Bio-economic modelling of arable farming system, comparison of conventional and organic farming systems in the Netherlands

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Abstract

Growing environmental concern in society combined with policy stimuli has encouraged a number of farmers to switch from conventional to organic production technologies. However, farmers' decisions on whether or not to make this switch have not been studied thoroughly thus far. The decision and possible governmental influences on it can be studied using a dynamic multiyear model of a farm. By using this model the bottlenecks of the conversion period can be analysed and the effect of different economic incentives on the conversion can be assessed. As a start in this paper two static linear programming models of a conventional arable farm and an organic arable farm are presented and the results are compared. The farms that are modelled are typical for the Central clay region of The Netherlands. The models include environmental externalities, such as, losses of nutrients and pesticide use, the level of which can be influenced by using different production structure (cropping plan). The conventional and organic farms are compared under current policy in the Netherlands by means of modelling. The results show that organic farming leads to less intensive land use with slightly better environmental results. Economic results of organic farming depend strongly on the crop prices, and the amount of labour use. Costs of hired labour are much higher in organic farming but on total costs are lower. This is mainly due to the less intensive cropping plan. Prices for organic products are higher than for similar conventional products, but lower yields and the less intensive cropping plan mitigates the effects on total revenues.

1. Introduction

Growing environmental concern in society combined with policy stimuli has encouraged a number of farmers to switch from conventional to organic production technologies. The Dutch government has set an ambitious target that by 2010 ten percent of the total agricultural area has to be organically managed. However in 2001 this figure was only about 1,5% (Melita, 2001). The conversion from conventional to organic farming systems is progressing more slowly than the government expected.

The objective of this paper is to present and test a linear programming model for a specialised conventional and a specialised organic arable farm in the central clay region in the North East Polder in the Netherlands. The set up of these two models and the technical, economic and environmental results are compared. These models will serve as a base for a dynamic linear programming model to study transition from conventional to organic farming.

The paper starts with presenting the two developed linear programming models. Next, modelling results are compared. The paper ends with a number of discussion points.

2. Model specification and data used for conventional and organic arable farm

General structure

The general structure of the conventional and organic arable farm models is shown in Table 1 and has the mathematical form of the standard linear programming problem:

Maximise $\{Z = c'x\}$
Subject to $Ax \leq b$
and $x \geq 0$
where:
x = vector of activities
c = vector of gross margins or costs per unit of activity
A = matrix of technical coefficients
b = vector of right hand side values

The activities and constraints of both LP models are simplified and grouped in Table 1. The groups of activities are shown at the top of the table under eleven headings: production activities representing different crops, seasonal labour, purchase of fertiliser and manure, N-fixation of certain crops, activities for calculating nutrient surplus, organic matter input, pesticides use and activity representing fixed costs.

The rows of the matrix indicate the type and form of the constraints included: total land availability, rotation restrictions, supply and demand of fixed and of seasonal labour, nutrient balance calculation for MINAS (Dutch Mineral Accounting System) regulation, maximum manure input restriction for MTAS (Manure Transfer Agreement System) regulation, several coupling restrictions for pesticides and organic matter content requirement.

The main difference between the two models is that the purchase of fertiliser and pesticides concerns only the conventional production. In case of organic farming the fertilising constraint includes only manure in addition to N-fixation by certain crops, and there is not link between production activities and pesticides. More detailed differences between activities and constraints of the two models will be explained in the next section.

The objective function of the LP model is to maximise the labour income, i.e. total returns from sold crops minus variable costs (including fertiliser, pesticides, variable operations, seasonal labour and MINAS tax on unacceptable surplus) and fixed costs. The output of the model also indicates the corresponding optimal production plan, labour use, manure and fertiliser purchase, pesticide use and environmental effects of both farming systems.

To get the optimal solution for the LP model CPLEX solver is used in GAMS (General Algebraic Modelling System) programming language.

Table 1. The general structure of the conventional and organic arable farm models

Activities	Crop production for sale	Seasonal labour	Purchase of fertiliser	Purchase of manure	N-fixation by crops	Nutrient surplus	Unaccaptable nutrient surplus	Organic matter input	Total pesticides use	Fixed costs	*Right-hand side*
Constraints											
Land availability	+1										<= available land
Rotation restrictions	+1										<= max. ha of each crop or group of crops
Labour in periods of 14 days	+aij	-1									<= available fixed labour in hours
Sesonal skilled and unskilled labour in periods of 14 days		+1									>= minimum sesonal labour use in hours
Fertilising requirements	+aij		-aij	-aij							<= 0
Nutrient balances at farm level	-aij		+aij	+aij	+aij	+aij					= 0
MINAS	-aij		+aij	+aij	+aij		-aij				<=accapteble nutrient surplus by MINAS
MTAS				+aij							<= max. manure regulated by MTAS
Linking production activities and pesticides	+aij								-1		= 0
Organic matter input	+aij			+aij				-aij			= 0
Fixed costs										1	= 1
Objective function	Gross margin excl. costs of fertiliser	Costs per hour	Costs per kg	Costs per t			MINAS tax per kg unaccaptable Surplus			Annual costs	

Activities

The analysed typical farm in the North East Polder (the region that served as a case study), in the central part of The Netherlands is a 48 ha arable farm with clay soil type. Typical crops in the region selected for the analysis include winter wheat, spring barley, seed and ware potato sugar beet, seed onion and carrot for the conventional model. For organic model besides these crops, which are grown in an organic way, the following crops are included: spring wheat, winter barley, kidney bean, green pea, alfalfa, celeriac and grass-clover. In order to both improve the organic matter content of the soil and fix nitrogen available after the main crop, green manure is also part of the rotation. After cereals winter radish is grown in the conventional situation and clover in the organic situation. In organic case also grass is used as green manure after kidney bean, sugar beet and seed potato.

The input data concerning costs and revenues of crops, crop yield, nutrient and pesticide use per crop on central clay soil for both conventional and organic model were obtained from the KWIN (2002). Information about the labour use and labour wages including hired skilled and unskilled labour was gathered from PPO (De Wolf, 2004). The nutrient content of crops was obtained from Anonymous (1996).

The yields, costs and revenues for different conventional and organic crops are shown in Table 2. The revenues of the crops are calculated by multiplication of crop prices and yield per crop. The costs of crop production include the costs of field operations (land preparation, planting/sowing, crop care, hand weeding and harvesting), costs of pesticide (in conventional case) and energy use and other costs like, interest, insurance and N-mineral sampling.

Table 2. Yields, costs and revenues for different conventional and organic crops

Crops	Conventional			Organic		
	Yield t/ha	Costs* Euro	Revenue Euro	Yield t/ha	Costs* Euro	Revenue Euro
ware potato	56.8	1681	5680	27.5	2255	7150
seed potato	38.7	3245	7740	26.0	2226	9620
sugar beet	65.5	1008	3344	50.0	884	4058
seed onion	58.4	1975	5256	35.0	1284	8750
carrot	77.0	9450	12320	55.0	12450	18700
winter wheat	8.7	484	1797	5.0	439	1926
spring barley	6.3	312	1526	4.5	393	1691
winter barley	-	-	-	3.8	339	1759
spring wheat	-	-	-	5.0	415	2176
kidney bean	-	-	-	2.2	624	2817
green pea	-	-	-	4.3	658	2763
alfalfa	-	-	-	12.0	169	960
celeriac	-	-	-	35.0	2666	8400
grass-claver	-	-	-	10.0	141	700

* Variable production costs do not include the costs of nutrients and labour

* Costs of green manure production is also included in seed potato, kidney bean, sugar beet and cereals

Data for the nutrient requirements of the conventional cropping activities were taken from Van Dijk (2003). In case of organic crops concerning phosphate and potassium the nutrient requirements were calculated by the balance method: requirement = removal by products + safety margin – deposition. For phosphate 20 kg per ha for potassium 40 kg per ha safety margin is calculated (De Wolf, 2004).

For nutrient supply, besides fertiliser purchase, various types of manure can be used: cattle, pig and poultry manure in the conventional case and in addition cattle stable manure in the organic situation. In the organic model all manure types have to satisfy the organic requirements for organic production as no fertiliser can be used. N-fixation can bring in nitrogen by kidney bean, green pea, alfalfa and grass clover. With the use of various manure types the model can optimise the NPK-supply.

The price of manure for the conventional farm is assumed to be zero according to the current market situation and the price of fertiliser is 0,55 Euro/kg N, 0,52 Euro/kg P205 and 0,31 Euro/kg K20. For organic farm the manure price is 9,08 Euro per ton manure (KWIN, 2002). Spreading of manure assumed to be made by contract workers. The costs of it for both farms are 4.54 Euro per ton (KWIN, 2002).

The nutrient content of each type of manure was gathered from PPO and the effective nitrogen content was calculated by use of the working coefficient for nitrogen in manure (Van Dijk, 2003). For sugar beet and seed onion in organic farming the manure should be supplied in autumn in order to have a good start for the crops in the beginning of the season. This means that the working coefficient for nitrogen from manure will be lower.

Constraints

Land

The holding's total area is the major limiting resource factor. In the North East Polder (the Central Clay Region) after the land had been reclaimed from the sea, farms ranged from 12 to 48 hectares. Nowadays, 48-hectare farm size characterises the region.

Rotation constraints

Most of the farmers in this region use 1:3 or 1:4 crop rotation in conventional situation. Other crop rotations i.e. 1:5 or 1:6 also can be found but they are not typical for the region. For the organic model 1:6 crop rotation was chosen, which characterises the organic farms in this area. The conventional LP model was set to choose between 1:3 and 1:4 crop rotation.

For agronomic reasons rotation restrictions were set for individual crops as for groups of crops. For individual crops: seed potato and ware potato were restricted to 1/3 of the total cultivated area (Loon et al, 1993; Bus et al, 1996). Seed onion and carrot was set to the maximum of 1/5 and sugar beet of 1/4 of the cultivated area (Visser et al, 1993; Schoneveld at al, 1991; Westerdijk et al, 1994). Concerning the groups of crops: cereals were restricted to 1/3 and root crops to 75% of the cultivated area (Darwingel, 1997; Timmer, 1999).

Rotation constraints concerning organic farming are stricter than those for conventional farming. For individual crops: potatoes, seed onion, carrot, kidney bean, green pea and celeriac the restriction set to the maximum of 1:6 of the cultivated area. For individual cereals and alfalfa the restriction set to 1:3, for sugar beet to 1:4. For the groups of crops: root crops (ware and seed potato, sugar beet, seed onion, carrot and celeriac) and mow crops (cereals, kidney bean, green pea, alfalfa and grass-clover) separately can be cultivated on ½ of the area. Green legumes (green pea and alfalfa) and dry legumes (kidney bean) are set to the maximum of 1:4 and 1:6 of the cultivated area, respectively (Wijnands en Dekking, 2002).

Labour

Most field operations on crops have to be performed during a certain period. Therefore, the year is divided into periods of two weeks. The amount of available family labour is assumed to be 1,1 labour unit 2255 h/year (De Wolf, 2004). The labour supply for family labour per period is assumed to be constant over the year. However in peak periods the model can use a maximum of 158 hours pert fortnight.

The claims for general work were derived from the Handbook for Farm Calculations (Schoorlemmer, 1997). This source advises a standard of 400 hours per farm per year, plus 10 hours per hectare for arable farms and 15 hours per hectare for vegetable farms. Organic farms are considered to have a similar need of hours like vegetable farms, according to the high amount of labour use and number of crops grown on the farm (De Wolf, 2004). General work can be done whenever there is a surplus of labour.

Apart from family labour there is the option of hiring seasonal labour. It is assumed that the amount of hired labour is not restricted by the total regional supply. Seasonal labour can be employed any time of the year for 9 Euro/ha and 18 Euro/ha for unskilled (youth/students) and skilled labour, respectively (CAO, 2000). For some field operations for both farming systems compulsory skilled or unskilled labour is needed, due to the fact that some farming activities require a minimum of two or more persons working at the same time. In that case, there is a minimum constraint for using hired labour for certain periods of each cropping activity.

Nutrient balances

In the Netherlands, environmental regulation has existed for a number of year. There are two relevant regulations for the arable farming. MINAS (Dutch Mineral Accounting System) focuses on the restriction of nutrient surpluses within the farm, specifically nitrogen and phosphate, and determines an acceptable level of surplus per farm at hectare level (100 kg N and 25 kg P_2O_5). The total acceptable surplus at farm level is subtracted from the actual total surplus. The farmer has to pay a levy per kg unacceptable surplus, which is 2,3 Euro/kg in case of nitrogen and 9 Euro/kg in case of phosphate (MANMF, 2003). The manure transfer agreement system (MTAS) sets a limit to the amount of manure that can be used on the farm. This limit is based on N content and is currently 170 kg N from manure per ha.

The models include a number of rows that register the losses of nitrogen (N), phosphate (P_2O_5) and potassium (K_2O) to the environment. Balances at farm level calculated by the total amount of nutrient input and output, consequently, total nutrient losses. Input is coming from seeds, fertiliser (conventional case), manure and N-fixation. The output is the real amount of nutrient content in the crop, which goes out form the farm.

In the conventional situation input of nutrients at farm level comes from purchase of fertiliser and different types of manure. In the organic situation input of nutrients come from manure purchase and by N-fixation by crops grown on the farm. In both cases the nutrient output is calculated by the total amount of nutrients contained in the crops that is sold from the farm.

In addition to the balance calculations MINAS restrictions were also included in the model as separate constraints. In MINAS N-fixation and the nutrient output by crops are based on standards. N-fixation for kidney beans amount 30 kg, for green pea 50 kg, for alfalfa 160 kg per hectare and for grass-clover no nitrogen fixation is calculated. For nutrient output MINAS uses a standard of 165 kg/ha for N and 65 kg/ha for P_2O_5 for all crops excluding alfalfa and grass-clover, where the standard is 5.8 kg N, 1,4 kg/t P_2O_5 and 5.9 kg N, 1,4 kg P_2O_5 per ton dry matter content, respectively (Tabellenbrochure, 2004).

Organic matter

In order to maintain the organic matter content of the soil both models calculate the input of organic matter at soil level. The crop residues, which left on the field, are also calculated as input. It is not as a restriction in the model, just a simple input calculation in both cases in order to know how much the difference is between conventional and organic farming concerning the organic matter of the soil.

Pesticides

The amount of pesticides used for the protection against weeds, pests and diseases is calculated in active ingredients (a.i.), which is the weight of the toxic substance in the applied product in kilograms. In our model the use of pesticides is calculated only for conventional products, because for organic production any use of synthetic chemical inputs is prohibited. The data for pesticides use of each crop at hectare level were collected from KWIN (2002). There is an additional row, which calculates the total pesticides purchase at farm level.

Fixed costs

Fixed costs are calculated separately from the LP model. Given input factors such as the size of the farm, basic machinery and buildings the costs are calculated for this specific region by PPO (Wijnands, F.G. en A.J. Dekking, 2002). The fixed cost are 121 960 Euro per year in case of conventional farm and 134 230 in case of organic farm.

The costs include the costs of land, buildings, fixed machinery and other costs like, maintenance of ditches as contract work and other general costs per farm and per hectare (Table 3).

Table 3. Fixed costs for 48 ha farm in Central clay region

costs	conventional	organic
Fixed machinery	41,140	46,430
Land	33,260	33,260
Buildings	40,990	46,350
Other costs	6,570	8,190
Total fixed costs	121,960	134,230

3. Results

In order compare conventional and organic farming under current policy and environmental regulations in The Netherlands, three situations are analysed and compared. There are two optimal situations calculated for the conventional farm model (1:3 and 1:4 crop rotation) and one for organic farm model (1:6 crop rotation). Technical, economic and environmental results of these situations are analysed and compared.

Technical results

The optimal production plan for conventional and organic farm models concerning 1:3, 1:4 and 1:6 crop rotation plan are presented in Table 4. The area different crops occupy in the optimal production plan from 48 ha cultivated area can be seen.

Table 4. Optimal production structure of conventional and organic farms for 1:3, 1:4 and 1:6 crop rotation plans

crops	conventional farm		organic farm
ha	rotation 1:3	rotation 1:4	rotation 1:6
conventional/organic			
winter wheat	0.0	0.0	0.0
spring barley	16.0	12.0	0.0
seed potato	16.0	12.0	8.0
sugar beet	0.0	4.8	0.0
seed onion	9.6	9.6	8.0
carrot	6.4	9.6	0.7
consumption potato	0.0	0.0	0.0
organic			
winter barley	-	-	0.0
spring wheat	-	-	8.0
kidney bean	-	-	8.0
green pea	-	-	8.0
alfalfa	-	-	0.0
celeriac	-	-	7.3
grass-claver	-	-	0.0
Total area (ha)	*48*	*48*	*48*

In all three situations seed potato and seed onion are produced on the maximum amount of area because of its high profitability. Furthermore, rotation restrictions on root crops determine the cropping plan. In conventional cases from cereal crops spring barley is produced instead of winter wheat, which is more profitable, due to the less nutrient requirements.

In organic farming more crops are included in the rotation than in conventional case due to the 1:6 rotation requirement in organic farming. Certain crops like i.e. carrot can not get to the optimal production plan, although they are more profitable then for example celeriac, because of high amount of labour requirement in peak periods (June and July). Kidney bean and green pea are not that profitable but they supply additional nitrogen as an input to the farm, which leads to less manure purchase for the farmer.

Technical results concerning labour use, nutrient application, organic matter input and pesticide use in conventional and in organic production can be seen in Table 5.

The labour requirement is much higher in case of organic farming than in conventional situations. Especially the amount of unskilled hired labour is quite different between these two farming systems, mainly because of weed control by hand.

The results concerning the nutrient supply in conventional farming shows that besides pig and poultry manure also fertiliser is applied. In organic farming only poultry manure is used and the total amount of nutrient application is lower than in conventional case. It is due to the more extensive farming system, N-fixing crops and green manure crops use in the organic rotation.

Table 5. Technical results from the model concerning conventional and organic farming.

	conventional farm rotation 1:3	conventional farm rotation 1:4	organic farm rotation 1:6
Labour			
Household labour use (h)	2255	2255	2255
Hired skilled labour use (h)	512	418	726
Hired unskilled labour use (h)	389	238	1975
Total hired labour use (h)	901	655	2701
Total labour use (h)	*3156*	*2910*	*4956*
Nutrient supply			
Fertiliser purchase (kg)			
N	1568	2544	0
P2O5	1920	2688	0
K2O	3616	4752	0
Manure purchase			
Cattle (t)	0	0	0
Pig (t)	95	258	0
Poultry(t)	153	55	214
N (kg)	5336	3530	6529
P2O5 (kg)	2992	2016	3639
K2O (kg)	4116	3092	4817
Organic matter input (kg)	38855	23558	73459
Pesticides level (a.i.):	136300	124710	0

As an average for a good maintenance of the soil minimum 1500 kg/ha organic matter should enter the farm (De Wolf, 2004). Organic matter input at soil level in conventional situation is much lower, which means that it does not reach the sustainable 1500 kg per hectare organic matter input. For 48 ha farm size it would be 72000 kg per farm. In organic farming this level is reached by higher poultry manure application, which has more organic matter content then pig manure, and by crop residues and green manure left on the field after harvesting the main crop.

Pesticide use is measured only in conventional case, because in organic situation no chemical pesticides are permitted.

Economic results

The economic results (Table 6) follow from the technical results. The revenue of the farms comes from the purchased crops and crop residues, i.e. straw. Although, the prices for organic products are higher, the returns for conventional products are approximately the same due to the lower yield production in organic farming. The costs from crop production are lower then in conventional situation. It is due to the fact that the same profitable crops (i.e. seed potato and seed onion) have higher costs in conventional situation, and also that in organic situation the production plan less intensive and more ‘cheap’ crops are grown.

The costs of hired labour are about three times higher than in conventional case and the costs for manure and fertiliser are lower in organic farming due to the more extensive farming and no fertiliser use.

Table 6. Economic results of conventional and organic farming

Euro	conventional farm rotation 1:3	conventional farm rotation 1:4	organic farm rotation 1:6
Revenue			
Returns from crops	277559	295973	283805
Costs			
Costs from crop production	137499	158066	69433
Hired labour	12721	9655	31613
Manure and fertiliser	4106	5692	2916
MINAS tax	0	0	0
Total costs	154326	173413	103962
Total gross margin	123234	122560	179843
Fixed costs	121960	121960	134230
Labour income (Euro/year)	1274	600	45613
Labour income (Euro/ha)	27	13	950

The total costs of production are higher in conventional farming and the returns are approximately the same as in organic situation, which after subtracting the fixed costs leads to the higher labour income in case of the organic farming.

Environmental results

Nutrient balance and losses of nitrogen and phosphate in kg per hectare in both organic and conventional situation are shown in Table 7. Real nutrient surplus is calculated as a difference between the total amount of nutrient content purchased by manure, fertiliser, seeds, deposition and N-fixation at farm level and the amount of removals with each crop from the farm. For MINAS input manure, nitrogen fertiliser and N-fixation is calculated. For MINAS output standards of 165 kg N and 65 kg P_2O_5 are used per ha.

By analysing the nutrient balance in all three farm situations, on Table 7 we can see that in the organic farm the nitrogen input is higher then in both conventional farm situations. This is mainly due to the high amount of manure purchase and N-fixation by legumes in organic farming. The nitrogen output is also higher in organic situation. This leads to a better environmental result in case of organic farming compared to the results of 1:3 crop rotation in conventional farm situation, but it is not better compared to the situation with 1:4 crop rotation. In case of phosphate there is almost no difference between three farm situations concerning the amount of phosphate surplus. Although, in organic farming the phosphate input and output is less to compare to both conventional situations.

By comparing the results of real and MINAS nutrient balance calculations, we can see that in case of nitrogen MINAS calculates lower input for all three farming situations. This difference especially in organic farming is considerable. By analysing the nitrogen output from the farm we can see that in conventional situations MINAS is over calculating the nitrogen output by the use of one standard output for all types of crops. In organic farming situation this difference is smaller. In all three farming situations for nitrogen no unacceptable surplus arise according to MINAS.

Table 7. Nutrient balance in kg per ha in conventional and organic farming

	Real balance		MINAS balance	
	N	P2O5	N	P2O5
Conventional				
1:3 crop rotation				
Input	**175**	**107**	**144**	**62**
manure	111	62	111	62
fertiliser	33	40	33	-
seed	6	2	-	-
deposition	25	2	-	-
fixation	-	-	-	-
Output	**118**	**49**	**165**	**65**
surplus	**57**	**58**	**-21**	**-3**
acceptable	-	-	100	25
1:4 crop rotation				
Input	**156**	**102**	**127**	**42**
manure	74	42	74	42
fertiliser	53	56	53	-
seed	5	2	-	-
deposition	25	2	-	-
fixation	-	-	-	-
Output	**119**	**50**	**165**	**65**
surplus	**37**	**52**	**-38**	**-23**
acceptable	-	-	100	25
Organic				
1:6 crop rotation				
Input	**216**	**79**	**149**	**76**
manure	136	76	136	76
seed	5	2	-	-
deposition	25	2	-	-
fixation	50	-	13	-
Output	**179**	**27**	**165**	**65**
surplus	**37**	**53**	**-16**	**11**
acceptable	-	-	100	25

In case of phosphate output from the farm, the MINAS system overestimates the amount especially in organic farming. However, in case of phosphate the balance calculated by MINAS does not include phosphate from fertiliser purchase. This way the real nutrient surplus is higher then what is calculated by MINAS.

Discussion

According to the results we can say that it is much more profitable to grow organic than produce in a conventional way. Then the question arises: why do the farmers not convert? The answer to this question has to do with (1) hired labour on more labour intensive organic production, (2) the transition period from conventional to organic farming and (3) the analysis of risk and uncertainty concerning the yield and market accessibility after conversion.

Hired labour

Problems mainly arise from the labour organisation that the farmer has to work together with seasonal labour and he can not organise efficiently the work together with them. It is due to the fact that conventional farmers did not get used to dealing with additional work force.

Transition period

Transition period is another problem if the farmer wants to convert to organic farming. This period takes 2 years during which the conversion product has to be grown in an organic way but can be sold only for conventional price. During this period also a lot of changes and investments should be done which can cause financial problems for the farmer. According to some research done in The Netherlands (Hoorweg, 2002) the payback time after conversion to organic arable farming depends on the farmers' initial situation. Farmers with short crop rotation (1:3) have longer payback period then those who have longer (1:4 or 1:5) crop rotation. This is due to the fact that more specialised farms have to invest more (especially in machinery) to convert to more extensive 1:6 organic crop rotation. This conversion period will be studied in more detail in subsequent research to analyse which years are financially the most difficult for the farmer and what kind of policy measures can be taken in order to encourage them to convert.

Risk and uncertainty (production and price risk)

In case of organic farming the production risk is much higher compared to conventional farming. This is mainly due to the fact that it is prohibited to use any kind of fertiliser and pesticides in organic farming which make the crops more resistant against pests and diseases. For example, 50% less yield for seed potato brings down the labour income from 45613 Euro to 7132 Euro per farm per year in organic farming, which is almost at the labour income level of conventional farm results.

The organic market access is another problem which can prohibit the farmers to convert to organic farming. If they can not sell their products as organic for higher price, after they produced it in organic way their income would drop also considerably. For example, if for seed potato the farmer could not find an organic market, only would sell it as a conventional product then he would get instead of 9620 Euro per hectare 7740 Euro/ha, which decreases the total labour income by 33% to 30572 Euro per year. At the moment in The Netherlands the market for some organic products is saturated. Lately many farmers converted to organic and now there is overproduction and the farmers can not sell their products for organic prices, like in our organic model, only for lower prices.

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