Evaluation of soybean

Could soybean comply with the expectations of the EU greening policy to be added to the Dutch list of nitrogen-fixing crops?

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WAGENINGEN UR
For quality of life

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Summary:
Soybean could offer farmers an extra opportunity to fill in ecological focus areas on their farm with nitrogen fixing crops. Its grain fits in a development towards more regionally produced protein crops for human consumption and animal feed. When soybean is accepted for ecological focus areas, it does not disturb market conditions, but promotes biodiversity and environmental goals.

Keywords: soybean, nitrogen-fixing crops, CAP, ecological focus areas

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Summary

Soybean could offer farmers an extra opportunity to fill in ecological focus areas on their farm with nitrogen fixing crops. Its grain fits in a development towards more regionally produced protein crops for human consumption and animal feed. From a financial perspective soybean cultivation is at present not attractive to farmers. When soybean is accepted for ecological focus areas, it will not compete with the profit of potato, sugar beet, wheat or barley crops which are grown on the other 95% of the farm, but with the 'profit' of green manure, catch crops, set aside and landscape features. This means that it does not disturb market conditions, but promotes biodiversity and environmental goals.

1 Introduction

In the letter of 5 June 2014 to the Dutch Parliament about the *'Uitwerking directe betalingen Gemeenschappelijk Landbouwbeleid* [*Execution of direct payments of the Common Agricultural Policy*], Minister Mrs Dijksma, designated a number of nitrogen-fixing crops (also called protein crops) that could be used in Ecological Focus Areas (EFA). The crops on the Dutch list for ecological focus areas are: alfalfa (*Medicago sativa*), esparcette (*Onobrychis viciifolia*), red clover (*Trifolium pratense*), birdsfoot trefoil (*Lotus corniculatus*), lupine (*Lupinus spp*), vetch (*Vicia spp)*[1] and field bean (*Vicia faba).*These crops were chosen as a result of their value for biodiversity and their low requirements for fertilization and pesticides.

The Minister has based her decision which crops could be admitted to a greater extent on a Wageningen UR report (Den Belder *et al*, 2014) *'Evaluatie van gewassen als mogelijke equivalente maatregel voor ecologische aandachtsgebieden in het nieuwe GLB'*, [*Evaluation of crops as possible equivalent measure for ecological focus areas in the new CAP*]. In this evaluation biodiversity received most attention. In this evaluation the score of soybean was lower than the score for other nitrogen-fixing crops. The ministry of Economic Affairs asked to evaluate soybean again taking into account other aspects such as cultivation of guaranteed GMO-free soybean and less dependence on soybean imports from oversees countries.

Society wishes to use more regional produced protein rich feed, which among others came clear in the letter of Minister Van Dam on 15 April 2016, answering a number of questions on this topic raised by Members of Dutch Parliament Dik-Faber, Geurts and Koşer Kaya. Besides other protein crops, soybeans could contribute to the regional protein production. There are several reasons (including guaranteed GMO-free cultivation, low need for fertilizers and crop protection, good for the soil structure, honey plant for wild bees, nitrogen fixation) that justify a reassessment of soybean. Dutch agribusiness (in particular Agrifirm) wishes to add soybean to the list of designated protein crops. The Ministry has approached the authors of Wageningen UR report to reconsider the qualities of soybean and to give their opinion if soybean could meet the objectives set by the European Commission on 'greening' the CAP.

[1] Vetches were added on 25 June 2014 by a letter of the Minister to the Parliament

2 The use of soya meal in the Netherlands

Europe depends for use of soy meal completely on imports from North and South America. Europe imports 97 percent of the soy meal and used in the period 2013-2015 on average 28.5 million tonnes of soy meal in animal feeds (ABN-AMRO, 2015). Almost one quarter of the European soybean import is entering via the ports of Amsterdam and Rotterdam. The Netherlands imports annually over 8 million tonnes of soybean, of which three quarters comes from South America. Of the entire imported soybean, less than 2.5 million tons remains in the Netherlands, 1.8 million tonnes of soybean is processed into animal feed; the rest is used in human nutrition (ABN-AMRO, 2015).

The soybean consists of around 20% of oil. The majority of soybean (85 percent) is 'crushed' to soy oil and soy meal. Soy meal is mainly used in animal feed. Originally it was considered as a by-product; now the economic value of soy meal approaches that of soy oil. Soy meal has a high protein content (average 46 percent) and the protein is of high quality. The digestibility is high and the amino acids composition corresponds to the needs of the animals. On average Dutch compound feed contains 14 percent soy products, especially in the form of soy meal (ABN-AMRO, 2015).

The strong dependence of Dutch animal feed on soybean imported from South America is under debate. There are concerns on the direct and indirect impact of soybean cultivation on ecosystems and communities in Brazil and Argentina in particular. For example, degradation of valuable nature, violation of land rights of the local population and excessive use of plant protection products. Other points of concern are 1. the dependence of the European livestock sector of (South) American soybean; it makes Europe vulnerable to geopolitical and currency fluctuations; 2. the gigantic import of nutrients in soybean causes an unbalance in mineral cycling and excessive manure production compared to the farmland acreage; and 3. the total dependency of genetically modified soybean; about 95 percent of the soybeans grown in the United States and South America is genetically modified. There is only a limited availability of GMO-free soybean on the world market.

3 Soybean cultivation in the Netherlands

Soybean is a crop which is cultivated in regions with hot summers, with a mean temperature of 20 to 30°C. Soybean is hardly cultivated in the EU, only 410,000 ha in 2012 as compared to 25 million ha in Brazil. The cultivation in Europe is mainly in Italy and some production is in Rumania, Hungary, France, Austria and Slovakia (De Rooij, 2013).

The acreage of protein crops in the Netherlands is small and is recently even a bit decreasing. The cultivated area in 2013 was 33 ha soybean, 76 ha lupine, 228 ha field bean and 231 peas (De Rooij, 2013). In 2014 the acreage for soybean and lupine increased slightly to 102 and 110 ha (Boerderij, 2014). In 2015 acreage of soybean increased further to 180 ha. However, due to bad weather conditions resulting in a low production and quality of the harvested grain, the acreage fell to 100 ha in 2016.

In the Netherlands the former Productschap Akkerbouw (Arable Production Board) subsidized an experiment in 2011 and 2012 to test the cultivation and production of seven protein crops on experimental farms Vredepeel (Vredepeel, Limburg) and 't Kompas (Valthermond, Drenthe). The low production, late ripening, susceptibility to night frost in spring and limited possibilities for chemical weed control were the weaker points of soybean. The protein content and quality of the proteins, however, were high (Van der Mheen and Timmer, 2013). Breeding for cultivars with a short growing season in order to ripen on time will be one of the most important issues to make the cultivation more attractive to farmers (Van Krimpen *et al.*, 2013). Agrifirm has initiated in 2013 a farm network project with 11 arable farmers to grow soybeans (Heselmans, 2013).

Recently, also in other western European countries experiments with soybean cultivation have started, for instance by the Flemish research institute ILVO in 2012 (ILVO, 2012). The Landwirtschaftskammer Nordrhein-Westfalen published a leaflet with information for soybean cultivation on organic farms, including a comparison of 12 cultivars from different origin (Landwirtschaftskammer Nordrhein-Westfalen, 2011).

Slow spring development and susceptibility to night frost are still a problem. When spring is cold and dry, the development will be slow and extra weed control is needed (Timmer *et al.*, 2015). When the weeds are well controlled in spring, the crop will remain almost clean until at the end of the season. *Sclerotinia sclerotiorum* (a plant pathogenic fungus which can cause a disease called white mould) can affect a wide range of hosts and spread quickly in the field from plant to plant. It is quite common that soybean is affected by *Sclerotinia*. The risks for following crops are not yet clear. The development of possible diseases and pests has to be monitored and evaluated for West-European temperate conditions. Also extra research is needed to know more about the host plant suitability of soybean for a number of important plant-parasitic nematode species. Timmer *et al.* (2015) have done some preliminary research for three for agriculture important nematode species: the root-knot nematode (*Meloidogyne chitwoodi*), the Northern root-knot nematode (*Meloidogyne hapla*) and the root-lesion nematode (*Pratylenchus penetrans*). If the status of soybean as a host for the main plant-parasitic nematode species is known, better choices can to be made for crop rotations that limit the risk of damage in other crops by plant-parasitic nematodes.

Besides the global Round Table on Responsible Soy (RTRS) initiative, several national initiatives like the Initiatief voor Duurzame Handel (IDH, Initiative for Sustainable Trade) and Stichting Initiatief Duurzame Soja (IDS, Sustainable Soy Initiative Foundation) aim to support the transition to the utilization of only responsible soybean in the Netherlands (CBS, 2013).

Although there is a widely concern in the Dutch society on soybean imported from North and South America, there are not yet alternative protein crops which could compete with the profit of common crops such as winter wheat and spring barley. The productivity of the adapted soybean cultivars is too low to become attractive for Dutch farmers, even when they could produce higher value GMO-free soybean.

4 Soybean as a nitrogen-fixing crop in ecological focus areas

In EU-Regulation 1307/2013 regarding establishing rules for direct payments to farmers under support schemes of the CAP, a member state could decide that the cultivation of nitrogen-fixing crops will be counting for the 5% ecological focus area on arable farms. The Dutch government has decided to designate already a number of nitrogen-fixing crops that may be cultivated in ecological focus areas: alfalfa, esparcette, red clover, birdsfoot trefoil, lupine, vetch and field bean. This is a rather small list compared to the German list (BMEL, 2015).

Adding soybean to this list of designated nitrogen-fixing crops will offer farmers an alternative crop which does not directly has to compete with common crops such as wheat and barley. It could be cultivated on the 5% ecological focus area and when farmers are growing it in cooperation with colleagues in the neighbourhood, they can produce considerable amounts, which makes harvest and processing of the soybean more attractive for companies to invest in a regional soybean chain. The goal could be to produce soybean for human consumption, but when weather conditions, weeds or diseases cause a lower product quality, the soy meal could be used for animal feed.

Adding soybean to the list of designated nitrogen-fixing crops, could give the cultivation of soybean a boost. Without this option we expect that growing soybean will be unattractive for Dutch farmers.

5 Does soybean fit in the ecological focus area concept?

In previous evaluation (Den Belder *et al.*, 2014) soybean was considered being not as attractive for ecological focus areas as some of the other nitrogen-fixing crops, although the differences between soybean and field bean were rather small. Why should it fit a few years later in the ecological focus area concept?

1. The previous evaluation was focussing predominately on biodiversity and environmental aspects. A small monitoring in July 2015 by Frans van Alebeek (personal communication, 2015) on a demonstration field of Agrifirm with different crops and cultivars at experimental farm Valthermond showed that soybean was attracting a variety of pollinating insects, but less then lupine and field bean. However, it is expected that soybean is flowering over a longer period, so attracting pollinators when other crops have already finished their flowering. Another observation is that young soybean plants seem very tasty for birds and mammals (like hare, rabbits and roe deer) causing sometimes severe crop damage. These observations have not yet been studied scientifically.

2. New field experiments (Timmer & De Visser, 2014a) showed that the grain yield of 3,800 kg/ha (grown with Rhizobium inoculation, but without N fertilisation) decreased when N fertilisation was applied in spring. N application reduced the number of Rhizobium nodules and reduced the stiffness of the crop during flowering and seed filling, causing (severe) lodging of the crop. This is likely to have had a significant negative effect on the yield, because of a lower photosynthetic efficiency of the crop. Also in two other trials (Vredepeel and Rolde) the yield did not increase via N application at the start of the season. Besides that, a higher N application also caused a delay in ripening of the grain. The effect of Rhizobium seed inoculation on the yield was large. Without treatment of the seed the grain yields was more than 2,200 kg/ha lower than with a Rhizobium inoculation.
   The conclusion might be that soybean can grow best without any N fertilisation. The N-fixating ability of soybean means that it facilitates crop production without N-fertilisation which contributes to a lower need of fossil energy for fertilizer production and the roots of soybean provides N-input for the succeeding crop. Soybean cultivation, like the cultivation of other leguminous (protein crops), could fit in organic farming and in ecological sensitive areas.

3. Currently the production of soybean is low (2.5 - 3 tonnes grain per ha) under the average weather conditions in the Netherlands. It was expected that soybean needs at least 180 warm and sunny days during the growing season (Den Belder *et al.*, 2014). Recent field trials in Rolde, Nieuw Beerta and Vredepeel have shown that for cultivation in the Netherlands several (new) varieties could be interesting to replace Adsoy, which is the most common used cultivar in the Netherlands at the moment. With these new varieties the production could increase by 20-25%. However, the results between years and locations differ, so it is not yet clear which varieties are the most promising (Timmer & De Visser, 2014b; 2014c; Timmer *et al.*, 2015). This may lead to the conclusion that these new varieties offer good opportunities to harvest soybean yields of 3.5 - 4 tonnes/ha in next years at Dutch farms. To get information on the best varieties, continuation of breeding and variety testing programmes is essential. Growing new soybean varieties on ecological focus areas could also enlarge the experience of Dutch farmers with soybean cultivation.

4. One of the goals of the EU payment for agricultural practices beneficial for the climate and the environment is crop diversification. Stimulating the cultivation of protein crops such as soybean supports that policy and increases the possibilities on farms for crop rotation. When productive soybean varieties become available for NW-European conditions, soybean could act

as a break crop in the mono culture of maize on fields apart from the farm buildings on dairy farms in the Netherlands (and Flanders).

5. GMO-free soybean production and regionally produced protein rich feed are strong points for soybean. The market demand for GM-free soy is growing rapidly (Van Krimpen *et al.*, 2013; CBS, 2013; Heselmans, 2013; ABN-AMRO, 2015), for human consumption as well as for animal feed. In Chapter 2 is already explained that there is hardly any GMO-free soy meal available at the world market. There is a public concern, however, for GM products in Europe, resulting in a growing market for protein grown under guaranteed GMO-free conditions.

6. Based on new information mentioned above, the previous evaluation of soybean by Den Belder at al. (2014) - see Annex 1 - could be reconsidered (Table 1), resulting in a higher score of soybean for flower visiting insects in Scenario 1, 2 and 3 and for birds and small mammals in Scenario 2 and 3. This brings the score for soybean at the same level as field bean. Adding to this the other arguments like GMO-free soy production, then it would be reasonable to treat soybean in the same way as field bean and lupine. Therefore the advice is to put soybean at the Dutch list of designated protein crops which may be used in Ecological Focus Areas.

Table 1A. Results of revised evaluation of soybean compared to evaluation of winter wheat, field bean and lupine by Den Belder et al., 2014. Scenario 1: no plant protection products (PPP) and no fertilisation (FER); Scenario 2: with PPP, no FER; Scenario 3: with PPP and with FER.

	Scenario 1: no PPP, no FER							**Scenario 2: with PPP, no FER**	**Scenario 3: with PPP, with FER**
	Diversity herbs	Diversity flower visitors	Birds, amall mammals	Emission restriction soil-water	Mitigation climate	Landscape and historic-cultural	Total A-F	Total A-F	Total A-F
	A	**B**	**C**	**D**	**E**	**F**			
Winter wheat	2	2	3	4	3	3	17	13	12
Soybean	3	3	3	3	3	3	18	16	16
Field bean	3	3	3	3	3	3	18	16	16
Lupine	3	3	3	3	3	4	19	17	17

Table 1B. Results of revised evaluation of soybean compared to evaluation of winter wheat, field bean and lupine by Den Belder et al., 2014. Scenario 2: with plant protection products (PPP), but no fertilisation (FER) and Scenario 3: with PPP and with FER.

	Scenario 2: with PPP, no FER							**Scenario 3: with PPP, with FER**						
	Diversity herbs	Diversity flower visitors	Birds, amall mammals	Emission restriction soil-water	Mitigation climate	Landscape and historic-cultural	Total A-F	Diversity herbs	Diversity flower visitors	Birds, amall mammals	Emission restriction soil-water	Mitigation climate	Landscape and historic- cultural	Total A-F
	A	**B**	**C**	**D**	**E**	**F**		**A**	**B**	**C**	**D**	**E**	**F**	
Winter wheat	1	1	3	2	3	3	13	1	1	3	2	2	3	12
Soybean	2	3	3	2	3	3	16	2	3	3	2	3	3	16
Field bean	2	3	3	2	3	3	16	2	3	3	2	3	3	16
Lupine	2	3	3	2	3	4	17	2	3	3	2	3	4	17

6 Consequences of adding soybean to the list of nitrogen-fixing crops that may be used in ecological focus areas

Soybean could offer farmers an extra opportunity to fill in ecological focus areas on their farm with nitrogen fixing crops. Its grain fits in a development towards more regionally (= European) produced protein crops for human consumption and animal feed. From a financial perspective soybean cultivation is at present not attractive to farmers. When soybean is accepted for ecological focus areas, it will not compete with the profit of potato, sugar beet, wheat or barley crops which are grown on the other 95% of the farm, but with the 'profit' of green manure, catch crops, set aside and landscape features. This means that it does not disturb market conditions, but promotes biodiversity and environmental goals.

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Annex 1 Summarizing table from evaluation by Den Belder *et al.*, 2014

Table S1.a. Results of the evaluation of crops in their contribution to greening as equivalent measure for EFA under three scenarios. Scenario 1: no plant protection products (PPP) and no fertilization (FER); Scenario 2: with PPP, no FER; Scenario 3: with PPP and with FER.

	Scenario 1: no PPP, no FER								Scenario 2: with PPP, no FER		Scenario 3: with PPP, with FER	
	Diversity beds[1]	Diversity flower visitors[1]	Birds, small mammals[1]	Emission/restriction soil water[1]	Irrigation climate[1]	Landscape and historico-cultural[1]	Total A-F	Contribution to greening[2]	Total A-F	Contribution to greening[2]	Total A-F	Contribution to greening[2]
	A	B	C	D	E	F						
Winter wheat	3	2	3	4	3	3	18		14		13	
Buckwheat	3	4	3	4	3	4	21	+	21	+	19	+
Soybean	3	2	3	3	3	3	17		14		14	
Oilseed rape (winter)	3	4	3	4	5	4	23	++	19	+	17	
Sunflower	3	4	3	4	5	4	23	++	20	+	18	
Oil flax	3	4	3	4	4	5	23	++	20	+	19	+
Peas	2	2	3	3	3	3	16		14		14	
Field beans	3	3	3	3	3	3	18		16		16	
Lupins	3	3	3	3	3	4	19	+	17		17	
Red clover	3	4	3	3	3	4	20	+	20	+	20	+
Vetch	3	3	3	3	3	3	18		18		18	
Bird's foot	3	4	3	3	4	4	21	+	21	+	21	+
Esparcette	3	4	3	3	4	4	21	+	21	+	21	+
Lucerne	3	4	4	3	3	4	21	+	21	+	21	+
Lentil	3	3	2	3	3	3	17		14		14	
Chick peas	3	3	2	3	3	3	17		14		14	
Brown beans/Marrowfat peas/Grey peas	3	3	2	3	3	3	17		14		14	
Sugar peas/Green peas	2	3	2	3	3	3	16		13		13	
French beans	2	3	2	3	3	3	16		13		12	
Fibre flax	2	4	3	4	4	5	22	++	19	+	17	
Hemp	2	2	3	4	4	3	18		18		17	
Stinging nettle	2	4	2	4	3	2	17		16		15	
Willow	2	4	3	5	5	3	22	++	21	+	21	+
Miscanthus	2	1	3	4	5	2	17		16		15	
Rotational fallow with spontaneous vegetation	4	4	4	4	3	3	22	++	22	++	22	++
Rotational fallow with green manure crop	3	4	3	4	3	3	20	+	20	+	20	+
Permanent fallow	5	5	5	4	3	5	27	+++	27	+++	27	+++

[1] *Criteria A - F: score 1 = small contribution; score 5 = high contribution; total score = total A - F*

[2] *Total score ≤18 = winter wheat = no contribution EFA; total score between 19-21 = some contribution EFA = +; total score between 22-24 = good contribution EFA = ++; total score between 25-27 = very good contribution EFA = +++*

Table S1.b. Results of the evaluation of crops in their contribution to greening as equivalent measure for EFA under three scenarios. Scenario 1: no plant protection products (PPP) and no fertilization (FER); Scenario 2: with PPP, no FER; Scenario 3: with PPP and FER.

	Scenario 2: with PPP, no FER								Scenario 3: with PPP, with FER							
	Diversity hosts[1]	Diversity flower visitors[1]	Birds, small mammals[1]	Emission reduction soil, water[1]	Mitigation climate[1]	Landscape and historic cultural[1]	Total A-F	Contribution to greening[2]	Diversity hosts[1]	Diversity flower visitors[1]	Birds, small mammals[1]	Emission reduction soil, water[1]	Mitigation climate[1]	Landscape and historico cultural[1]	Total A-F	Contribution to greening[2]
	A	B	C	D	E	F			A	B	C	D	E	F		
Winter wheat	2	1	3	2	3	3	14		2	1	3	2	2	3	13	
Buckwheat	3	4	3	4	3	4	21	+	2	4	3	3	3	4	19	+
Soybean	2	2	2	2	3	3	14		2	2	2	2	3	3	14	
Oilseed rape (winter)	2	3	2	3	5	4	19	+	2	3	2	2	4	4	17	
Sunflower	1	3	3	4	5	4	20	+	1	3	3	3	4	4	18	
Oil flax	2	3	3	3	4	5	20	+	2	3	3	2	4	5	19	+
Peas	1	2	3	2	3	3	14		1	2	3	2	3	3	14	
Field beans	2	3	3	2	3	3	16		2	3	3	2	3	3	16	
Lupine	2	3	3	2	3	4	17		2	3	3	2	3	4	17	
Red clover	3	4	3	3	3	4	20	+	3	4	3	3	3	4	20	+
Vetch	3	3	3	3	3	3	18		3	3	3	3	3	3	18	
Bird's foot	3	4	3	3	4	4	21	+	3	4	3	3	4	4	21	+
Esparcette	3	4	3	3	4	4	21	+	3	4	3	3	4	4	21	+
Lucerne	3	4	4	3	3	4	21	+	3	4	4	3	3	4	21	+
Lentils	2	2	2	2	3	3	14		2	2	2	2	3	3	14	
Chick peas	2	2	2	2	3	3	14		2	2	2	2	3	3	14	
Brown beans/Marrow fat peas/Grey peas	2	2	2	2	3	3	14		2	2	2	2	3	3	14	
Sugar peas/Green peas	1	2	2	2	3	3	13		1	2	2	2	3	3	13	
French beans	1	2	2	2	3	3	13		1	2	2	2	2	3	12	
Fibre flax	2	3	2	3	4	5	19	+	1	3	2	2	4	5	17	
Hemp	2	2	3	4	4	3	18		2	2	3	3	4	3	17	
Stinging nettle	2	3	2	4	3	2	16		2	3	2	3	3	2	15	
Willow	2	4	3	4	5	3	21	+	2	4	3	4	5	3	21	+
Miscanthus	2	1	3	3	5	2	16		2	1	3	3	4	2	15	
Rotational fallow with spontaneous vegetation	4	4	4	4	3	3	22	++	4	4	4	4	3	3	22	++
Rotational fallow with green manure crop	3	4	3	4	3	3	20	+	3	4	3	4	3	3	20	+
Permanent fallow	5	5	5	4	3	5	27	+++	5	5	5	4	3	5	27	+++

[1] *Criteria A - F: score 1 = low contribution; score 3 = high contribution; total score = total A - F*

[2] *Total score ≤18 = winter wheat = no contribution EFA; total score between 19-21 = some contribution EFA = +; total score between 22-24 = good contribution EFA = ++; total score between 25-27 = very good contribution EFA = +++*

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Plant researchers of Wageningen UR aim to utilise plant properties to help solve issues concerning food, raw materials and energy. They are devoting their knowledge of plants and their up-to-date facilities to increasing the innovative capacity of our clients. In doing so, they work on improving the quality of life.

The mission of Wageningen UR (University & Research centre) is 'To explore the potential of nature to improve the quality of life'. Within Wageningen UR, nine specialised research institutes of the DLO Foundation have joined forces with Wageningen University to help answer the most important questions in the domain of healthy food and living environment. With approximately 30 locations, 6,000 members of staff and 10,000 students, Wageningen UR is one of the leading organisations in its domain worldwide. The integral approach to problems and the cooperation between the various disciplines are at the heart of the unique Wageningen Approach.