CO-EXISTENCE COSTS UNDER GERMAN REGULATION – CASE STUDIES OF BT MAIZE

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Co-existence Costs under German Regulation –Case Studies of Bt maize

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Introduction

Co-existence relates to the economic consequences of adventitious presence of material from one crop in another and the principle that farmers should be able to cultivate freely the agricultural crops they choose, be it GM crops, conventional or organic crops (European Commission, 2003a, b). Labelling has been recommended as a tool to enable farmers' and consumers' choice between products and to avoid further market and trade disruptions. This requires Identity Preservation systems, which imply additional costs at all stages of the food and feed chain. Critical factors to determine these costs – among others – are the tolerance level for GM contamination influenced from factors such as agricultural production systems and structures which differ significantly between EU member countries and regions. The European Commission recommended in their guidelines measures which guarantee compliance with the thresholds. One of the most important and effective measure is to isolate fields which are cultivated with genetically modified organisms (GMOs) from fields with conventional varieties of the same crop by implementing buffer zones of a certain width between the respective fields.

This paper contributes analysis of digitalized maps in order to quantify potential conflicts arising through this kind of co-existence measure. Estimations have been made for production systems whether they are GM or non-GM producers. Results are presented for two model regions situated in Southern Germany which are characterized by small-scaled fields. In both model regions a fictive and randomized cultivation of Bt maize has been considered within three scenarios with differing adoption rates of Bt maize: In a first phase an adoption rate of 10% was considered for this new technology which was raised to adoption rates of 30% and 50%[1] in the two other scenarios. All Bt maize farmers

[1] The differing adoption rates are based on the number of farmers which decide to grow Bt maize. In case a farmer is cultivating Bt maize it is assumed that all maize fields of the farm are grown with a Bt variety.

have been selected randomly through a statistical algorithm. Illustrations and calculations have been done by using geographical information system software.

Data

Data sources of this analysis have been digitized maps and official data from the federal Ministry of Agriculture which includes information about field size, cultivation on the fields and user of fields.

Model region

The analysis has been done in two model regions which have agricultural area in use (AAU) between 30,800 ha in model region I and nearly 50,000 ha in model region II (Table 1). Agricultural crop land (ACL) is between 20,000 and 30,000 ha with high shares of maize in model region I (44% of ACL) and low maize cultivation in model region II (19% of ACL). Average field sizes are between 1.89 ha and 2.17 ha in both model regions which characterizes the typical small-scaled landscape of Southern Germany which can be regarded as a particular challenge to ensure co-existence between differing production systems.

Table 1: Characteristics of the analysed model regions

Model region	AAU	ACL	Maize share [1)]	Permanent crops and pasture land	Average field size
	ha	ha	%	%	ha
I	30,812	20,900	44	32	2.17
II	47,572	31,511	19	34	1.89

AAU: Agricultural area in use
ACL: Agricultural crop land
[1)] Relation of agricultural area cultivated with maize to ACL in total

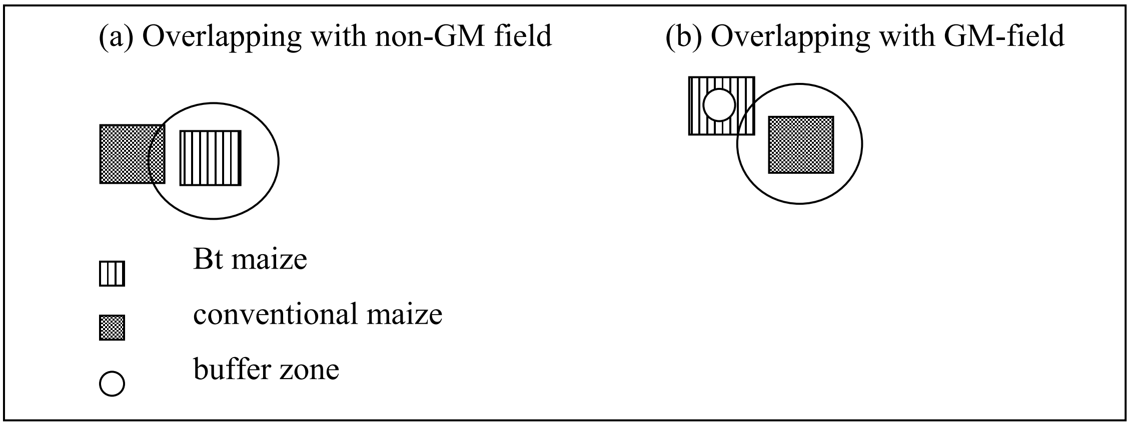
Source: Own investigation

Approach

Within this paper two main questions will be analysed:

- Which amount of conventional fields would be affected by isolating Bt maize fields. This analysis answers the question of how many potential conflicts can arise in regions through side by side positioned maize fields which are cultivated with GM and non-GM varieties (figure 1a).
- How many Bt maize fields fulfil the condition of being isolated from conventional maize fields. Which proportion of Bt maize fields are forced to implement buffer zones around their fields in order to comply with recommended thresholds? This analysis answers the question of a maximum Bt maize production in a specific region using buffer zones as recommended co-existence measure (figure 1b).

Figure 1: Approach of regional analysis by using GIS-software ArcView



The discussion concerning the width of the isolation distance between Bt maize and conventional maize fields in order to comply with the legal threshold of 0,9% of adventitious presence of GMOs is still running in Germany since Germany has not yet implemented national regulations for this issue including Good Farming Practices (GFP). Therefore a variety of buffers zones around Bt maize fields are considered ranging from 20 m to 100 m as indicated in table 2.

A buffer zone of 20 m is in line with the results of the German field trial experiments (so-called “Erprobungsanbau”) where out-crossing rates of Bt maize were analysed under German conditions in 2005. According to this experiences a isolation distance of 20 m is sufficient in maize to comply with the threshold of 0.9% GM adventitious presence (Weber, W. E., T. Bringezu, et al. (2005a,b).

Table 2: Model assumptions and scenarios

<table>
<tr><th rowspan="2">Model region</th><th>Bt maize adoption</th><th>Isolation distance</th></tr>
<tr><td>%</td><td>m</td></tr>
<tr><td>I</td><td rowspan="2">10
30
50</td><td rowspan="2">20
50
100</td></tr>
<tr><td>II</td></tr>
</table>

Analyses have been done with geographical information system software by buffering maize fields. Intersections were identifying due to a geographical processing instrument and special queries.

In our first approach Bt maize fields were randomly selected and buffered in order to identify those conventional maize fields which are positioned in a distance of 20, 50 or 100 m to Bt maize fields. Calculations of conventional maize fields which are influenced by buffer zones have been done using intersection tools and special queries (figure 1 a). In following those influenced conventional maize fields are called “affected” maize fields.

In our second approach we analysis conventional maize fields by buffering them in order to look how much Bt maize fields are in the neighbourhood of these conventional maize fields. Those ones which are closer than 20m, 50m or 100 m have to hold the respective distances on their adjacent Bt maize field and need a buffer zone (figure 1 b). Bt maize fields which are more than 20m, 50m or 100m away from conventional maize fields are “isolated” from conventional maize fields and need no buffer zone in order to comply with existing thresholds. In the following we call those fields “isolated” Bt maize fields. Summarizing isolated Bt maize and the remaining Bt maize on fields which needs buffer zone are called “non-conflict” Bt maize area”.

Results of simulation experiments

In the following the results of the simulation experiments are presented which give estimations of affected conventional maize area, fields and farms by the implementation of buffer zones around Bt maize fields (see figure 1 a) as well as on estimations of the non-conflict Bt maize cultivation area in a region by implementation of buffer zones around conventional maize fields (figure 1 b).

Affected conventional maize area and farms

Model region I represent an area with high importance of maize production which is documented by the fact that 44% of ACL is covered by this crop. As indicated in table 3 a relatively high number of fields and farms which grow conventional maize are affected by an increasing adoption of Bt maize. In order to give an impression on the absolute and relative dimension of the co-existence problem in a region, the cropping areas of Bt maize and conventional varieties are given in absolute numbers of the concerned area, fields and farms in the region. Furthermore it is indicated which percentage of the farms and fields which are cultivating conventional varieties are influenced by differing isolation distances of 20 m, 50 m or 100 m respectively around the Bt maize fields.

In an initial scenario with 10% Bt maize adoption in the region I, it can be observed that between 1% to 7% of the conventional maize area are affected by neighbouring Bt maize fields depending on the isolation distance required. With increasing adoption rates and long buffer zones the proportion of affected conventional maize area increases up to 31% (table 3). Due to the fact that Germany favours isolation distances of 20 m for maize according to the experiences gained in the German test field trials (“Erprobungsanbau”) (Weber, W. E., T. Bringezu, et al., (2005a,b)), a rather small proportion of the conventionally cultivated maize area would be affected by potential pollen flow of Bt maize varieties which would be around 1% for low adoption rates (10%) and raise up to 4% in a higher level of technology diffusion (50% adoption) (table 3).

With respect to potential conflicts among farmers growing Bt maize or conventional varieties in the same region, not only the area grown with specific varieties is a point of interest but also the percentages of farmers which are influenced by neighbouring Bt maize fields. The simulations in model region I indicate that already with a low adoption rate of 10% for Bt maize farmers, a substantial part of the farmers growing non-GM varieties (around 19% to 25%) might be influenced by cross pollination of neighbouring Bt maize fields. If adoption of Bt maize increases to 30% this figure raise to around half of the "conventional" farmers and to more than three quarters in case of 50% adoption rate of Bt maize (table 3) thus showing the great dimension of potential conflicts among farmers in case of unclear regulations of co-existence issues.

Table 3: Extent of affected conventional maize by Bt maize in model region I (with high proportion of maize in rotation)

Adoption rate (%)	Isolation distance (m)	Initial situation			Simulation of Bt maize cultivation						Results of simulations [1)]		
		Total maize area (ha)	Number of fields	Number of farms	Bt maize area (ha)	Number of fields	Number of farms	Conventional maize area (ha)	Number of fields	Number of farms	Affected conventional maize area (%)	Percentage of fields (%)	Percentage of farms (%)
10	20	9101	4224	869	851	394	87	8250	3830	782	1	10	19
	50										3	16	22
	100										7	24	25
30	20				2420	1211	261	6681	3013	608	3	31	47
	50										8	46	51
	100										20	71	57
50	20				3921	1755	435	5180	2469	434	4	46	64
	50										13	67	70
	100										31	100	77

[1)] Affected maize has been set in relation to conventional maize area, fields and farms in the appropriate scenarios

Source: Own investigation

Model region II is characterized by a relatively low relevance of maize cultivation with a share of 19% maize on total ACL (table 1). Comparing the results of model region II with those of model region I it can be observed that regions with low maize cultivation show lower affection rates with respect to conventional maize area, fields and farms. In model region II amplitudes of affection rates range for isolation distances of 20 m from 1% to 3% over all adoption levels, regarding the affected conventional maize area. In analogy to the results observed in model region I the percentage of influenced farms is substantially higher than those of affected area ranging from 13% (in case of 10% Bt adoption and 20 m isolation distance) to 66% (if we have a 50% Bt maize adoption rate and 100 m isolation distance) (table 4). This result again shows the high potential of conflicts concerning co-existence and liability issues even in production areas where maize does not play a dominant role.

Table 4: Extent of affected conventional maize by Bt maize in model region II (low proportion of maize in rotation)

Adoption rate (%)	Isolation distance (m)	Initial situation			Simulation of Bt maize cultivation						Results of simulations [1)]		
		Total maize area (ha)	Number of fields	Number of farms	Bt maize area (ha)	Number of fields	Number of farms	Conventional maize area (ha)	Number of fields	Number of farms	Affected conventional maize area (%)	Percentage of fields (%)	Percentage of farms (%)
10	20	6105	3083	936	530	279	94	5575	2804	842	1	6	13
	50										2	8	15
	100										5	12	19
30	20				1557	781	281	4548	2302	655	1	15	29
	50										4	20	34
	100										11	30	40
50	20				2427	1161	468	3678	1922	468	3	24	51
	50										8	33	56
	100										19	49	66

1) Affected maize has been set in relation to conventional maize area, fields and farms in the appropriate scenarios

Source: Own investigation

Potential Bt maize cultivation area in a region

As mentioned above farms with maize production with genetically modified varieties have been selected randomly in three different scenarios. In addition to the question how many fields grown with conventional maize varieties are influenced by adjacent Bt maize fields, it is also interesting to raise the reverse question of how many Bt maize fields fulfil the condition of being isolated from conventional maize fields (i. e. which proportion of Bt maize fields respectively farmers are forced to implement buffer zones around their fields in order to comply with recommended thresholds) since this analysis gives some insight in the potential area which can be grown with GM crops in a region without conflicts with neighbouring farms. The analyses within this paper concentrate on Bt maize fields which comply isolation distances of 20 m, 50 m or 100 m respectively to conventional maize fields.

Table 5 provides an overview of the situation in model region I which is characterised by a high relevance of maize in crop rotation. It can be observed that with an increasing isolation distance the proportion of "isolated" Bt maize[2] fields decreases significantly if the same adoption rate is considered in a region. If we take a 10% adoption of Bt maize 40% of all Bt maize fields can be cultivated without being in "conflict" with neighbouring maize fields grown with conventional varieties if a 20 m isolation distance is required (table 5). In case it is sufficient to fulfil an 100 m isolation distance this figure decreases to 25% of all Bt maize fields in model region I (table 5). The same effect can be observed in the other region under investigation: In model region II which is characterised by a relatively low proportion of maize in crop rotation 58% of the total Bt maize area is "isolated" in case of an isolation distance of 20 m versus 38% in case of an isolation distance of 100 m (and an adoption rate of 10% in both cases) (table 6).

Regarding the recommended German isolation distance of 20 m for maize, the "isolated" Bt maize area increases with increasing adoption rates from 40% (in the initial 10% adoption scenario) to 54% (in the 50% adoption scenario) in model region I (table 5), i. e. if 10% of farmers decide to plant Bt maize in a region with high relevance of maize in crop rotation 40% of the potential Bt maize area is not affected from this specific co-existence measure. Reverse, this means that 60% of Bt maize area is affected by this measure (table 5). In case

[2]Isolated maize needs no buffer zone since conventional maize fields are not within the respective isolation distance. Non-conflict Bt maize is the area can be grown with Bt maize without being influenced by neighbouring conventional maize fields if the respective isolation distance is considered.

the adoption rate of Bt maize increases in a region, the proportion of Bt maize fields which needs buffer zones is decreasing taking into account a given isolation distance. This effect can be shown very clearly in model region I and a 20 m required isolation distance where 60% of all Bt maize fields need a buffer zone in case of 10% adoption rate and only 46% in case of a 50% Bt maize adoption (table 5). The same effect occurs in case of other isolation distances in model region I (table 5) and can be explained by the fact that a higher proportion of cultivated Bt maize fields already serves as "buffer zones" for other adjacent Bt maize fields in case of higher adoption rates of Bt maize. We find the same tendency in model region II (table 6) but the percentages of Bt maize fields which need buffer zones are lower compared to model region I due to the lower relevance of maize in crop rotation in model region II.

In a final step we analysed how much area is required of the total acreage of Bt maize fields to implement the buffer zones in order to respect a given isolation distance for maize or - reversely spoken - which part of the total Bt maize area can be cultivated without being influenced by adjacent conventional maize fields. The results of this analysis are shown in the right columns of tables 5 and 6. Although the absolute acreages which are necessary for buffer zones significantly increase with higher Bt maize adoption rates and raising isolation distances, the relative proportion of Bt maize fields which can be cultivated without being influenced by adjacent conventional maize fields increases as well in case of a higher Bt maize adoption (tables 5, 6). This effect is even higher in regions with intensive cultivation of maize (model region I) compared to model region II.

Table 5: Isolated Bt maize in model region I

Adoption rate	Isolation distance 20 m						
	Total Bt maize area	Isolated Bt maize [1)]		Bt-maize fields need buffer zone		Non-conflict Bt maize area [2)]	
%	ha	ha	%	ha	%	ha	%
10	851	342	40	509	60	559	66
30	2420	1261	52	1159	48	1697	70
50	3921	2107	54	1813	46	2767	71
	Isolation distance 50 m						
%	ha	ha	%	ha	%	ha	%
10	851	280	33	571	67	357	42
30	2420	1099	45	1320	55	1297	54
50	3921	1890	48	2031	52	2263	58
	Isolation distance 100 m						
%	ha	ha	%	ha	%	ha	%
10	851	217	25	634	75	179	21
30	2420	845	35	1575	65	816	34
50	3921	1556	40	2364	60	1496	38

[1)] This area needs no buffer zone since conventional maize fields are not within the respective isolation distance.
[2)] This area can be grown with Bt maize without being influenced by neighbouring conventional maize fields if the respective isolation distance is considered.
Source: Own investigations

Table 6: Isolated Bt maize in model region II

Adoption rate	Isolation distance 20 m						
	Total Bt maize area	Isolated Bt maize [1)]		Bt-maize fields need buffer zone		Non-conflict Bt maize area [2)]	
%	ha	ha	%	ha	%	ha	%
10	530	306	58	224	42	412	78
30	1557	1022	66	535	34	1301	84
50	2427	1579	65	848	35	2016	83
	Isolation distance 50 m						
%	ha	ha	%	ha	%	ha	%
10	530	265	50	265	50	297	56
30	1557	938	60	619	40	1034	66
50	2427	1401	58	1026	42	1561	64
	Isolation distance 100 m						
%	ha	ha	%	ha	%	ha	%
10	530	203	38	327	62	210	40
30	1557	786	50	771	50	802	52
50	2427	1159	48	1268	52	1208	50

[1)] This area needs no buffer zone since conventional maize fields are not within the respective isolation distance.
[2)] This area can be grown with Bt maize without being influenced by neighbouring conventional maize fields if the respective isolation distance is considered.
Source: Own investigation

Economic impact of buffer zones

According to the Recommendations on co-existence measures of the European Commission of July 2003 the GM farmers are responsible for applying and bearing the cost of co-existence measures like buffer zones (Commission of the European Communities 2003). In this context the question arises how to cultivate the buffer zone on GM-farmers fields? Amongst other approaches (Menrad, K. and D. Reitmeier (2006)) we have the possibility of calculate the costs of buffer zones by assuming that the GM farmer cultivates conventional maize on the isolated buffer zone area. Additional costs are differences between gross margins of Bt maize and conventional maize. Important differing positions are insecticide treatment, yield, price for commodity, extra machinery costs and efforts concerning cleaning machineries.

In order to quantify the costs of the suggested co-existence measure, it is necessary to make assumptions concerning the economics of Bt maize since no empirical evidence exists with respect to the economic performance of Bt maize in Germany due to lack of commercial planting of this crop. Table 7 gives an overview of literature findings on key parameters influencing the economics of Bt maize. According to the reported experiences, it can be assumed that the yields of Bt maize might increase in particular in regions with a high infestation level to the European Corn Borer. Due to the resistance of Bt maize against this insect, insecticide use is often reported to decrease when cultivating Bt maize. In contrast, the seed costs of Bt maize will increase due to the technology fee which farmers have to pay to the seed breeding companies. However, there is no final conclusion possible concerning positive or negative changes in gross margins of Bt maize in comparison to non-GM varieties.

In order to estimate potential coexistence costs we take data from Degenhardt et al. 2003. He analysed the impact of existing pest management systems against the European Corn Borer and compared the efficiency of the differing systems. Compared to biological and chemical pest management methods, Bt maize had the highest impact on larvae of the European Corn Borer with efficiency rates of nearly 100 %. Cost calculations of Degenhardt et al. 2003 result in economic benefits of around 84 to 93 €/ha for cultivating Bt maize by considering higher yields in the range of up to 15% and seed costs of plus 35 €/ha compared to conventional seeds. Users of synthetic insecticides gain between € 18 to 55 € per ha when applying common insecticide management methods. Non-insecticide users do not benefit from their ecological insecticide treatment (trichogramma application) in case of high infestation levels. In such a situation their losses account for 52 to 57 €/ha (Degenhardt et al. 2003).

Table 7: Change of economic parameters of conventional maize compared to Bt maize

Economic Parameter	Trait[1,2]	Reported changes of parameter in GM-maize	Source	Country
	IR	↑	Marra et al. (1998)	USA
	IR	↑ (if infestation is high)	Rice and Pilcher (1998)	USA
	IR	↓	Fernandez-Cornejo and McBride (2002)	USA
	HT	↑	Fernandez-Cornejo and McBride (2002)	USA
	IR	↓ (1998-1999)	Carpenter and Gianessi (2001)	USA
	IR	↑ (1997)	Carpenter and Gianessi (2001)	USA
	IR	↑ (if area with high infestation levels)	Hyde et al. (1999)	?
	IR	↑ 84-93 €/ha (referring to no insecticide treatment)	Degenhard (2003)	Germany
Gross margin	IR	↔ (if area with low to medium infestation levels)	Hyde et al. (1999)	?
	IR	1.8 % - 2.5 % ↑	Brookes (2002)	Spain
	IR	5 % ↑	Brookes (2002)	Spain
	IR	↑ (if infestation is high)	Rice and Pilcher (1998)	USA
	IR	↑	Carpenter and Gianessi (2001)	USA
	IR	↑	Hyde et al. (1999)	?
Yield	HT	↓ (1996-2001) ↑ (2002-2003)	Benbrook (2003)	USA
Herbicide	IR	0 % -100 % ↓	Brookes (2002)	Spain
Insecticide	IR+HT	↓ (1996-2001) ↑ (2002-2003)	Benbrook (2003)	USA
	IR + HT	↓	Fernandez-Cornejo and McBride (2002)	USA
	IR	↔	Carpenter and Gianessi (2001)	USA
Herbicide + Insecticide	IR	30 % -35 % ↑	Benbrook (2001)	USA, Canada
	IR	12 % -19 %↑	Brookes (2002)	Spain
	IR	12 % -19 %↑	Brookes (2002)	Spain
Costs of seeds	IR	↑ 35 €/ha	Degenhard (2003)	Germany

IR: Insect resistance (mostly resistance due to *Bacillus thuringiensis* (Bt) toxin)
HT: Herbicide tolerance

Source: Modified according to Menrad, K. and D. Reitmeier (2006)

In order to quantify the costs of the buffer zone a profit of 38 €/ha to 66 €/ha, which can indicate in proportions of between 3.35 and 6.23 of variable costs of conventional maize was assumed according to Degenhardt et al. 2003. This profit implies higher yields[3] of between around 3% and 4%, higher seed costs of 35 €/hectare and insecticide savings of 40 €/ha (Degenhardt et al. 2003).

As indicated in table 8 the additional costs of buffer zones costs are increasing with higher adoption rates from 19,289 € (10% scenario) to 76,134 € (50% scenario) in model region I. This results in additional costs of 222 € per farm in the 10% scenario and 175 € in the 50% scenario. In model region II where only half of the maize is grown compared to region I additional costs per farm range from 48 € to 33 €. This additional costs increase consequently with regard to increasing isolation distances of 50 m and 100 m.

Table 8: Additional costs of 20 m, 50 m and 100 m buffer zones on Bt maize fields

Isolation distance of 20 m								
Adoption rate	Model region I - intensive maize production				Model region II - extensive maize production			
	Buffer zone	bt-maize farms in region	Accumulated additional costs [1)]		Buffer zone	bt-maize farms in region	Accumulated additional costs	
%	area (ha)	n	€/region	€/farm	area (ha)	n	€/region	€/farm
10	292	87	19289	222	118	94	4499	48
30	722	261	47680	183	256	281	9741	35
50	1154	435	76134	175	411	468	15625	33
Isolation distance of 50 m								
Adoption rate	Model region I - intensive maize production				Model region II - extensive maize production			
	Buffer zone	bt-maize farms in region	Accumulated additional costs [1)]		Buffer zone	bt-maize farms in region	Accumulated additional costs	
%	area (ha)	n	€/region	€/farm	area (ha)	n	€/region	€/farm
10	494	87	32576	375	233	94	8869	95
30	1122	261	74085	284	523	281	19888	71
50	1658	435	109409	252	866	468	32898	70
Isolation distance of 100 m								
Adoption rate	Model region I - intensive maize production				Model region II - extensive maize production			
	Buffer zone	bt-maize farms in region	Accumulated additional costs [1)]		Buffer zone	bt-maize farms in region	Accumulated additional costs	
%	area (ha)	n	€/region	€/farm	area (ha)	n	€/region	€/farm
10	634	87	41868	482	320	94	12178	130
30	1575	261	103930	399	755	281	28695	102
50	2364	435	156053	359	1219	468	46306	99

[1)] Region I: Gross margin of Bt maize is 66 €/ha higher than those of conventional varieties
[2)] Region II: Gross margin of Bt maize is 38 €/ha higher than those of conventional varieties
Source: Own investigation

[3] Price for conventional maize in 5 years average is 117.7 €/tonne (tax included).

The results above do not imply additional costs of machinery cleaning or organisational efforts. Messéan, A., F. Angevin, et al. (2006) mentioned costs of cleaning single seed drillers and combines from 38.38 € to 57 €. But these costs of machinery cleaning can occur in both model regions and thus do not influence the relative cost situation between the regions.

Conclusion

Taken all together it can be concluded that there is a substantial proportion of fields which are cultivated with non-GM varieties to be influenced by cross pollination of Bt maize. This refers in particular to regions with small scaled fields and high relevance of maize in crop rotation. The affection rates of conventional maize area are substantially lower compared to the rate of affected conventional maize fields or farms. This indicates a high potential of conflicts among farmers particularly in intensive maize regions and trace back to a very dispersed landscape pattern which is characteristic for the Southern part of Germany and neighbouring regions. In particular for such regions there is a strong need of clear and easy–to-handle implementation of co-existence schemes and measures to ensure freedom of choice for farmers and consumers.

In contrast there is a higher potential for "isolating" fields cultivated with Bt maize in regions with low proportions of maize in crop rotation compared to intensive maize cultivating regions. Under German conditions of small-scaled fields, rather small farms and scattered ownership of land, buffer zones of more then 20 m around Bt maize fields will cause substantial organisational efforts - both in regions with high and low proportion of maize in crop rotation. Due to average field sizes of around 2 ha buffer zones with more than 20 m would substantially limit the remaining area which is suitable for Bt maize cultivation.

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