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# Taifun Soy Info

Specialist information for soy producers and processors

Source: Taifun-Tofu GmbH

# Ecological aspects of soybean cultivation in Germany

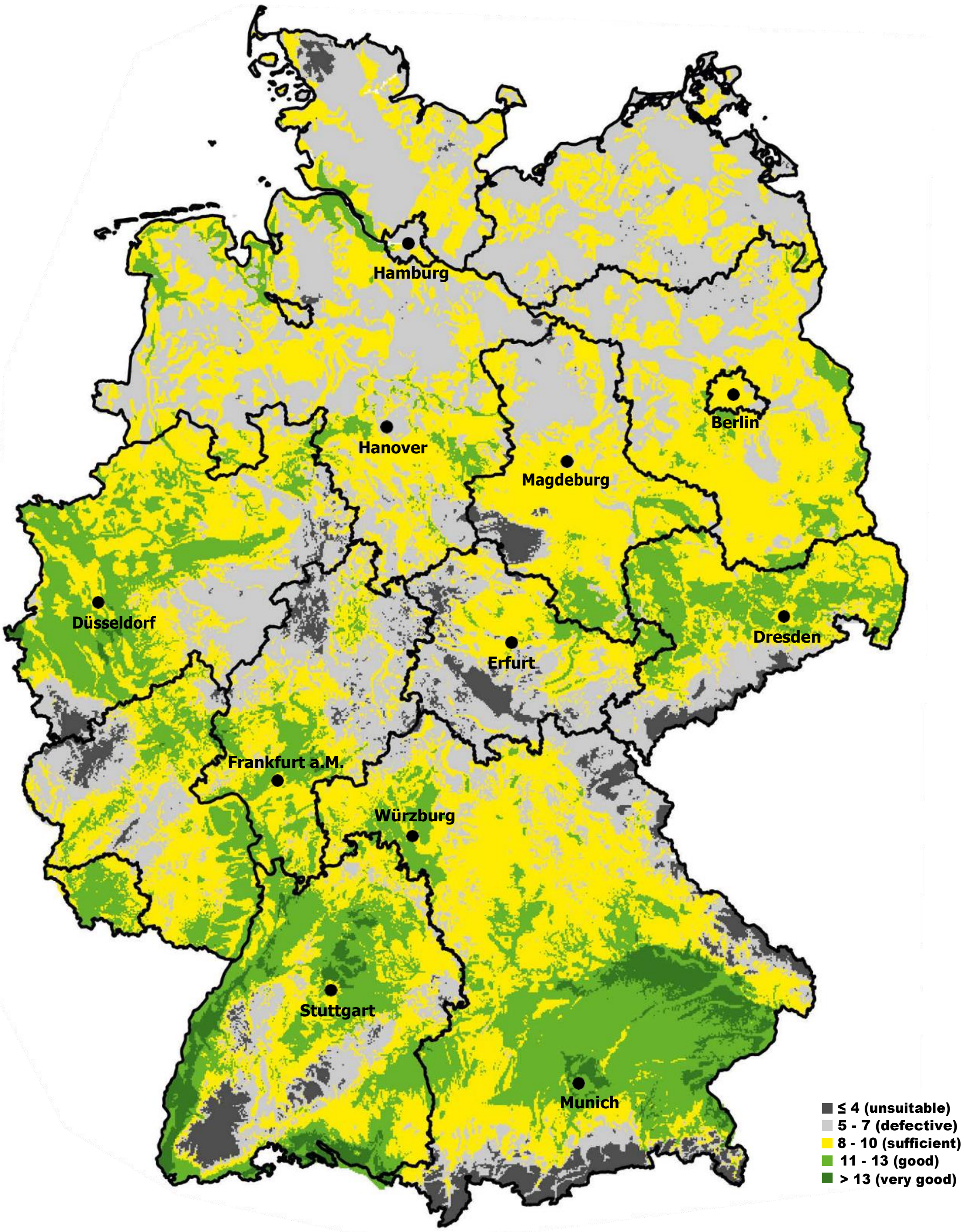
## 1. Introduction

The area under soybean cultivation in Germany has grown continuously since 2008 from 700 ha to over 32,900 ha in 2020. The biggest part of this area is found in Bavaria and Baden-Wuerttemberg (26,700 ha) with the rest in the other federal states (several hundred ha each). Only in the city states no soybean is cultivated. Soybean has been the most important grain legume in Baden-Wuerttemberg since 2018 and since 2019 also in Bavaria. In 2020, 4,190 farmers cultivated soybeans with an average cultivation area of 7.9 ha in Germany.

Despite increasing areas under cultivation, most of the soybeans used in Germany are still imported. German cultivation covers only about 1% of the demand. Current calculations show that many areas in Germany would be suitable for the cultivation of soybeans (Fig. 1). An extrapolation of the potential soybean cultivation in Germany, assuming realistic yields and a well tolerable soybean share in the crop rotation, shows that from a purely agronomical point of view, more than 2 million metric tons of soy could already be cultivated in Germany today (Table 1). This is currently offset by approx. 5 million tonnes of imported soy.

For many consumers, soybean is considered a dubious crop. A plant that is genetically modified and imported from overseas, where it is cultivated under ecologically and socially questionable conditions with a high use of pesticides. It is easily overlooked that soy cultivation in Germany offers several ecological advantages.

On the other hand, with growing soybean acreage in Germany, there is a risk that in particular regions soybeans will be cultivated with a too high share in the crop rotation, that crop rotation diseases will occur and that the use of pesticides will increase. Cultivation on erosion-prone slopes or excessive irrigation can also lead to negative environmental effects.




**Suitability for soybean cultivation calculated based on accumulated temperature according to CHU from 01.05. - 15.09., accumulated precipitation from 01.06. - 31.08., soil values and global radiation from 01.06. - 30.09.**

Source: Roßberg D., Recknagel J. (2017): : Untersuchungen zur Anbaueignung von Sojabohnen in Deutschland. JOURNAL FÜR KULTURPFLANZEN, 69 (4). S. 137–145

Figure 1: Cultivation suitability for soybeans considering accumulated temperature, summer precipitation, soil conditions and global radiation. Source: JKI.

Table 1: Calculation of the cultivation potential for soybeans in Germany. Source: www.sojafoerderring.de

| Suitability for cultivation Soy (1) | Total acreage(2) | Share of soy(3) | Soy acreage | Average yield (4) | Soy quantity |
|---|---|---|---|---|---|
| > 13 (very good) | 343,020 ha | 20% | 68,604 ha | 3,2 t/ha | 219.533 t |
| 11 - 13 (good) | 2,788,623 ha | 15% | 418,293 ha | 2,7 t/ha | 1.129.392 t |
| 8 - 10 (sufficient) | 5,999,251 ha | 5% | 299,963 ha | 2,5 t/ha | 749.906 t |
| **Total** | | | **786,860 ha** | | **2.098.831 t** |

(1 ) According to map JKI. Roßberg, Recknagel 2017 (2) ATKIS data 2013, transmitted by Neukampf/Roßberg, JKI on 28.10.16 (3) Assumption of the author (4) Average numbers

# 2. The great opportunity: promoting soil fertility

## a) Nitrogen fixation

As a legume, soy can fix atmospheric nitrogen through a symbiosis with rhizobia. The proportion of nitrogen that the soybean plant itself can fix and the amount of nitrogen remaining in the soil after harvest depends on many factors such as the availability of water and nitrogen in the soil. After reviewing 637 scientific data sets on the N2 fixation of soy, Salvagiotti et al. (2008) found that under conventional cultivation an average of 50-60% of the N requirement is provided through biological N fixation (i.e. from the air). However, only the easily measurable nitrogen fixed in the above-ground plant biomass was included in this approach (partial nitrogen balance). Due to the high measurement effort, there are only few studies on the nitrogen fixed in the root biomass and rhizosphere.

Salvagiotti et al. estimate that for soybeans the amount of underground nitrogen is about 24% of the total nitrogen. If this proportion is included, 50% of the data sets still had a negative nitrogen balance. The average balance was -4 kg N per hectare and thus almost balanced. The estimated values varied greatly depending on environmental conditions and ranged from -38 to +41 kg nitrogen per hectare. The most negative balances were measured mainly in stands with very high yields (over 45 dt per hectare) (Salvagiotti et al., 2008). With lower yields, the balance was increasingly positive.

The proportion of biologically fixed nitrogen can vary greatly and depends on several factors. For example a good water availability and low nitrogen contents in the soil (especially low nitrate contents), as well as a good availability of symbiotic rhizobia for nitrogen fixation (either by seed inoculation or by presence in the soil on long-standing soybean sites) and a good supply with other nutrients favour biological nitrogen fixation. Salvagiotti et al. (2008) found the maximum level of biological nitrogen fixation of soy at 377 kg N per hectare.

Paeßens et al (2019) determined in a trial with two varieties (Merlin and ES Mentor) at two organic farms in **southern Germany** a three-year average N uptake from the N2 fixation of 83%. **The average N2 fixation was 217 kg/ha with an average yield of 41.6 dt/ha. On average a specific N2 fixation of 5.3 kg N/dt yield was achieved. The average N balance was -42 kg/ha.**

## b) Enrichment and diversification of crop rotations

Legumes are generally well suited to lengthening the crop rotations. In organic farming legumes also play a central role in nitrogen supply.

However, traditional grain legumes such as field beans or peas are susceptible to diseases and pests. Soils on which the yields of traditional grain legumes decrease over the years show "legume fatigue". A cultivation interval of up to seven years must be maintained in order to contain the so-called crop rotation diseases. Soy does not show this phenomenon and could therefore contribute to an enrichment of crop rotations without having to forgo on the supply of nitrogen by a legume. In experiments where soybeans were grown on soils where peas and field beans did not develop well, soybeans were found to show increasing yields and remained free of disease (Urbatzka et al., 2015).

However, positive aspects of soy cultivation are lost if soy is cultivated too often and in too narrow crop rotations. Experiments in which clover grass was completely replaced by soy in the crop rotation showed that soy reduced the organic carbon content (an important indicator of humus content and soil health), whereas it increased in crop rotation with clover grass (Castell et al., 2017). In addition, soil nitrogen levels (an indicator of soil fertility) in crop rotation remained consistent with soy, whereas they increased with clover grass.

## c) Promotion of earthworms

Earthworms make important contributions to soil fertility: their channels have a positive influence on aeration and water infiltration. Earthworms decompose litter and thus provide nutrients to other soil organisms and plants. Therefore, the number and biomass of earthworms are important indicators for a healthy soil.

Earthworms are favoured above all by careful tillage with little ploughing (Castell et al., 2017; Ehrmann, 2016; Hubbard et al., 1999), by sufficient food availability in the form of litter, and by a preferably constant soil climate with sufficient humidity (Tian et al., 1997). This is favoured by a sufficient year-round covering of the soil with plants or plant residues. Especially with regard to climate change and more frequent extreme weather events, the promotion of earthworms in arable land makes sense. Their channels are main infiltration routes for water into the soil and thus prevent surface erosion and capping. They also ensure better aeration of the deeper soil layers, allowing plants to grow deeper roots and making them less susceptible to water stress in dry periods (Ehrmann, 2016).

Soy experts observe that after soy many earthworms are found in the soil and that the soil is well loosened. Due to the falloff of nutrient-rich leaves in September and the fact that the litter remains on the field after harvest in October, soy introduces a lot of plant material that can be used by earthworms. In addition, soy litter is very rich in nutrients and above all in nitrogen and therefore quickly usable for earthworms (Tian et al., 1993). Due to the good soil condition after soy, the plough can often be omitted and the subsequent crop can directly be sown, which in turn is positive for the earthworm population.

## d) Preciding crop effect

In the case of soy, the preceding crop effect is mainly due to the provision of nitrogen for subsequent crops, but also due to the good soil structure and nutrient-rich litter as food for soil organisms. The effect can be estimated by the nitrogen balance of the soybean plants on the one hand, and on the other hand by the growth of the subsequent crops in comparison to other preceding crops.

In Germany, grain legumes only play a very small part in crop rotation. Cereals, rapeseed, maize and sugar beet dominate conventional agriculture (Federal Statistical Office, 2020). In crop rotations without legumes, the nitrogen demand must be covered exclusively by the use of fertilizers. If legumes are integrated into crop rotation, the use of fertilizers can be reduced.

In an experiment in which the preceding crop effect of different grain legumes (such as soy, pea, field bean or blue lupin) for winter wheat was tested, it was shown that for wheat, soy has a comparable preceding crop effect to other grain legumes (Zimmer et al., 2015).

In a trial comparing the preceding crop effect of soy and clover grass for winter wheat and, in the second year, summer barley, it was shown that important quality characteristics of wheat were better with clover grass as the preceding crop than with soy as the preceding crop (Castell et al., 2017).

The preceding crop effect of soy therefore takes an intermediate position. It is higher than that of non-legumes, comparable to that of other grain legumes, but lower than that of fodder legumes such as clover grass.

# 3. Risk of nitrate dislocation?

A possible danger in the cultivation of legumes is the leaching of nitrogen into the groundwater in the form of water-soluble nitrate after harvest. This is favoured by heavy precipitation and soils with low field capacity (e.g. sandy soils).

Investigations in water protection areas in Baden-Wuerttemberg from 2009 to 2017 show that the pre-winter Nmin content after soybeans is on average 34 kg N/ha (Fig. 2). The values range between 23 and 40 kg/N ha (Finck, LTZ Augustenberg, 2018, unpublished). Compared with other grain legumes such as field beans (53 kg N/ha) and peas (56 kg N/ha), soybeans show significantly lower pre-winter Nmin contents (Table 2).

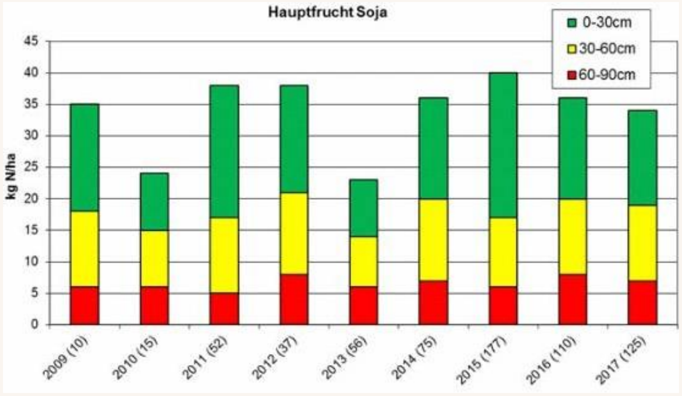



Fig. 2: Autumn nitrate contents (15.10. - 15.11.) after soybeans in water protection areas in Baden-Wuerttemberg from 2009 to 2017. In brackets: Number of sampled areas. Source: Finck, LTZ, 2018, unpublished

Table 2: Autumn nitrate N contents after legumes. Source: LTZ, SchALVO data 2001-2014, mean values for soil profile 0-90 cm.

| Crop | Autumn nitrate content kg N/ha |
|---|---|
| Grassland | 16 |
| Clover grass | 20 |
| Soybeans | 34 |
| Lentils | 37 |
| Clover | 40 |
| Sweet lupines | 51 |
| Broad beans | 53 |
| Peas | 56 |

# 4. Risk Erosion

Erosion, i.e. the loss of fertile topsoil due to wind or water surface run-off, has always been a major problem in agriculture. Erosion generally occurs on unplanted or uncovered soil. Fields on slopes and in areas with heavy rainfall and a lot of surface runoff are particularly at risk of erosion. Crops with wide row spacing and frequent mechanical soil cultivation, like soy in organic farming, have an increased risk of erosion. In addition, soy is sown late and has a slow youth development. This means that the soil remains uncovered for a long time and the risk of erosion is high for a long time. The Bavarian State Institute for Agriculture recommends to avoid intensive mechanical weed control on areas with a slope gradient of more than 10%.

When cultivating soy, attention should be paid to erosion-reducing cultivation techniques, especially on areas that are highly vulnerable to erosion, such as on slopes. Measures to reduce erosion, like e.g. mulch seeding, should be taken.

However, mulch seeding is not yet successfully practised in Germany. In addition, after harvest of the preceding crop, it makes sense to establish a catch crop that covers the soil until soy seeding. In a survey, 75% of the Austrian and 30% of the Bavarian organic farmers stated that they cultivate a catch crop before soy (Jobst et al., 2014).

On slopes, work should be carried out parallel to the slope. In addition, the creation of structures such as hedges or paths parallel to the slope (Edelmann, 2010) and the reorganisation of the field helps.

Conservation soil tillage has a particularly positive effect on soil structure, which has been shown to reduce erosion. It involves less, shallower or no ploughing and further reduces the use of machinery wherever possible. In trials comparing farming systems (normal ploughing as opposed to reduced ploughing and no ploughing), it was found that the less the soil was tilled, the less topsoil was eroded by artificial irrigation (Ehrmann, 2016).

Another approach is the so-called strip tillage, where not the whole field is tilled, but only strips where the seed is placed. This method has already been used successfully in maize and rape cultivation (Edelmann, 2010).

A special cultivation method is the so-called mulch seeding. Here soy is sown into a rolled, hardy catch crop without prior tillage. The theoretical advantages are good weed control as the soil is covered the whole time, good erosion control and positive effects on soil health due to reduced tillage. Experiments have shown the ecological benefits, but yields have been so low that the method cannot be recommended (Urbatzka et al., 2017).

# 5. Risk of humus decomposition

In a survey of Austrian and Bavarian organic farmers with soybean cultivation, 25% stated that they prepared the soil for soybean sowing without ploughing (Jobst et al., 2014). Conservation soil tillage methods have thus already been introduced into the practice of soybean cultivation.

In contrast, the frequent hoeing and harrowing to regulate weeds in organic soybean cultivation must be viewed critically from the perspective of humus conservation.

Especially the humus content, the number of coarse pores (important for good soil aeration, rooting and water infiltration), as well as the number of soil organisms increased with decreasing working depth in a trial in Saxony (Nitzsche et al., 2002). In a long-term experiment between different cultivation systems it was found that especially intensive tillage has a negative effect on the carbon supply in the soil. Biomass input had a positive effect on soil carbon stocks. The different cultivation systems and biodiversity were only secondary factors for soil carbon stocks (Cates et al., 2016).

A comparison of the greenhouse gas balance and carbon sequestration of 10 organic and 10 conventional Bavarian farms showed that two organic farms with a high proportion of legumes in their crop rotation achieved the highest C sequestration (Schmid et al., 2012). This is mainly due to the build-up of humus in the soil through the input of carbon-rich root mass. As a legume, soy also has the potential to contribute to a high C-sequestration in the soil.

## 6. Potential: Nurse-crops in soy

One approach to increase the preceding crop effect of soy is to sow nurse-crops, i.e. catch crops that are sown before the soy harvest and only really establish after the harvest (von Beesten, 2015). The advantage over a subsequent crop such as winter wheat is that these plants have longer time to establish and can therefore absorb more of the available nitrogen and retain it for the subsequent crop. There are two possibilities to establish the nurse-crops: Very small nurse-crops, which grow like grass, could be sown with the last mechanical weed control and, with sufficient water availability, would have time to establish until the soybean harvest in October. The other possibility is to sow nurse-crops before the soybean grains are mature, i.e. from the end of August. The seed of the nurse-crop is then covered by the falling soybean leaves and, if sufficient water is available, can germinate and establish until harvesting at the end of September to mid-October. In mild regions such as the Upper Rhine, the nurse-crop can establish until winter to absorb the nitrogen fixed in the soil by the soybean stand. In spring, a subsequent crop with a high nitrogen requirement can be sown. How well these methods work and how much more nitrogen can be made available for subsequent crops in comparison to an immediate sowing still need to be researched.

## 7. Risk: Excessive water consumption for irrigation

Soy has a high water requirement during flowering and especially at the time of pod filling. On many sites, irrigation can therefore be profitable and lead to significantly higher yields (cf. Butz, 2016). Calculations of the suitability of soybean cultivation in Germany, which also consider summer precipitation in the critical phase, show areas that are well suited for soybean cultivation (cf. Fig. 1). In the Upper Rhine, a region in which a lot of soy is cultivated, both the mean summer precipitation with approx. 230 mm to over 265 mm (JKI, 2018) and the groundwater recharge rate with approx. 200-400 mm per year (Jankiewicz et al., 2005) are high in a Germany-wide comparison. The Upper Rhine is therefore well suited for soybean cultivation, since the high groundwater recharge rate makes possibly needed irrigation ecologically justifiable. In Eastern Germany, many areas in Saxony, Brandenburg and Saxony-Anhalt are also well suited for soybean cultivation due to high summer temperatures. However, both the summer precipitation with partly less than 180 mm to 205 mm (JKI, 2018) and the groundwater recharge rate with partly less than 50 mm to 150 mm per year (Jankiewicz et al., 2005) are significantly lower than in the Upper Rhine. Here, large-scale soybean cultivation with irrigation should be regarded more critical due to the low availability of water.

Due to climate change it can be assumed that precipitation will shift from summer to winter in Germany. Less precipitation and a lower groundwater recharge are expected (Gudera, 2014).

The cultivation of drought-tolerant soy varieties and water-efficient irrigation methods are therefore important measures for a sustainable development of soybean cultivation in Germany. Drought resistance is already a breeding goal in order to counteract the possible increase in summer drought. For example, attempts are being made to interbreed soy genotypes whose rhizobia fix nitrogen even under drought stress in varieties for the cultivation in Central Europe (Hahn, 2018).

# 8. Outlook

A significant increase in soybean cultivation in Germany could contribute to a reduction in emissions from shipping. However, corresponding research is not available.

More soybean cultivation in Germany in conjunction with area-based livestock farming could be an important element in water protection, the implementation of the EU Nitrate Directive and the path to sustainable agriculture. However, the facts are as well-known as the resistance is great.

**The advantages of soybean cultivation in Germany**

- GMO-free - not treated with glyphosate
- No deforestation of rainforest
- Reduces import dependency
- Sustainable production under strict German environmental regulations and social standards
- Enriches crop rotations, revitalizes the soil, can solve crop rotation problems
- Can fix atmospheric nitrogen and saves fertiliser
- Particularly valuable grain legume with a high content of essential amino acids for the nutrition of humans and livestock
- Cultivation is sensible and profitable for many farmers in different regions of Germany

**Tips for sustainable soybean cultivation**

1. Select the appropriate proportion of soy in the crop rotation. Do not exceed one quarter to one third.
2. Choose a good position in the crop rotation: As a N-fixing crop it should precede a N-consuming one
3. Use N2 fixation: Do not grow soy before or after other legumes or on soils with high Nmin contents.
4. Inoculate seeds to maximize N2 fixation .
5. Avoid nitrate leaching after soy. Use catch crops and nurse-crops if climatic conditions allow it. No ploughing for subsequent winter cereals .
6. Avoid water erosion. Avoid slopes > 10%! Apply mulch sowing and reduced tillage on areas at risk of erosion.
7. Promote earthworms: No ploughing after soy.
8. Do not waste water. Use water-efficient irrigation methods.

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