model farms described are summarised and compared with their main characteristics in the following table (see Figure 1).

***Figure 1**: Overview of the main characteristics of the model farms*

farm	**Cash Crop Farm**	**Cash Crop Farm**	**vegetable farm**	**fodder crops farm**
location	**good arable farming locations (e.g. Soester Börde)**	**weak arable farming locations (e.g. Brandenburg)**	**favourable regions**	**low mountain range region**
cultivation system	conventional			
soil cultivation	turning soil cultivation, seedbed preparation, seeding	non-turning soil cultivation, rotary harrow for seedbed preparation and seeding	turning soil cultivation	turning soil cultivation, seedbed preparation, seeding
field size	5 ha	40 ha	2 ha	5 ha
yield potential	high	low (variant + 20%)[1]	medium	medium
Type of soil	medium soil	light soil	medium soil	medium soil
mechanisation in kW (Power of the strongest tractor used in the production process)	120-kW	200-kW	120-kW	120-kW
distance between field and farmstead	2 km	4 km	2 km	2 km
Farm size in hectare				
Arable land (owned)	100 ha	100 ha	100 ha	20 ha or 25 ha[2]
Arable land (leased)	20 ha (768 €/ha)	20 ha (220 €/ha)		
grassland (owned)				60 ha or 75 ha
Crops considered				
grain	Winter wheat, Winter barley, Winter rye, Oats, Spring barley	Winter wheat, Winter barley, Winter rye		Winter wheat, Winter barley
maize	Silage maize, Grain maize	Silage maize		Silage maize
fodder crops				arable grass
oil fruits	Winter oilseed rape	Winter oilseed rape		
root crops	Sugar beet, Table potatoes, Starch potatoes			
legumes	field bean	forage peas		
vegetable				Asparagus, Onion, Carrots, Cauliflower, Iceberg lettuce, Bush bean Pea, Lamb's lettuce

[1] In addition, a variation with medium yields was calculated for the weak arable farming location (yield +20%).

[2] For the fodder crop farm, two different land configurations (80 ha and 100 ha) with a constant grassland share of 75% are assumed.

The effects on crop yields of not using chemical-synthetic pesticides were assessed with the help of a literature survey, interviews with experts and evaluations of the university's own "Merklingsen" trial. In principle, the benefit of the use of plant protection products is primarily higher and more stable yields.

The following table shows the yield effects of not using chemical crop protection in arable farming (see Figure 2).

***Figure 2**: Effects of changes in the use of plant protection products on the individual fruits of arable farms*

Crop	Rel. reduction in yield due to renunciation of …				
	Herbicide	Fungicide	Insecticide	GR*	Total
Winter wheat	16%	13%	1%	0%	30%
Winter barley	14%	14%	1%	0%	29%
Winter rye	14%	14%	1%	0%	29%
Oats	5%	5%	1%	0%	11%
Spring barley	7%	5%	1%	0%	13%
Silage maize	12%	0%	0%	0%	12%
Grain maize	12%	0%	0%	0%	12%
Winter oilseed rape	12%	6%	16%	5%	39%
Sugar beet	12%	5%	6%		23%
Table potato	10%	22%	6%		38%
Starch potato	10%	22%	6%		38%
Field bean Forage pea	2%	5%	6%		13%

The average yield losses for winter cereals amount to approx. 30%, for potatoes and winter rape to approx. 40%. Summer cereals, the grain legumes field bean and field pea as well as maize are associated with significantly lower yield losses when cultivated without chemical plant protection.

In the fodder farms, a different assumption was made for winter wheat cultivation. Here, in addition to the already described yield reduction (30%) due to the renunciation of plant protection products, a surcharge of five per cent was applied to take into account the growth of previously cultivated arable grass. This increases the amount of relative yield reduction to 35%.

In the management of permanent grassland by the fodder farm, the effects of not using plant protection products on the fresh mass yield of the fodder are presented using two scenarios:

- **Scenario I** assumes a **medium intensity level for the use of chemical plant protection products.** Consequently, not using chemical pesticides results in a 5% decrease in yield in terms of fresh mass (quantitative) and energy content (qualitative).
- **In scenario II,** a **high intensity level for the use of chemical plant protection products is** assumed, in which a reduction in yield of 10% is caused by not using plant protection products.

The yield reductions for the vegetable species investigated were derived from expert discussions and literature evaluations. The following table shows the yield reductions for vegetables as a result of not using chemical plant protection (see Figure 3). The estimates are subject to uncertainties, as the occurrence of diseases and pests varies greatly from year to year. If certain pests occur and there are critical, wet weather conditions, it is also possible that there will be total failure if chemical plant protection products are not used.

***Figure 3**: Yield reductions vegetables by abandoning chemical crop protection*

crop	yield reduction due to the renunciation of plant protection products ...				Total
	Herbicide	Fungizide	Insecticide	GR*	
asparagus	20%	30%	30%	0%	**80%**
onion	20%	30%	10%	0%	**60%**
carrots	10%	20%	10%	0%	**40%**
cauliflower	0%	10%	20%	0%	**30%**
iceberg lettuce	10%	20%	30%	0%	**60%**
bush bean	20%	20%	10%	0%	**50%**
radish	0%	50%	50%	0%	**100%**
pea	15%	10%	10%	0%	**35%**
lamb's lettuce	20%	10%	0%	0%	**30%**

In principle, the study was calculated using KTBL data. Some of the KTBL prices have been modified. The producer prices for the production processes in arable farming and fodder production have been adjusted according to the LfL (Landesanstalt für Landwirtschaft) Bavaria and for vegetables on the basis of expert discussions and information from the AMI. For fertilisation in the crop production methods, the nitrogen fertiliser requirement was calculated according to the specifications of the official advisory service. The

Nutrients phosphorus and potassium were added according to the withdrawals. It should be noted that harvest residues such as straw or beet leaves remain on the land, so only the nutrient removal has been compensated by the main crop product. In this way, the quantities of fertiliser applied and the associated costs were adjusted to the yield effects of not using plant protection products. For the design of the crop production methods without the use of chemical plant protection products, the seed costs for cereals and maize were reduced by the dressing costs. The sowing rate was increased by 10% in some cases to compensate for losses due to mechanical plant protection measures. Weed management is carried out mechanically, whereby the choice of implements and the number of passes for mechanical weed control (MC) is based on the management of organic crop production methods within the web application "*Leistungs-Kostenrechnung Pflanzenbau*"/ Activity-based costing for plant cultivation", the evaluated literature and interviews with experts.

In order to calculate the business impacts for the model farms, the performance measure direct and labour cost-free performance (DAL) was selected. The DAL is calculated by deducting the direct costs and the fixed and variable labour costs from the output. In contrast to the DB, the DAL thus also includes the fixed wage costs (for salaried employees, the wage rate for farm managers) and the fixed machine costs in the calculation. Since only the variable costs are taken into account in the contribution margin, it mainly reflects the short-term adjustment costs of the measures. In order to consider the medium-term adjustment costs, however, the DAL should be used.

***Figure 4**: Calculation scheme of the performance measures contribution margin (DB) and direct and labour cost-free performance (DAL).*

	revenue	sales from selling of products
–	direct costs	material costs (seeds, fertiliser, plant protection products), interest costs for the deployed capital
–	variable labour completion costs	variable machine costs (fuel and lubricants, repairs), services provided by agricultural contractors
=	**contribution margin (DB)**	
–	fixed labour completion costs	fixed machine costs (depreciation, interest costs, insurance premiums, equipment storage costs) salaries for permanent employees imputed salary rate
=	**direct and labour-cost-free performance**	

The results on the abandonment of chemical plant protection are summarised in the following diagrams 5 - 12.

On arable land with high yield potential (e.g. Soester Börde), the income reductions due to the abandonment of chemical plant protection are very high for the economically strong crops winter wheat, winter rape and sugar beet. The cultivation of winter rape and sugar beet is then also associated with a high cultivation risk. As a result of not using fungicides, potato cultivation in particular loses its economic attractiveness. Table potatoes are then no longer economically viable to grow. Without chemical crop protection, the cultivation risk increases considerably, so that potato cultivation would be abandoned in many cases. The losses amount to € 427 for winter rape, € 360 for winter wheat and € 345 for sugar beet. Maize gains in relative competitiveness compared to the other fruits, so that its cultivation is expanded. In the model farm with the typical crops, on very good arable land, the economic impact is -449 €/ha. This is mainly due to the fact that potatoes are no longer cultivated, the crop rotation is extended and a lease is no longer worthwhile at a high lease price level.

***Figure 5**: Results "Arable site with high yield potential*

Cash Crop Farm - good arable farming locations with high yield potencial							results of linear programming				
crop	yields and earnings				difference		reference system		without PPP		Difference
	with PPP		without PPP								
	dt/ha	DAL in €/ha	dt/ha	DAL in €/ha	(dt/ha)	DAL in €/ha	ha	%	ha	%	%
winter wheat	98,60	806,00 €	69,02	446,67 €	-29,58	- 359,33 €	38,40	33%	19,20	20%	-13%
winter barley	78,80	204,69 €	55,95	48,14 €	-22,85	- 156,55 €					
winter rye	78,80	451,54 €	55,95	245,48 €	-22,85	- 206,06 €			14,40	15%	15%
oats	59,20	140,06 €	52,69	111,10 €	-6,51	- 28,96 €					
spring barley	69,00	714,11 €	60,03	636,55 €	-8,97	- 77,56 €	3,84	3%	9,60	10%	7%
silage maize	528,00	523,47 €	464,64	467,01 €	-63,36	- 56,46 €					
grain maize	114,00	692,93 €	100,32	522,02 €	-13,68	- 170,91 €			19,20	20%	20%
winter oil seed rape	44,10	731,62 €	27,03	305,07 €	-17,07	- 426,55 €	38,40	33%	19,20	20%	-13%
sugar beet	700,00	1.360,43 €	539,00	1.015,83 €	-161,00	- 344,60 €	17,28	15%	14,40	15%	
table potato	550,00	1.131,13 €	341,00	- 915,41 €	-209,00	- 2.046,54 €					
starch potato	650,00	1.372,52 €	403,00	6,95 €	-247,00	- 1.365,57 €	17,28	15%			-15%
field bean	49,30	223,17 €	42,89	141,26 €	-6,41	- 81,91 €					
				fallow land			4,80		4,00		
				total			120	100%	100	100%	
				leases land			yes		no		
				DAL in €			93.391,53 €		48.512,74 €		
				Difference in €/farm			-		44.878,79 €		
				Difference in €/ha			-		448,79 €		

On the arable land with a low yield potential, the farms only achieve a comparatively low DAL (direct and labour cost-free performance). Without a single farm payment, profitable arable farming is hardly possible. Doing without chemical crop protection is not economically viable if a site already has a low profit level in the initial situation.

***Figure 6**: Results "Arable site with low yield potential*

Cash Crop Farm - weak arable farming locations with low yield potencial							results of linear programming			
crop	yields and earnings				difference		reference system		without PPP	
	with PPP		without PPP							
	dt/ha	DAL in €/ha	dt/ha	DAL in €/ha	(dt/ha)	DAL in €/ha	ha	%	ha	%
winter wheat	59,20	342,29 €	41,44	62,75 €	-17,76	- 279,54 €	38,40	33%	19,20	
winter barley	54,20	61,20 €	38,48	- 107,10 €	-15,72	- 168,30 €	0,00	0	0,00	
winter rye	39,40	- 21,50 €	27,97	- 174,78 €	-11,43	- 153,28 €	0,00	0	0,00	
silage maize	352,00	191,44 €	309,76	124,89 €	-42,24	- 66,55 €	38,40	33%	19,20	
winter oil seed rape	29,40	465,15 €	17,93	37,14 €	-11,47	- 428,01 €	38,40	33%	19,20	
forage peas	24,70	- 214,00 €	21,49	- 220,98 €	-3,21	- 6,98 €	0,00	0%	0,00	
				fallow land			4,80		4,00	
				total			120,00	100%	61,6	100%
				leases land			yes		no	
				DAL in €			33.693,95 €		4.096,58 €	
				Difference in €/farm			-		**29.597,37 €**	
				Difference in €/ha			**economically unfeasible**			

For the location, a monetary **yield increase of 20 %** (due to higher prices or yields) has been calculated as the second variant. In the model farm, dispensing with chemical crop protection results in a reduction in income of 309 € /ha (see Figure 7). This is based on the assumption that a three-tier crop rotation can be established without chemical crop protection. In the medium term, this is hardly possible due to increasing crop rotation problems, so that on sites with low yield potential, arable farming without chemical crop protection is not economically viable at given crop prices.

***Figure 7**: Results "Arable site with low yield potential (+20%)".*

Cash Crop Farm - weak arable farming locations with medium yield potencial (variation: +20%)							results of linear programming					
crop	yields and earnings				difference		reference system		without PPP		without PPP	
	with PPP		without PPP				3 crop rotation cycle		5 crop rotation cycle		3 crop rotation cycle	
	dt/ha	DAL in €/ha	dt/ha	DAL in €/ha	(dt/ha)	DAL in €/ha	ha	%	ha	%	ha	%
winter wheat	71,04	587,53 €	49,73	234,36 €	-21,31	- 353,17 €	38,40	33%	19,20		38,40	33%
winter barley	65,04	246,45 €	46,18	24,37 €	-18,86	- 222,08 €	0,00	0	19,20		0,00	0
winter rye	47,28	118,97 €	33,57	- 75,09 €	-13,71	- 194,06 €	0,00	0	0,00		0,00	0
silage maize	422,40	364,02 €	371,71	276,73 €	-50,69	- 87,29 €	38,40	33%	19,20		38,40	33%
winter oil seed rape	35,28	713,57 €	21,52	188,65 €	-13,76	- 524,92 €	38,40	33%	19,20		38,40	33%
forage peas	29,64	- 113,27 €	25,79	- 133,26 €	-3,85	- 19,99 €	0,00	0%	0,00		0,00	0%
				fallow land			4,80		4,00		4,80	
				total			120,00	100%	80,8	100%	120,00	100%
				leases land			yes		no		yes	
				DAL in €			59.277,57 €		13.683,71 €		22.206,98 €	
				Difference in €/farm			-		**45.593,86 €**		-	**37.070,59 €**
				Difference in €/ha			**economically unfeasible**				-	**308,92 €**

For the conceptual design of the model farm "fodder production", the focus was placed on a dairy farm in a low mountain region. It is assumed that the model farm's agricultural land is characterised by a high proportion of permanent grassland (75 % of the lagricultural and). The dairy cattle fodder farm was calculated in four variants:

1. **Scarce land** for dairy farming and **high intensity of PPP on** grassland
2. **Scarce land** for dairy farming and **medium intensity of PPP on** grassland
3. **Land** for dairy farming **not scarce** and **high PPP intensity** on grassland
4. **Land** for dairy farming **not scarce** and **medium PPP intensity** on grassland

On farms with a high intensity of crop protection and scarce land, the renunciation of herbicides causes yield reductions (fresh mass yield and quality) on grassland of approx. 10 % of the yield in MJ NEL. This leads to a shortage of basic fodder, which the farm cannot fully compensate for internally, not even by increasing the proportion of silage used from grassland. In principle, the legal requirements for crop rotation also set narrow limits to the expansion of silage maize cultivation on such farms. The shortage of basic fodder therefore causes a reduction in the number of dairy cattle. Overall, this results in income reductions of 305 €/ha for the model farm (variant 1) (see Figure 8). With medium plant protection intensity, the renunciation of chemical plant protection causes lower yield reductions of 5% of the yield in MJ NEL and thus a lower basic fodder shortage. Overall, the reduced yields and higher costs result in income losses of 205 €/ha (see Figure 9).

***Figure 8**: Results "scarce land for dairy farming and high PPP intensity on grassland".*

fodder crop farm - 80 ha with high PPP intensity							results of linear programming				
crop	yields and earnings				difference		reference system		without PPP		Difference
	with PPP		without PPP								
	dt/ha	DAL in €/ha	dt/ha	DAL in €/ha	(dt/ha)	DAL in €/ha	ha	%	ha	%	%
winter wheat	78,90	518,06 €	55,23	203,87 €	-23,67	- 314,19 €					
winter barley	68,90	106,46 €	48,92	42,95 €	-19,98	- 63,51 €					
silage maize	440,00	695,66 €	387,20	602,10 €	-52,80	- 93,56 €	13,40	16,75%	13,40	16,75%	0,00%
arable grass	237,60	560,02 €	237,60	560,02 €	0,00	- €	6,60	8,25%	6,60	8,25%	0,00%
permanent grassland	190,30	388,08 €	171,27	382,97 €	-19,03	- 5,11 €	47,48	59,35%	50,85	63,57%	4,22%
hay	93,20	533,35 €	83,88	509,63 €	-9,32	- 23,72 €	12,52	15,65%	9,15	11,43%	-4,22%
dairy farming		1.594,52 €		1.547,20 €	0,00	- 47,32 €	100,00	100,00%	88,38	88,38%	-11,62%
				total amount of agricultural land (AL)			80,00	100%	80,00	100%	
				cow places			100,00	100%	88,38	88%	
				DAL in €			161.161,22 €		136.746,66 €		
				Difference in €/farm			-		24.414,56 €		
				Difference in €/ha			-		305,18 €		

***Figure 9**: Results "scarce land for dairy farming and medium PPP intensity on grassland".*

fodder crop farm - 80 ha with medium PPP intensity							results of linear programming				
crop	yields and earnings				difference		reference system		without PPP		Difference
	with PPP		without PPP								
	dt/ha	DAL in €/ha	dt/ha	DAL in €/ha	(dt/ha)	DAL in €/ha	ha	%	ha	%	%
winter wheat	78,90	518,06 €	55,23	203,87 €	-23,67	- 314,19 €					
winter barley	68,90	106,46 €	48,92	42,95 €	-19,98	- 63,51 €					
silage maize	440,00	695,66 €	387,20	602,10 €	-52,80	- 93,56 €	13,40	16,75%	13,40	16,75%	0,00%
arable grass	237,60	560,02 €	237,60	560,02 €	0,00	- €	6,60	8,25%	6,60	8,25%	0,00%
permanent grassland	190,30	471,39 €	180,79	456,99 €	-9,51	- 14,40 €	47,48	59,36%	50,82	63,53%	4,17%
hay	93,20	616,66 €	88,54	594,79 €	-4,66	- 21,87 €	12,52	15,64%	9,18	11,47%	-4,17%
dairy farming		1.634,08 €		1.591,23 €	0,00	- 42,85 €	100,00	100,00%	93,63	93,63%	-6,37%
				total amount of agricultural land (AL)			80,00	100%	80,00	100%	
				cow places			100,00	100%	93,63	94%	
				DAL in €			165.383,37 €		148.985,83 €		
				Difference in €/farm			-		16.397,54 €		
				Difference in €/ha			-		204,97 €		

In the other variants of the fodder farms, the yield reductions in the silage maize and grassland areas could be compensated internally, because the farms have sufficient land. Dairy farming does not have to be restricted in this case. There are only yield reductions and cost increases on grassland and arable land. On fodder farms with a high intensity of crop protection, income is reduced by 136 €/ ha (see Figure 10), and on fodder farms with a medium intensity of crop protection, income is reduced by 109 €/ha (see Figure 11).

***Figure 10**: Results "Land provision for dairy farming not scarce and high PPP intensity on grassland".*

fodder crop farm - 100 ha with high PPP intensity							results of linear programming				
crop	yields and earnings				difference		reference system		without PPP		Difference
	with PPP		without PPP								
	dt/ha	DAL in €/ha	dt/ha	DAL in €/ha	(dt/ha)	DAL in €/ha	ha	%	ha	%	%
winter wheat	78,90	518,06 €	55,23	203,87 €	-23,67	- 314,19 €					
winter barley	68,90	106,46 €	48,92	42,95 €	-19,98	- 63,51 €					
silage maize	440,00	695,66 €	387,20	602,10 €	-52,80	- 93,56 €	16,75	16,75%	16,75	16,75%	0,00%
arable grass	237,60	560,02 €	237,60	560,02 €	0,00	- €	8,25	8,25%	8,25	8,25%	0,00%
permanent grassland	190,30	388,08 €	171,27	382,97 €	-19,03	- 5,11 €	37,07	37,07%	52,04	52,04%	14,97%
hay	93,20	533,35 €	83,88	509,63 €	-9,32	- 23,72 €	37,93	37,93%	22,96	22,96%	-14,97%
dairy farming		1.594,52 €		1.547,20 €	0,00	- 47,32 €	100,00	100,00%	100,00	100,00%	0,00%
				total amount of agricultural land (AL)			100,00	100%	100,00	100%	
				cow places			100,00	100%	100,00	100%	
				DAL in €			174.712,94 €		161.148,90 €		
				Difference in €/farm			-		13.564,04 €		
				Difference in €/ha			-		135,64 €		

***Figure 11**: Results "Land provision for dairy farming not scarce and medium PPP intensity on grassland".*

fodder crop farm - 100 ha with medium PPP intensity							results of linear programming				
crop	yields and earnings				difference		reference system		without PPP		Difference
	with PPP		without PPP								
	dt/ha	DAL in €/ha	dt/ha	DAL in €/ha	(dt/ha)	DAL in €/ha	ha	%	ha	%	%
winter wheat	78,90	518,06 €	55,23	203,87 €	-23,67	- 314,19 €					
winter barley	68,90	106,46 €	48,92	42,95 €	-19,98	- 63,51 €					
silage maize	440,00	695,66 €	387,20	602,10 €	-52,80	- 93,56 €	16,75	16,75%	16,75	16,75%	0,00%
arable grass	237,60	560,02 €	237,60	560,02 €	0,00	- €	8,25	8,25%	8,25	8,25%	0,00%
permanent grassland	190,30	471,39 €	180,79	456,99 €	-9,51	- 14,40 €	37,08	37,08%	46,70	46,70%	9,62%
hay	93,20	616,66 €	88,54	594,79 €	-4,66	- 21,87 €	37,92	37,92%	28,30	28,30%	-9,62%
dairy farming		1.634,08 €		1.591,23 €	0,00	- 42,85 €	100,00	100,00%	100,00	100,00%	0,00%
				total amount of agricultural land (AL)			100,00	100%	100,00	100%	
				cow places			100,00	100%	100,00	100%	
				DAL in €			181.052,07 €		170.123,20 €		
				Difference in €/farm			-		10.928,87 €		
				Difference in €/ha			-		109,29 €		

Farms with optimal process management manage to cultivate grassland without chemical plant protection. For these fodder farms, only comparatively low income reductions result from the cultivation of silage maize.

The selection of the outdoor vegetables studied was based on their cultivation importance in Germany, so that the most important vegetable groups are represented. The vegetables studied were asparagus (the vegetable with the greatest cultivation importance in Germany), onions, carrots (the most important vegetable in organic farming in terms of cultivation volume), beans, peas, iceberg lettuce, cauliflower and lamb's lettuce. These represent the most important crop groups: cabbage vegetables, leaf and stem vegetables, root and tuber vegetables, fruit vegetables and legumes. The crop groups cover about 75 % of German vegetable production, each individual crop group at least 10 %.
In vegetable cultivation, compliance with quality parameters plays a central role for marketing. If the quality parameters are not adhered to, the produces can not be marketed.

Doing without chemical plant protection can therefore quickly lead to total failure. Especially harmful fungi and pests are often difficult to control without chemical plant protection, as alternative methods of regulation are hardly available. The use of crop protection nets is one of the few alternative measures and offers protection against some pests in cabbage crops. The use is associated with comparatively high costs (approx. 1,500 € per ha and year). The cultivation risks, depending on the weather, increase considerably when fungicides and insecticides are not used.

Herbicides can be replaced by alternative methods to varying degrees depending on the type of crop. Plant crops (e.g. lettuce and cabbage) are better suited for this than acid crops (carrots and onions). If herbicides are not used, manual hand hoeing and weeding play the central role in the economic impact. Extensive hand hoeing and weeding over time leads to high costs. It is also questionable whether there is sufficient availability of labour (or seasonal labour) during peak work periods on farms specialising in a few crops.

***Figure 12**: Results vegetable farm*

culture	yields and earnings						difference		results				
	with PPP			without PPP					reference system		without PPP		Difference
	yields/ha		DAL in €/ha	yields/ha		DAL in €/ha	(dt/ha)	DAL in €/ha	ha	%	ha	%	%
asparagus	70,00	dt	3.338,00 €	14,00	dt	-12.778,00 €	- 56,00	-16.116,00 €	19,20	20%			-20%
onion	475,00	dt	4.984,27 €	190,00	dt	- 6.360,88 €	- 285,00	-11.345,15 €	19,20	20%			-20%
carrots	750,00	dt	28.218,07 €	450,00	dt	5.997,04 €	- 300,00	-22.221,03 €	19,20	20%	19,20	20%	0%
cauliflower	21.000,00	units	6.239,48 €	14.700,00	units	1.529,06 €	- 6.300,00	- 4.710,42 €	19,20	20%	19,20	20%	0%
iceberg lettuce	60.000,00	units	5.867,78 €	24.000,00	units	- 9.194,37 €	-36.000,00	-15.062,15 €	19,20	20%			-20%
bush bean	120,00	dt	243,62 €	60,00	dt	- 1.010,89 €	- 60,00	- 1.254,51 €					
pea	65,00	dt	- 277,28 €	42,30	dt	- 157,15 €	- 22,70	120,13 €					
lamb's lettuce	68,00	dt	10.855,60 €	47,60	dt	3.693,04 €	- 20,40	- 7.162,56 €			19,20	20%	20%
sugar beet	700,00	dt	1.360,42 €	539,00	dt	1.015,69 €	- 161,00	- 344,73 €			19,20	20%	20%
winter wheat	98,60	dt	806,00 €	69,20	dt	446,67 €	- 29,40	- 359,33 €			19,20	20%	20%
fallow land	0,00		- 193,42 €	0,00		- 193,42 €			4,00	4%	4,00	4%	
* The cultivation areas of individual crops (in %) refer to the arable land excluding fallow land. (100 ha arable land - 4 ha fallow land = 96 ha) (96 ha = 100%)						DAL in €				933.260,24 €		242.711,12 €	
						Difference in €/farm			-			690.549,12 €	
						Differece in €/ha			-			6.905,49 €	

About the individual vegetable species:

Cultivation of **legumes** with peas and beans is already only marginally profitable in integrated cultivation; without the use of chemical pesticides, cultivation is not viable at constant price/cost ratios.

Carrots (root vegetable group) and **onions** (onion vegetable group) play a central role in many growing regions in Germany in terms of cultivation importance and profitability. For both vegetables, a high use of manual labour is to be expected if herbicides are not used. Only at a high price level is cultivation still economical if chemical plant protection is dispensed with. According to this study, carrots can be grown economically without chemical plant protection, whereas this is not the case for onions.

In the case of **asparagus**, the most important crop in Germany in terms of area, not using insecticides and fungicides leads to relatively high yield losses, so that growing asparagus without chemical crop protection at a constant price level is not economically viable.

Growing **cauliflower** without insecticides leads to relatively moderate yield reductions when using crop protection nets against pests. Mechanical weed control is well possible. Cultivation of cauliflower without chemical crop protection leads to income reductions of about 4,710 € per ha.

Field and iceberg lettuce can be grown economically successfully under current conditions with a DAL of 10,856 €/ha for field lettuce and 5,868 €/ha for iceberg lettuce. With hand weeding of 40 Akh/ha and moderate yield reductions of approx. 30 %, the renunciation of chemical plant protection for lamb's lettuce leads to income losses of approx. 7,163 €/ha. If fungicides are not used, the cultivation risk increases significantly due to weather conditions. The cultivation of iceberg lettuce is not profitable without chemical plant protection.

The vegetable cultivation of the most important crop groups has been mapped with a model farm. Within the crop groups, the most important vegetable species in terms of cultivation volume were selected. In the model farm, the cultivation of asparagus, onions and iceberg lettuce was abandoned as a result of the decision not to use chemical pesticides, as the cultivation is no longer economically viable. Lamb's lettuce, potatoes and winter wheat were then included in the crop rotation. The renunciation of chemical plant protection has resulted in profit reductions of € 6,900 per ha in the model farm.

Overall, it can be assumed that if chemical plant protection is abandoned, many farms will give up growing vegetables, or at least certain types of vegetables, because cultivation is no longer economically viable.

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Appendix

Annex 1: Crops for the good arable farming location

The crops are shown in direct comparison for the two possible variants of crop management (conventional and without plant protection products (= without PPP).

Comparison - Winter wheat	conventional	without PPP
Yields (dt/ha)	98,60	69,02
Proceeds	2.484,72 €	1.739,30 €
Seeds	102,60 €	92,47 €
Fertiliser	522,63 €	412,61 €
Lime	38,00 €	38,00 €
PPP incl. water	230,52 €	- €
Hail insurance	20,37 €	14,23 €
Interest	6,86 €	4,18 €
Direct costs	920,98 €	561,49 €
variable machine costs	314,84 €	313,68 €
Services	3,22 €	3,22 €
Interest[1]	- €	- €
variable costs	1.239,05 €	878,39 €
Contribution margin	**1.245,67 €**	**860,91 €**
fixed machine costs	298,49 €	287,68 €
fixed labor costs	141,18 €	126,56 €
Direct costs and operational costs	1.678,72 €	1.292,64 €
DAL[2]	**806,00 €**	**446,67 €**

[1] The interest is considered within the variable machine costs and services.
[2] DAL = direct and labour-cost-free performance

Comparison - Winter barley	conventional	without PPP
Yields (dt/ha)	78,80	55,95
Proceeds	1.698,14 €	1.205,68 €
Seeds	78,40 €	69,76 €
Fertiliser	419,54 €	329,80 €
Lime	38,00 €	38,00 €
PPP incl. water	206,44 €	
Hail insurance	13,91 €	9,82 €
Interest	5,67 €	3,36 €
Direct costs	761,95 €	450,74 €
variable machine costs	302,08 €	299,34 €
Services	3,22 €	3,22 €
Interest	- €	- €
variable costs	1.067,26 €	753,30 €
Contribution margin	**630,88 €**	**452,38 €**
fixed machine costs	296,48 €	287,00 €
fixed labor costs	129,71 €	117,24 €
Direct costs and operational costs	1.493,45 €	1.157,54 €
DAL	**204,69 €**	**48,14 €**

Comparison - Winter rye	conventional	without PPP
Yields (dt/ha)	78,80	55,95
Proceeds	1.756,45 €	1.247,08 €
Seeds	68,40 €	64,68 €
Fertiliser	388,94 €	299,20 €
Lime	38,00 €	38,00 €
PPP incl. water	160,82 €	- €
Hail insurance	14,40 €	10,23 €
Interest	5,03 €	3,09 €
Direct costs	675,58 €	415,20 €
variable machine costs	267,88 €	257,82 €
Services	3,22 €	3,22 €
variable costs	946,69 €	676,24 €
Contribution margin	**809,76 €**	**570,84 €**
fixed machine costs	241,81 €	227,00 €
fixed labor costs	116,42 €	98,36 €
Direct costs and operational costs	1.304,91 €	1.001,60 €
DAL	**451,54 €**	**245,48 €**

Comparison - Oats	conventional	without PPP
Yields (dt/ha)	59,20	52,69
Proceeds	1.272,21 €	1.132,27 €
Seeds	79,30 €	77,51 €
Fertiliser	267,82 €	243,68 €
Lime	38,00 €	38,00 €
PPP incl. water	60,46 €	- €
Hail insurance	10,39 €	9,24 €
Interest	3,42 €	2,76 €
Direct costs	459,39 €	371,20 €
variable machine costs	273,16 €	268,85 €
Services	3,22 €	3,22 €
variable costs	735,77 €	643,27 €
Contribution margin	**536,43 €**	**489,00 €**
fixed machine costs	280,35 €	272,20 €
fixed labor costs	116,02 €	105,70 €
Direct costs and operational costs	1.132,15 €	1.021,17 €
DAL	**140,06 €**	**111,10 €**

Comparison - Spring barley	conventional	without PPP
Yields (dt/ha)	69,00	60,03
Proceeds	1.948,56 €	1.695,25 €
Seeds	91,00 €	83,62 €
Fertiliser	287,58 €	272,29 €
Lime	38,00 €	38,00 €
PPP incl. water	143,07 €	- €
Hail insurance	15,95 €	13,91 €
Interest	4,32 €	3,06 €
Direct costs	579,91 €	410,88 €
variable machine costs	274,03 €	276,67 €
Services	3,22 €	3,22 €
variable costs	857,17 €	690,77 €
Contribution margin	**1.091,39 €**	**1.004,48 €**
fixed machine costs	265,45 €	262,54 €
fixed labor costs	111,84 €	105,39 €
Direct costs and operational costs	1.234,45 €	1.058,70 €
DAL	**714,11 €**	**636,55 €**

Comparison - silage maize	conventional	without PPP
Yields (dt/ha)	528,00	464,64
Proceeds	2.096,16 €	1.844,62 €
Seeds	242,00 €	224,17 €
Fertiliser	796,02 €	713,15 €
Lime	38,00 €	38,00 €
PPP incl. water	128,14 €	- €
Hail insurance	15,46 €	13,54 €
Interest	9,15 €	7,31 €
Direct costs	1.228,77 €	996,17 €
variable machine costs	155,48 €	174,67 €
Services	3,22 €	3,22 €
variable costs	1.387,47 €	1.174,06 €
Contribution margin	**708,69 €**	**670,56 €**
fixed machine costs	110,61 €	120,77 €
fixed labor costs	74,61 €	82,78 €
Direct costs and operational costs	1.572,69 €	1.377,61 €
DAL	**523,47 €**	**467,01 €**

Comparison - grain maize	conventional	without PPP
Yields (dt/ha)	114,00	100,32
Proceeds	2.937,78 €	2.585,25 €
Seeds	220,00 €	203,79 €
Fertiliser	476,58 €	432,04 €
Lime	38,00 €	38,00 €
PPP incl. water	154,18 €	- €
Hail insurance	21,64 €	19,06 €
Interest	6,83 €	5,20 €
Direct costs	917,23 €	698,09 €
variable machine costs	653,11 €	672,29 €
Services	3,22 €	3,22 €
variable costs	1.573,56 €	1.373,60 €
Contribution margin	**1.364,22 €**	**1.211,64 €**
fixed machine costs	541,34 €	551,50 €
fixed labor costs	129,95 €	138,12 €
Direct costs and operational costs	2.244,85 €	2.063,22 €
DAL	**692,93 €**	**522,02 €**

Comparison - Winter oilseed rape	conventional	without PPP
Yields (dt/ha)	44,10	27,03
Proceeds	2.294,52 €	1.406,54 €
Seeds	80,85 €	80,85 €
Fertiliser	468,71 €	334,10 €
Lime	38,00 €	38,00 €
PPP incl. water	292,25 €	- €
Hail insurance	44,17 €	34,60 €
Interest	6,93 €	3,66 €
Direct costs	930,91 €	491,21 €
variable machine costs	263,19 €	260,17 €
Services	3,22 €	1,21 €
Interest	- €	1,96 €
variable costs	1.197,32 €	754,55 €
Contribution margin	**1.097,20 €**	**651,99 €**
fixed machine costs	248,98 €	242,79 €
fixed labor costs	116,61 €	104,14 €
Direct costs and operational costs	1.562,91 €	1.101,48 €
DAL	**731,61 €**	**305,06 €**

Comparison - table potato	conventional	without PPP
Yields (dt/ha)	550,00	341,00
Proceeds	7.375,50 €	4.572,81 €
Z-planting material, loose	1.425,00 €	1.425,00 €
Oil radish, Z seed	59,20 €	59,20 €
Lime	38,00 €	38,00 €
Fertiliser	799,84 €	513,61 €
PPP incl. water	581,35 €	- €
Hail insurance	60,33 €	37,41 €
Interest	22,23 €	15,55 €
Direct costs	2.985,95 €	2.088,77 €
variable machine costs	719,27 €	785,25 €
variable wage costs	145,81 €	145,81 €
Services	3,22 €	3,22 €
variable costs	3.854,25 €	3.023,05 €
Contribution margin	**3.521,25 €**	**1.549,76 €**
fixed machine costs	1.992,41 €	2.028,66 €
fixed labor costs	397,71 €	436,51 €
Direct costs and operational costs	6.244,37 €	5.488,22 €
DAL	**1.131,13 €**	**-915 ,41 €**

Comparison - Starch potato	conventional	without PPP
Yields (dt/ha)	650,00	403,00
Proceeds	5.687,50 €	3.526,25 €
Z-planting material, loose	975,00 €	975,00 €
Oil radish, Z seed	59,20 €	59,20 €
Lime	38,00 €	38,00 €
Fertiliser	848,12 €	552,03 €
PPP incl. water	582,49 €	- €
Hail insurance	46,52 €	28,84 €
Interest	19,12 €	12,40 €
Direct costs	2.568,45 €	1.665,47 €
variable machine costs	669,11 €	725,62 €
variable wage costs	145,60 €	145,60 €
Services	3,22 €	3,22 €
variable costs	3.386,38 €	2.539,91 €
Contribution margin	**2.301,12 €**	**986,34 €**
fixed machine costs	559,44 €	583,57 €
fixed labor costs	369,16 €	395,82 €
Direct costs and operational costs	4.314,98 €	3.519,30 €
DAL	**1.372,52 €**	**6,95 €**

Comparison - sugar beet	conventional	without PPP
Yields (dt/ha)	700,00	539,00
Proceeds	3.367,00 €	2.592,59 €
Seeds	316,11 €	316,11 €
Fertiliser	547,23 €	454,21 €
Lime	38,00 €	38,00 €
PPP incl. water	488,71 €	- €
Hail insurance	27,57 €	21,27 €
Interest	10,63 €	6,22 €
Direct costs	1.428,25 €	835,81 €
variable machine costs	198,30 €	338,06 €
Services	3,22 €	3,22 €
Interest	6,05 €	10,24 €
variable costs	1.635,82 €	1.187,33 €
Contribution margin	**1.731,18 €**	**1.405,26 €**
fixed machine costs	267,34 €	280,78 €
fixed labor costs	103,42 €	108,79 €
Direct costs and operational costs	2.006,58 €	1.576,90 €
DAL	**1.360,42 €**	**1.015,69 €**

Comparison - Field bean	conventional	without PPP
Yields (dt/ha)	49,30	42,89
Proceeds	1.237,43 €	1.076,56 €
Seeds	114,00 €	114,00 €
Fertiliser	162,68 €	168,93 €
Lime	38,00 €	38,00 €
PPP incl. water	155,36 €	- €
Hail insurance	10,14 €	8,83 €
Interest	3,60 €	2,47 €
Direct costs	483,78 €	332,23 €
variable machine costs	185,32 €	242,70 €
Services	1,20 €	- €
Interest	1,40 €	1,82 €
variable costs	671,70 €	576,75 €
Contribution margin	**565,73 €**	**499,81 €**
fixed machine costs	242,30 €	256,42 €
fixed labor costs	100,25 €	102,13 €
Direct costs and operational costs	1.014,25 €	935,30 €
DAL	**223,18 €**	**141,26 €**

***Annex 2**: Crops for the weak arable farming location*

Comparison - Winter wheat	**conventional**	**without PPP**
Yields (dt/ha)	59,20	41,44
Proceeds	1.491,84 €	1.044,29 €
Seeds	102,60 €	92,47 €
Fertiliser	371,69 €	296,14 €
Lime	38,00 €	38,00 €
PPP incl. water	100,98 €	- €
Hail insurance	12,27 €	8,51 €
Interest	4,69 €	3,26 €
Direct costs	630,23 €	438,38 €
variable machine costs	215,46 €	229,17 €
Services	3,22 €	3,22 €
Interest[1]	- €	- €
variable costs	848,91 €	670,77 €
Contribution margin	**642,93 €**	**373,52 €**
fixed machine costs	215,71 €	227,13 €
fixed labor costs	84,93 €	83,64 €
Direct costs and operational costs	1.149,55 €	981,54 €
DAL[2]	**342,29 €**	**62,75 €**

[1] The interest is considered in the variable machine costs & services.
[2] DAL = direct and labour-cost-free performance

Comparison - Winter barley	**conventional**	**without PPP**
Yields (dt/ha)	54,20	38,48
Proceeds	1.168,01 €	829,29 €
Seeds	78,40 €	69,76 €
Fertiliser	326,62 €	259,75 €
Lime	38,00 €	38,00 €
PPP incl. water	126,75 €	- €
Hail insurance	9,57 €	6,79 €
Interest	4,35 €	2,81 €
Direct costs	583,69 €	377,11 €
variable machine costs	216,09 €	233,46 €
Services	3,22 €	3,22 €
Interest	- €	- €
variable costs	803,00 €	613,79 €
Contribution margin	**365,01 €**	**215,50 €**
fixed machine costs	223,32 €	240,17 €
fixed labor costs	80,49 €	82,43 €
Direct costs and operational costs	1.106,81 €	936,39 €
DAL	**61,20 €**	**- 107,10 €**

Comparison - Winter rye	conventional	without PPP
Yields (dt/ha)	39,40	27,97
Proceeds	878,23 €	623,54 €
Seeds	69,60 €	64,68 €
Fertiliser	248,36 €	199,58 €
Lime	38,00 €	38,00 €
PPP incl. water	79,43 €	
Hail insurance	7,20 €	5,07 €
Interest	3,32 €	2,31 €
Direct costs	445,91 €	309,64 €
variable machine costs	190,71 €	205,86 €
Services	3,22 €	3,22 €
variable costs	639,84 €	518,72 €
Contribution margin	**238,39 €**	**104,82 €**
fixed machine costs	189,03 €	205,73 €
fixed labor costs	70,85 €	73,86 €
Direct costs and operational costs	899,72 €	798,31 €
DAL	**-21,49 €**	**- 174,77 €**

Comparison - silage maize	conventional	without PPP
Yields (dt/ha)	352,00	309,76
Proceeds	1.397,44 €	1.229,75 €
Seeds	242,00 €	224,17 €
Fertiliser	569,56 €	507,13 €
Lime	38,00 €	38,00 €
PPP incl. water	82,92 €	- €
Hail insurance	10,30 €	9,05 €
Interest	7,07 €	5,84 €
Direct costs	949,85 €	784,19 €
variable machine costs	108,25 €	136,02 €
Services	3,22 €	3,22 €
variable costs	1.061,32 €	923,43 €
Contribution margin	**336,12 €**	**306,32 €**
fixed machine costs	91,79 €	112,63 €
fixed labor costs	52,89 €	68,80 €
Direct costs and operational costs	1.206,00 €	1.104,86 €
DAL	**191,44 €**	**124,89 €**

Comparison - Winter oilseed rape	conventional	without PPP
Yields (dt/ha)	29,40	17,93
Proceeds	1.529,68 €	933,11 €
Seeds	55,77 €	55,77 €
Fertiliser	357,93 €	261,43 €
Lime	38,00 €	38,00 €
PPP incl. water	121,53 €	- €
Hail insurance	37,55 €	22,82 €
Interest	4,58 €	2,84 €
Direct costs	615,36 €	380,86 €
variable machine costs	186,63 €	210,50 €
Services	3,22 €	3,22 €
variable costs	805,21 €	594,58 €
Contribution margin	**724,47 €**	**338,53 €**
fixed machine costs	188,02 €	219,57 €
fixed labor costs	71,29 €	81,82 €
Direct costs and operational costs	1.064,52 €	895,97 €
DAL	**465,16 €**	**37,14 €**

Comparison - forrage peas	conventional	without PPP
Yields (dt/ha)	24,70	21,49
Proceeds	594,28 €	517,03 €
Seeds	86,35 €	86,35 €
Fertilizer	78,89 €	68,64 €
Lime	38,00 €	38,00 €
PPP with water	89,88 €	- €
Hail insurance	10,86 €	9,57 €
interests	2,28 €	1,52 €
Direct costs	306,26 €	204,08 €
variable machine costs	207,99 €	217,59 €
services	1,21 €	1,21 €
variable costs	515,46 €	422,88 €
contribution margin	**78,82 €**	**94,15 €**
fixed maschine costs	224,95 €	241,88 €
fixed labour costs	67,87 €	73,24 €
Direct costs and operational costs	808,28 €	738,00 €
DAL	**- 214,00 €**	**- 220,97 €**

***Annex 3**: Crops for the weak arable farming location (yield: +20%)*

Comparison - Winter wheat	**conventional**	**without PPP**
Yields (dt/ha)	71,04	49,73
Proceeds	1.790,21 €	1.253,15 €
Seeds	102,60 €	92,47 €
Fertiliser	422,05 €	331,39 €
Lime	38,00 €	38,00 €
PPP incl. water	100,98 €	- €
Hail insurance	14,64 €	10,23 €
Interest	5,09 €	3,54 €
Direct costs	683,36 €	475,63 €
variable machine costs	215,46 €	229,17 €
Services	3,22 €	3,22 €
Interest[1]	- €	- €
variable costs	902,04 €	708,02 €
Contribution margin	**888,17 €**	**545,13 €**
fixed machine costs	215,71 €	227,13 €
fixed labor costs	84,93 €	83,64 €
Direct costs and operational costs	1.202,68 €	1.018,79 €
DAL[2]	**587,53 €**	**234,36 €**

[1] The interest is considered within the variable machine costs & service

[2]DAL = direct and labour-cost-free performance

Comparison - Winter barley	**conventional**	**without PPP**
Yields (dt/ha)	65,04	46,18
Proceeds	1.401,61 €	995,14 €
Seeds	78,40 €	69,76 €
Fertiliser	372,73 €	292,49 €
Lime	38,00 €	38,00 €
PPP incl. water	126,75 €	- €
Hail insurance	11,45 €	8,18 €
Interest	4,70 €	3,06 €
Direct costs	632,03 €	411,49 €
variable machine costs	216,09 €	233,46 €
Services	3,22 €	3,22 €
Interest	- €	- €
variable costs	851,34 €	648,17 €
Contribution margin	**550,27 €**	**346,97 €**
fixed machine costs	223,32 €	240,17 €
fixed labor costs	80,49 €	82,43 €
Direct costs and operational costs	1.155,15 €	970,77 €
DAL	**246,46 €**	**24,37 €**

Comparison - Winter rye	conventional	without PPP
Yields (dt/ha)	47,28	33,57
Proceeds	1.053,87 €	748,25 €
Seeds	69,60 €	64,68 €
Fertiliser	281,88 €	223,35 €
Lime	38,00 €	38,00 €
PPP incl. water	79,43 €	
Hail insurance	8,59 €	6,14 €
Interest	3,58 €	2,49 €
Direct costs	481,08 €	334,66 €
variable machine costs	190,71 €	205,86 €
Services	3,22 €	3,22 €
variable costs	675,01 €	543,74 €
Contribution margin	**378,86 €**	**204,51 €**
fixed machine costs	189,03 €	205,73 €
fixed labor costs	70,85 €	73,86 €
Direct costs and operational costs	934,89 €	823,33 €
DAL	**118,98 €**	**-75,08 €**

Comparison - silage maize	conventional	without PPP
Yields (dt/ha)	422,40	371,71
Proceeds	1.676,93 €	1.475,70 €
Seeds	242,00 €	224,17 €
Fertilizer	673,61 €	598,69 €
Lime	38,00 €	38,00 €
PPP with water	82,92 €	- €
Hail insurance	12,36 €	10,89 €
interests	7,87 €	6,54 €
Direct costs	1.056,76 €	878,29 €
variable machine costs	108,25 €	136,02 €
services	3,22 €	3,22 €
variable costs	1.168,23 €	1.017,53 €
contribution margin	**508,70 €**	**458,17 €**
fixed maschine costs	91,79 €	112,63 €
fixed labour costs	52,89 €	68,80 €
Direct costs and operational costs	1.312,91 €	1.198,96 €
DAL	**364,02 €**	**276,74 €**

Comparison - Winter oilseed rape	conventional	without PPP
Yields (dt/ha)	35,28	21,52
Proceeds	1.835,62 €	1.119,73 €
Seeds	55,77 €	55,77 €
Fertiliser	407,42 €	291,62 €
Lime	38,00 €	38,00 €
PPP incl. water	121,53 €	- €
Hail insurance	45,15 €	27,48 €
Interest	5,01 €	3,10 €
Direct costs	672,88 €	415,97 €
variable machine costs	186,63 €	210,50 €
Services	3,22 €	3,22 €
variable costs	862,73 €	629,69 €
Contribution margin	**972,89 €**	**490,04 €**
fixed machine costs	188,02 €	219,57 €
fixed labor costs	71,29 €	81,82 €
Direct costs and operational costs	1.122,04 €	931,08 €
DAL	**713,58 €**	**188,65 €**

Comparison - forage peas	conventional	without PPP
Yields (dt/ha)	29,64	25,79
Proceeds	713,14 €	620,43 €
Seeds	86,35 €	86,35 €
Fertilizer	94,67 €	82,36 €
Lime	38,00 €	38,00 €
PPP with water	89,88 €	- €
Hail insurance	13,07 €	11,41 €
interests	2,41 €	1,64 €
Direct costs	324,38 €	219,76 €
variable machine costs	207,99 €	217,59 €
services	1,21 €	1,21 €
variable costs	533,58 €	438,56 €
contribution margin	**179,56 €**	**181,87 €**
fixed maschine costs	224,95 €	241,88 €
fixed labour costs	67,87 €	73,24 €
Direct costs and operational costs	826,40 €	753,68 €
DAL	**- 113,26 €**	**- 133,25 €**

***Annex 4**: Crops for the fodder farm*

Comparison - Winter wheat	**conventional**	**Without PPP**
Yields (dt/ha)	78,90 €	55,23 €
Akh/ha	6,08 €	5,40 €
Proceeds	1.988,28 €	1.391,80 €
Seeds	93,47 €	94,62 €
Fertiliser	461,10 €	354,61 €
Lime	38,00 €	38,00 €
PPP incl. water	152,62 €	- €
Hail insurance	16,28 €	11,45 €
Interest	5,71 €	3,74 €
Direct costs	767,18 €	502,42 €
variable machine costs	291,31 €	290,59 €
Services	3,22 €	3,22 €
Interest	2,21 €	- €
variable costs	1.063,91 €	796,23 €
Contribution margin	**924,37 €**	**595,56 €**
fixed machine costs	275,52 €	275,52 €
fixed labor costs	130,79 €	116,17 €
Direct costs and operational costs	1.470,22 €	1.187,92 €
DAL	**518,06 €**	**203,87 €**

Comparison - Winter barley	**conventional**	**Without PPP**
Yields (dt/ha)	68,90 €	48,92 €
Akh/ha	5,68 €	5,10 €
Proceeds	1.484,80 €	1.054,20 €
Seeds	78,40 €	71,49 €
Fertiliser	391,22 €	300,46 €
Lime	38,00 €	38,00 €
PPP incl. water	153,36 €	
Hail insurance	12,19 €	8,67 €
Interest	5,05 €	3,14 €
Direct costs	**678,22 €**	**421,76 €**
variable machine costs	286,71 €	204,55 €
Services	9,71 €	3,20 €
Interest	- €	- €
variable costs	974,64 €	629,51 €
Contribution margin	**510,15 €**	**424,69 €**
fixed machine costs	281,47 €	271,99 €
fixed labor costs	122,22 €	109,75 €
Direct costs and operational costs	1.378,33 €	1.011,25 €
DAL	**106,46 €**	**42,95 €**

Comparison - silage maize	conventional	Without PPP
Yields (dt/ha)	440,00 €	387,20 €
NEL (MJ/ha)	101.200,00 €	89.056,00 €
ME (MJ/ha)	167.640,00 €	147.523,20 €
Akh/ha	9,25 €	9,63 €
Proceeds	2.244,00 €	1.974,72 €
Seeds	242,00 €	228,93 €
Fertiliser	154,83 €	76,66 €
Lime	38,00 €	38,00 €
PPP incl. water	128,14 €	- €
Hail insurance	12,88 €	11,33 €
Interest	4,32 €	2,58 €
Direct costs	580,17 €	357,50 €
variable machine costs	353,43 €	382,03 €
Services	3,22 €	3,22 €
Interest		- €
variable costs	936,82 €	742,76 €
Contribution margin	**1.307,18 €**	**1.231,96 €**
fixed machine costs	412,75 €	422,91 €
fixed labor costs	198,77 €	206,94 €
Direct costs and operational costs	1.548,34 €	1.372,62 €
DAL	**695,66 €**	**602,10 €**

Arable grass	conventional
Yields (dt/ha)	237,60 €
NEL (MJ/ha)	47.520,00 €
ME (MJ/ha)	80.427,60 €
Akh/ha	11,18 €
Proceeds	1.710,72 €
Seeds	60,00 €
Fertiliser	- €
Lime	38,00 €
Interest	0,74 €
Direct costs	98,74 €
variable machine costs	418,74 €
Services	2,22 €
Interest	3,16 €
variable costs	522,85 €
Contribution margin	**1.187,87 €**
fixed machine costs	387,43 €
fixed labor costs	240,42 €
Direct costs and operational costs	1.150,70 €
DAL	**560,02 €**

Comparison - permanent grassland high PPP- Intensity - silage production	conventional	Without PPP
Yields (dt/ha)	190,30 €	171,27 €
NEL (MJ/ha)	40.102,60 €	32.480,68 €
ME (MJ/ha)	67.183,30 €	54.418,47 €
Akh/ha	8,72 €	9,12 €
Proceeds	1.433,36 €	1.290,02 €
Seeds	18,00 €	33,00 €
Fertiliser	111,93 €	95,25 €
Plant protection products (PPP)	122,52 €	- €
Interest	1,89 €	0,96 €
Direct costs	254,34 €	129,22 €
variable machine costs	299,21 €	289,58 €
Services	1,50 €	1,50 €
Interest	2,26 €	2,18 €
variable costs	557,31 €	422,48 €
Contribution margin	**876,05 €**	**867,54 €**
fixed machine costs	300,45 €	288,45 €
fixed labor costs	187,52 €	196,12 €
Direct costs and operational costs	1.045,28 €	907,06 €
DAL	**388,08 €**	**382,97 €**

Comparison - permanent grassland medium PPP intensity - silage production	conventional	Without PPP
Yields (dt/ha)	190,30 €	180,79 €
NEL (MJ/ha)	40.102,60 €	36.189,89 €
ME (MJ/ha)	67.183,30 €	60.632,93 €
Akh/ha	8,53 €	8,62 €
Proceeds	1.433,36 €	1.361,69 €
Seeds	18,00 €	33,00 €
Fertiliser	111,93 €	103,59 €
Plant protection products	50,20 €	- €
Interest	1,35 €	1,02 €
Direct costs	181,48 €	137,62 €
variable machine costs	296,28 €	289,58 €
Services	1,50 €	1,50 €
Interest	2,23 €	2,18 €
variable costs	481,49 €	430,88 €
Contribution margin	**951,87 €**	**930,81 €**
fixed machine costs	297,04 €	288,45 €
fixed labor costs	183,44 €	185,37 €
Direct and labour costs	961,97 €	904,71 €
DAL	**471,39 €**	**456,99 €**

Comparison - hay high PPP intensity	conventional	Without PPP
Yields (dt/ha)	93,20 €	83,88 €
NEL (MJ/ha)	43.810,00 €	35.481,24 €
ME (MJ/ha)	74.700,00 €	60.506,84 €
Akh/ha	10,35 €	10,63 €
Proceeds	1.570,42 €	1.413,38 €
Seeds	18,00 €	33,00 €
Fertiliser	26,85 €	18,68 €
Plant protection products	122,52 €	- €
Interest	1,26 €	0,39 €
Direct costs	168,63 €	52,07 €
variable machine costs	386,73 €	376,42 €
Services	1,51 €	1,51 €
Interest	2,91 €	2,83 €
variable costs	559,78 €	432,84 €
Contribution margin	**1.010,64 €**	**980,54 €**
fixed machine costs	254,77 €	242,36 €
fixed labor costs	222,53 €	228,55 €
Direct costs and operational costs	1.037,07 €	903,74 €
DAL	**533,35 €**	**509,63 €**

Comparison - hay medium PPP-Intensity	conventional	Without PPP
Yields (dt/ha)	93,20 €	88,54 €
NEL (MJ/ha)	43.810,00 €	39.533,11 €
ME (MJ/ha)	74.700,00 €	67.416,57 €
Akh/ha	10,16 €	10,13 €
Proceeds	1.570,42 €	1.491,90 €
Seeds	18,00 €	33,00 €
Fertiliser	26,85 €	22,77 €
Plant protection products	50,20 €	
Interest	0,71 €	0,42 €
Direct costs	95,76 €	56,19 €
variable machine costs	383,80 €	376,42 €
Services	1,51 €	1,51 €
Interest	2,89 €	2,83 €
variable costs	483,96 €	436,95 €
Contribution margin	**1.086,46 €**	**1.054,95 €**
fixed machine costs	251,36 €	242,36 €
fixed labor costs	218,44 €	217,80 €
Direct costs and operational costs	953,76 €	897,11 €
DAL	**616,66 €**	**594,79 €**

***Annex 5**: dairy farming on the fodder farm*

Comparison - high PPP intensity	**Dairy cow conventional**	**Dairy cow without chemical crop protection**
Proceeds	**6.011,99 €**	**6.011,99 €**
Breeding heifer	821,64 €	832,42 €
Roughage	1.004,61 €	1.040,08 €
Milk performance feed	1.224,96 €	1.224,96 €
Mineral feed	99,28 €	99,28 €
Water/energy/straw/TAV/ disinfection/insurance/animal identification	244,28 €	244,28 €
Interest	77,19 €	78,26 €
Direct costs	3.471,96 €	3.519,28 €
variable machine costs	180,33 €	180,33 €
var. Labour costs	- €	- €
Services	- €	- €
variable costs	3.652,29 €	3.699,61 €
Contribution margin	2.359,70 €	2.312,38 €
fixed machine costs	57,95 €	57,95 €
fixed labor costs	707,22 €	707,22 €
Direct costs and operational costs	4.417,46 €	4.464,78 €
DAL	**1.594,53 €**	**1.547,21 €**

Comparison - medium PPP intensity	Dairy cow conventional	Dairy cow without chemical PPP
Proceeds	**6.011,99 €**	**6.011,99 €**
Breeding heifer	812,08 €	821,70 €
Roughage	975,49 €	1.007,75 €
Milk performance feed	1.224,96 €	1.224,96 €
Mineral feed	99,28 €	99,28 €
Water/energy/straw/TAV/disinfection/ insurance/animal identification	244,28 €	244,28 €
Interest	76,32 €	77,29 €
Direct costs	3.432,41 €	3.475,26 €
variable machine costs	180,33 €	180,33 €
var. Labour costs	- €	- €
Services	- €	- €
variable costs	3.612,74 €	3.655,59 €
Contribution margin	2.399,25 €	2.356,40 €
fixed machine costs	57,95 €	57,95 €
fixed labor costs	707,22 €	707,22 €
Direct costs and operational costs	4.377,91 €	4.420,76 €
DAL	**1.634,08 €**	**1.591,23 €**

Comparison - high PPP intensity	Heifer rearing conventional	Heifer rearing without chemical crop protection
Proceeds	**742,56 €**	**742,56 €**
Cow calf	49,56 €	49,56 €
Roughage	414,27 €	428,57 €
Milk performance feed	62,64 €	62,64 €
Mineral feed	17,24 €	17,24 €
Water/Energy/ Straw/TAV/ Disinfection/ Insemination/ Insurance/ Animal Identification	118,55 €	118,55 €
Interest	18,38 €	18,81 €
Direct costs	680,64 €	695,37 €
variable machine costs	46,59 €	46,59 €
var. Labour costs	- €	- €
Services	- €	- €
variable costs	727,23 €	741,96 €
Contribution margin	15,33 €	0,60 €
fixed machine costs	41,69 €	41,69 €
fixed labor costs	87,94 €	87,94 €
Direct costs and operational costs	856,86 €	871,59 €
Building costs	264,00 €	264,00 €
Full costs/animal/a	**1.120,86 €**	**1.135,59 €**
Full costs/animal	**2.535,88 €**	**2.569,21 €**

Comparison - medium PPP intensity	Heifer rearing conventional	Heifer rearing without chemical crop protection
Proceeds	**742,56 €**	**742,56 €**
Cow calf	49,56 €	49,56 €
Roughage	401,62 €	414,36 €
Milk performance feed	62,64 €	62,64 €
Mineral feed	17,24 €	17,24 €
Water/energy/straw/TAV/disinfection/ insurance/animal identification	118,55 €	118,55 €
Interest	18,00 €	18,38 €
Direct costs	667,61 €	680,73 €
variable machine costs	46,59 €	46,59 €
var. Labour costs	- €	- €
Services	- €	- €
variable costs	714,20 €	727,32 €
Contribution margin	28,36 €	15,24 €
fixed machine costs	41,69 €	41,69 €
fixed labor costs	87,94 €	87,94 €
Direct costs and operational costs	843,83 €	856,95 €
Building costs	264,00 €	264,00 €
Full costs/animal/a	**1.107,83 €**	**1.120,95 €**
Full costs/animal	**2.506,40 €**	**2.536,09 €**

***Annex 6**: Crops for the vegetable farm*

asparagus (average yield of pale asparagus, planting costs without pre-cultivation year, 10 stand years, 20,000 plants/ha, early/late variety 50 %/ 50 %)

Comparison - Asparagus	**integrated**	**without chemical PPP**
Yields (dt/ha)	70,00	14,00
Proceeds	**39.503 €**	**7.901 €**
Slides	953 €	953 €
Fertiliser	276 €	102 €
Seed Oil Radish Tramline	46 €	46 €
PPP	1.111 €	- €
Hail insurance	230 €	115 €
Water /drip hose	688 €	688 €
Marketing fee	6.286 €	2.235 €
Direct costs	9.590 €	4.139 €
variable machine costs	2.044 €	1.874 €
variable wage costs	13.455 €	6.610 €
Services	2.349 €	1.811 €
Interest	86 €	32 €
variable costs	27.524 €	14.466 €
Contribution margin	11.979 €	-6.565 €
fixed machine costs	5.087 €	5.036 €
fixed labor costs	3.554 €	1.178 €
Direct costs and operational costs	36.165 €	20.679 €
DAL	**3.338 €**	**-12.778 €**

Cauliflower fresh market commodity, summer cultivation, 1.2 m bed width - modified

Comparison - Cauliflower	integrated	without chemical PPP
Yields (pieces/ha)	21.000,00	14.700,00
Proceeds	**18.060,00 €**	**12.642,00 €**
Seedlings	1.890 €	1.890 €
Fertiliser	669 €	389 €
Lime	38 €	38 €
PPP	315 €	- €
Hail insurance	517 €	362 €
Water	320 €	312 €
Marketing fee	1.571 €	1.100 €
Interest	27 €	20 €
Direct costs	5.347 €	4.111 €
variable machine costs	996 €	996 €
variable wage costs	3.202 €	3.725 €
Services	18 €	18 €
Interest	21 €	24 €
variable costs	9.583 €	8.873 €
Contribution margin	**8.477 €**	**3.769 €**
fixed machine costs	1.387 €	1.358 €
fixed labor costs	851 €	881 €
Direct costs and operational costs	11.821 €	11.113 €
DAL	**6.239 €**	**1.529 €**

Bush Beans, processed goods, harvest by processors

Comparison - Bush beans	**integrated**	**without chemical PPP**
Yields (dt/ha)	120,00	60,00
Proceeds	**2.220,00 €**	**1.110,00 €**
Seeds	441,00 €	485,10 €
Fertiliser	186,91 €	123,82 €
Lime	12,54 €	12,54 €
PPP	358,77 €	54,00 €*
Hail insurance	63,56 €	31,78 €
Irrigation	186,56 €	182,00 €
Marketing fee	- €	- €
Interest	9,37 €	6,67 €
Direct costs	1.258,71 €	895,90 €
variable machine costs	199,59 €	266,21 €
variable wage costs	45,22 €	484,03 €
Services	17,50 €	17,63 €
Interest	1,97 €	5,76 €
variable costs	1.522,99 €	1.669,53 €
Contribution margin	**697,01 €**	**-559,53 €**
fixed machine costs	249,79 €	278,14 €
fixed labor costs	203,61 €	173,22 €
Direct costs and operational costs	1.976,38 €	2.120,89 €
DAL	**243,62 €**	**- 1.010,89 €**
* biological PPP: Coniothyrium minitans		

Iceberg lettuce, fresh market produce, summer cultivation, harvesting with self-propelled harvesting belt, 1.2 m bed width

Comparison - Iceberg lettuce	**integrated**	**without chemical PPP**
Yields (pieces/ha)	60.000,00	24.000,00
Proceeds	**27.600,00 €**	**11.040,00 €**
Seedlings	3.500,00 €	3.675,00 €
Fertiliser	315,88 €	168,67 €
Lime	- €	- €
PPP	215,35 €	- €
Hail insurance	2.031,91 €	812,76 €
Irrigation	159,23 €	156,00 €
Marketing fee	2.401,20 €	960,48 €
Interest	43,12 €	28,86 €
Direct costs	8.666,69 €	5.801,78 €
variable machine costs	1.866,65 €	2.601,70 €
variable wage costs	6.476,54 €	7.040,62 €
Services	12,50 €	12,68 €
Interest	41,78 €	48,27 €
variable costs	17.064,16 €	15.505,05 €
Contribution margin	**10.535,84 €**	**- 4.465,05 €**
fixed machine costs	2.958,38 €	2.972,74 €
fixed labor costs	1.709,68 €	1.756,57 €
Direct costs and operational costs	21.732,22 €	20.234,37 €
DAL	**5.867,78 €**	**- 9.194,37 €**

mark peas, processed goods, harvested by processors

Comparison - Mark peas	integrated	without chemical PPP
Yields (dt/ha)	65,00	42,30
Proceeds	**1.670,50 €**	**1.085,83 €**
Seeds	400,00 €	440,00 €
Fertiliser	127,15 €	85,64 €
Lime	12,54 €	12,54 €
PPP	534,99 €	- €
Hail insurance	47,81 €	31,09 €
Water	109,70 €	104,00 €
Marketing fee	- €	- €
Interest	9,24 €	5,05 €
Direct costs	1.241,43 €	678,31 €
variable machine costs	257,82 €	217,52 €
variable wage costs	45,22 €	40,48 €
Services	17,50 €	17,63 €
Interest	2,40 €	2,07 €
variable costs	1.564,37 €	956,01 €
Contribution margin	**106,13 €**	**129,81 €**
fixed machine costs	201,09 €	153,78 €
fixed labor costs	182,32 €	133,18 €
Direct costs and operational costs	1.947,78 €	1.242,98 €
DAL	**-277,28 €**	**-157,15 €**

Lamb's lettuce, fresh market produce, autumn cultivation, direct sowing, hand harvesting, 1.8 m bed width - modified

Comparison - Lamb's lettuce	integrated	without chemical PPP
Yields (kg/ha)	6.800,00	4.760,00
Proceeds	**26.996,00 €**	**18.897,20 €**
Seeds	1.687,50 €	1.856,25 €
Fertiliser	213,95 €	163,33 €
Lime	- €	- €
PPP	338,01 €	- €
Hail insurance	1.987,45 €	1.391,21 €
Water	107,61 €	104,00 €
Marketing fee	2.348,65 €	1.644,06 €
Interest	50,12 €	38,69 €
Direct costs	6.733,29 €	5.197,53 €
variable machine costs	675,20 €	687,50 €
variable wage costs	6.197,72 €	6.713,32 €
Services	12,50 €	12,59 €
Interest	51,64 €	55,60 €
variable costs	13.670,35 €	12.666,54 €
Contribution margin	**13.325,65 €**	**6.230,66 €**
fixed machine costs	1.353,10 €	1.340,87 €
fixed labor costs	1.116,95 €	1.196,74 €
Direct costs and operational costs	16.140,40 €	15.204,16 €
DAL	**10.855,60 €**	**3.693,04 €**

Carrots, fresh market produce, Washing Carrot,

Comparison - Carrots	integrated	without chemical PPP
Yields (dt/ha)	750,00	450,00
Price (€/dt)	70,00 €	70,00 €
Proceeds	**52.500,00 €**	**31.500,00 €**
Seeds	1.320,00 €	1.452,00 €
Fertiliser	582,74 €	349,64 €
Lime	38,00 €	38,00 €
PPP	339,00 €	- €
Hail insurance	1.503,08 €	901,85 €
Water	3,33 €	- €
Marketing fee	4.567,50 €	2.740,50 €
Interest	62,65 €	41,11 €
Direct costs	8.416,29 €	5.523,10 €
variable machine costs	5.076,71 €	5.430,59 €
variable wage costs	1.234,46 €	3.670,35 €
Services	17,50 €	17,50 €
Interest	47,47 €	68,39 €
variable costs	14.792,43 €	14.709,94 €
Contribution margin	**37.707,57 €**	**16.790,06 €**
fixed machine costs	8.748,71 €	9.066,07 €
fixed labor costs	740,79 €	1.726,95 €
Direct costs and operational costs	24.281,93 €	25.502,96 €
DAL	**28.218,07 €**	**5.997,04 €**

Comparison - carrots (low price level)	integrated	without chemical PPP
Yields (dt/ha)	750,00	450,00
Price (€/dt)	39,00 €	39,00 €
Proceeds	**29.250,00 €**	**17.550,00 €**
Seeds	1.320,00 €	1.452,00 €
Fertiliser	582,74 €	349,64 €
Lime	38,00 €	38,00 €
PPP	339,00 €	- €
Hail insurance	837,43 €	502,46 €
Water	3,33 €	- €
Marketing fee	2.544,75 €	1.526,85 €
Interest	42,49 €	29,02 €
Direct costs	5.707,73 €	3.897,97 €
variable machine costs	5.076,71 €	5.430,59 €
variable wage costs	1.234,46 €	3.670,35 €
Services	17,50 €	17,50 €
Interest	47,47 €	68,39 €
variable costs	12.083,87 €	13.084,80 €
Contribution margin	**17.166,13 €**	**4.465,20 €**
fixed machine costs	8.748,71 €	9.066,07 €
fixed labor costs	740,79 €	1.726,95 €
Direct costs and operational costs	21.573,37 €	23.877,82 €
DAL	**7.676,63 €**	**-6.327,82 €**

onions, sowing onions, supply to packing plants

Comparison - Onions	integrated	without chemical PPPs
Yields (dt/ha)	475,00	190,00
Proceeds	**12.825,00 €**	**5.130,00 €**
Seeds	1.291,50 €	1.420,65 €
Fertiliser	442,77 €	204,70 €
Lime	38,00 €	38,00 €
PPP	458,98 €	- €
Hail insurance	944,18 €	377,67 €
Water	166,64 €	156,00 €
Marketing fee	- €	- €
Interest	25,07 €	16,48 €
Direct costs	3.367,14 €	2.213,50 €
variable machine costs	1.832,86 €	1.977,07 €
variable wage costs	143,64 €	4.680,21 €
Services	17,50 €	17,63 €
Interest	14,95 €	50,07 €
variable costs	5.376,09 €	8.938,48 €
Contribution margin	**7.448,91 €**	**- 3.808,48 €**
fixed machine costs	1.808,04 €	1.895,79 €
fixed labor costs	656,61 €	656,61 €
Direct costs and operational costs	7.840,74 €	11.490,88 €
DAL	**4.984,26 €**	**- 6.360,88 €**

***Appendix 7**: Results of the model farms*

Model farm 1: Cash Crop Farm - good arable site

Cash Crop Farm - good arable farming locations with high yield potencial							results of linear programming				
crop	yields and earnings				difference		reference system		without PPP		Difference
	with PPP		without PPP								
	dt/ha	DAL in €/ha	dt/ha	DAL in €/ha	(dt/ha)	DAL in €/ha	ha	%	ha	%	%
winter wheat	98,60	806,00 €	69,02	446,67 €	-29,58	- 359,33 €	38,40	33%	19,20	20%	-13%
winter barley	78,80	204,69 €	55,95	48,14 €	-22,85	- 156,55 €					
winter rye	78,80	451,54 €	55,95	245,48 €	-22,85	- 206,06 €			14,40	15%	15%
oats	59,20	140,06 €	52,69	111,10 €	-6,51	- 28,96 €					
spring barley	69,00	714,11 €	60,03	636,55 €	-8,97	- 77,56 €	3,84	3%	9,60	10%	7%
silage maize	528,00	523,47 €	464,64	467,01 €	-63,36	- 56,46 €					
grain maize	114,00	692,93 €	100,32	522,02 €	-13,68	- 170,91 €			19,20	20%	20%
winter oil seed rape	44,10	731,62 €	27,03	305,07 €	-17,07	- 426,55 €	38,40	33%	19,20	20%	-13%
sugar beet	700,00	1.360,43 €	539,00	1.015,83 €	-161,00	- 344,60 €	17,28	15%	14,40	15%	
table potato	550,00	1.131,13 €	341,00	- 915,41 €	-209,00	- 2.046,54 €					
starch potato	650,00	1.372,52 €	403,00	6,95 €	-247,00	- 1.365,57 €	17,28	15%			-15%
field bean	49,30	223,17 €	42,89	141,26 €	-6,41	- 81,91 €					
				fallow land			4,80		4,00		
				total			120	100%	100	100%	
				leases land			yes		no		
				DAL in €			93.391,53 €		48.512,74 €		
				Difference in €/farm			-				**44.878,79 €**
				Difference in €/ha			-				**448,79 €**

Model farm 2: Cash Crop Farm- weak arable site

Cash Crop Farm - weak arable farming locations with low yield potencial							results of linear programming			
crop	yields and earnings				difference		reference system		without PPP	
	with PPP		without PPP							
	dt/ha	DAL in €/ha	dt/ha	DAL in €/ha	(dt/ha)	DAL in €/ha	ha	%	ha	%
winter wheat	59,20	342,29 €	41,44	62,75 €	-17,76	- 279,54 €	38,40	33%	19,20	
winter barley	54,20	61,20 €	38,48	- 107,10 €	-15,72	- 168,30 €	0,00	0	0,00	
winter rye	39,40	- 21,50 €	27,97	- 174,78 €	-11,43	- 153,28 €	0,00	0	0,00	
silage maize	352,00	191,44 €	309,76	124,89 €	-42,24	- 66,55 €	38,40	33%	19,20	
winter oil seed rape	29,40	465,15 €	17,93	37,14 €	-11,47	- 428,01 €	38,40	33%	19,20	
forage peas	24,70	- 214,00 €	21,49	- 220,98 €	-3,21	- 6,98 €	0,00	0%	0,00	
				fallow land			4,80		4,00	
				total			120,00	100%	61,6	100%
				leases land			yes		no	
				DAL in €			33.693,95 €		4.096,58 €	
				Difference in €/farm			-			**29.597,37 €**
				Difference in €/ha						**economically unfeasible**

Model farm 2: Cash Crop Farm- weak arable site (variation: +20%)

Cash Crop Farm - weak arable farming locations with medium yield potencial (variation: +20%)							results of linear programming					
crop	yields and earnings				difference		reference system		without PPP		without PPP	
	with PPP		without PPP				3 crop rotation cycle		5 crop rotation cycle		3 crop rotation cycle	
	dt/ha	DAL in €/ha	dt/ha	DAL in €/ha	(dt/ha)	DAL in €/ha	ha	%	ha	%	ha	%
winter wheat	71,04	587,53 €	49,73	234,36 €	-21,31	- 353,17 €	38,40	33%	19,20		38,40	33%
winter barley	65,04	246,45 €	46,18	24,37 €	-18,86	- 222,08 €	0,00	0	19,20		0,00	0
winter rye	47,28	118,97 €	33,57	- 75,09 €	-13,71	- 194,06 €	0,00	0	0,00		0,00	0
silage maize	422,40	364,02 €	371,71	276,73 €	-50,69	- 87,29 €	38,40	33%	19,20		38,40	33%
winter oil seed rape	35,28	713,57 €	21,52	188,65 €	-13,76	- 524,92 €	38,40	33%	19,20		38,40	33%
forage peas	29,64	- 113,27 €	25,79	- 133,26 €	-3,85	- 19,99 €	0,00	0%	0,00		0,00	0%
				fallow land			4,80		4,00		4,80	
				total			120,00	100%	80,8	100%	120,00	100%
				leases land			yes		no		yes	
				DAL in €			59.277,57 €		13.683,71 €		22.206,98 €	
				Difference in €/farm			-		**45.593,86 €**		-	**37.070,59 €**
				Difference in €/ha					**economically unfeasible**		-	**308,92 €**

Model farm 3: Fodder farm

		high PPP intensity				medium PPP intensity			
	fodder crop farm - 80 ha	reference system		without PPP		reference system		without PPP	
		ha/places	%	ha/places	%	ha/places	%	ha/places	%
scarce land	silage maize	13,40	16,75%	13,40	16,75%	13,40	16,75%	13,40	16,75%
	arable grass	6,60	8,25%	6,60	8,25%	6,60	8,25%	6,60	8,25%
	permanent grassland	47,48	59,35%	50,85	63,57%	47,48	59,36%	50,82	63,53%
	hay	12,52	15,65%	9,15	11,43%	12,52	15,64%	9,18	11,47%
	dairy farming	100,00	100,00%	88,38	88,38%	100,00	100,00%	93,63	93,63%
	Total amount agricultural land	80,00	100%	80,00	100%	80,00	100%	80,00	100%
	cow places	100,00	100%	88,38	88%	100,00	100%	93,63	94%
	DAL in €	161.161,22 €		136.746,66 €		165.383,37 €		148.985,83 €	
	Difference in €/farm	-		**24.414,56 €**		-		**16.397,54 €**	
	Difference in €/ha	-		**305,18 €**		-		**204,97 €**	
	fodder crop farm - 100 ha	reference system		without PPP		reference system		without PPP	
		ha/places	%	ha/places	%	ha/places	%	ha/places	%
no scarce land	silage maize	16,75	16,75%	16,75	16,75%	16,75	16,75%	16,75	16,75%
	arable grass	8,25	8,25%	8,25	8,25%	8,25	8,25%	8,25	8,25%
	permanent grassland	37,07	37,07%	52,04	52,04%	37,08	37,08%	46,70	46,70%
	hay	37,93	37,93%	22,96	22,96%	37,92	37,92%	28,30	28,30%
	dairy farming	100,00	100,00%	100,00	100,00%	100,00	100,00%	100,00	100,00%
	Total amount agricultural land	100,00	100%	100,00	100%	100,00	100%	100,00	100%
	cow places	100,00	100%	100,00	100%	100,00	100%	100,00	100%
	DAL in €	174.712,94 €		161.148,90 €		181.052,07 €		170.123,20 €	
	Difference in €/farm	-		**13.564,04 €**		-		**10.928,87 €**	
	Difference in €/ha	-		**135,64 €**		-		**109,29 €**	

Model farm 4: vegetable farm

culture	yields and earnings						difference		results				
	with PPP			without PPP					reference system		without PPP		Difference
	yields/ha		DAL in €/ha	yields/ha		DAL in €/ha	(dt/ha)	DAL in €/ha	ha	%	ha	%	%
asparagus	70,00	dt	3.338,00 €	14,00	dt	-12.778,00 €	- 56,00	-16.116,00 €	19,20	20%			-20%
onion	475,00	dt	4.984,27 €	190,00	dt	- 6.360,88 €	- 285,00	-11.345,15 €	19,20	20%			-20%
carrots	750,00	dt	28.218,07 €	450,00	dt	5.997,04 €	- 300,00	-22.221,03 €	19,20	20%	19,20	20%	0%
cauliflower	21.000,00	units	6.239,48 €	14.700,00	units	1.529,06 €	- 6.300,00	- 4.710,42 €	19,20	20%	19,20	20%	0%
iceberg lettuce	60.000,00	units	5.867,78 €	24.000,00	units	- 9.194,37 €	-36.000,00	-15.062,15 €	19,20	20%			-20%
bush bean	120,00	dt	243,62 €	60,00	dt	- 1.010,89 €	- 60,00	- 1.254,51 €					
pea	65,00	dt	- 277,28 €	42,30	dt	- 157,15 €	- 22,70	120,13 €					
lamb's lettuce	68,00	dt	10.855,60 €	47,60	dt	3.693,04 €	- 20,40	- 7.162,56 €			19,20	20%	20%
sugar beet	700,00	dt	1.360,42 €	539,00	dt	1.015,69 €	- 161,00	- 344,73 €			19,20	20%	20%
winter wheat	98,60	dt	806,00 €	69,20	dt	446,67 €	- 29,40	- 359,33 €			19,20	20%	20%
fallow land	0,00		- 193,42 €	0,00		- 193,42 €			4,00	4%	4,00	4%	
* The cultivation areas of individual crops (in %) refer to the arable land excluding fallow land. (100 ha arable land - 4 ha fallow land = 96 ha) (96 ha = 100%)						DAL in €			933.260,24 €		242.711,12 €		
						Difference in €/farm			- 690.549,12 €				
						Differece in €/ha			- 6.905,49 €				