Thünen Baseline 2015 – 2025: Agri-economic projections for Germany

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Abstract

This article presents the Thünen Baseline 2015 – 2025, a projection of medium-term developments of the agricultural sector in Germany, addressing agricultural trade, prices, production, land use, income and environmental aspects. The Baseline was established using and combining several models of the Thünen Modelling Network. In the Thünen Baseline 2015 – 2025, a favourable outlook for world agricultural markets, in combination with a weak Euro, contribute to the positive development of many agricultural product prices and farm incomes in Germany. The abolishment of the milk quota and rising milk prices are key factors in the projected increase of milk production to 37 million tons by 2025. However, a sensitivity analysis, based on a scenario which assumes an appreciation of the Euro, highlights the extent to which export-oriented sectors (e.g., the milk sector) depend on macro-economic developments. Germany is the only member state without voluntary coupled support payments in the Baseline. The use of coupled payments in the other EU member states has only small negative effects on Germany. Reduction of ammonia emissions and high regional nitrogen soil surpluses remain among the key environmental challenges for agricultural policy.

Keywords: *agricultural policy, impact assessment, modelling, Germany, modelling network*

Zusammenfassung

Thünen-Baseline 2015 – 2025: Agrarökonomische Projektionen für Deutschland

Dieser Artikel stellt ausgewählte Ergebnisse der Thünen-Baseline 2015 – 2025, einer Abschätzung zukünftiger mittel- bis langfristiger Entwicklungen des deutschen Agrarsektors, dar. Für die Erstellung der Thünen-Baseline wurden mehrere agrarökonomische Modelle im Verbund eingesetzt. Dargestellt werden Projektionsergebnisse für Agrarhandel, Preise, Produktion, Landnutzung, Einkommen und Umweltwirkungen. In der Thünen-Baseline 2015 – 2025 tragen günstige Aussichten auf dem Weltagrarmarkt in Kombination mit einem schwachen Euro dazu bei, dass sich die Einkommen vieler Betriebe in Deutschland bis 2025 positiv entwickeln. Vor dem Hintergrund des Auslaufens der Milchquote sowie steigender Milchpreise wird bis zum Jahr 2025 eine Ausdehnung der Milcherzeugung auf gut 37 Millionen Tonnen projiziert. Jedoch zeigt eine Variationsrechnung, die eine Wiederaufwertung des Euro unterstellt, wie stark gerade die exportorientierten Sektoren (wie z. B. Milch) von der Entwicklung gesamtwirtschaftlicher Kennzahlen abhängig sind. Die aktuelle Verwendung gekoppelter Zahlungen in anderen EU-Mitgliedsstaaten hat nur geringe negative Auswirkungen auf die Landwirtschaft in Deutschland, dem einzigen Mitgliedsstaat mit vollständiger Entkopplung aller Direktzahlungen. Die Reduzierung von Ammoniakemissionen und die Vermeidung regional hoher Flächenbilanzüberschüsse von Stickstoff gehören auch in Zukunft zu den größten Herausforderungen für die Agrarumweltpolitik.

Schlüsselwörter: *Agrarpolitik, Politikfolgenabschätzung, Modellierung, Deutschland, Modellverbund*

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1 Introduction

The so-called 'Thünen Baseline' provides projections of medium-term developments of the agricultural sector in Germany, addressing agricultural trade, prices, production, land use, income and environmental aspects. It is established and published regularly every two years. This article presents and discusses selected results of the Thünen Baseline 2015 – 2025 as well as the assumptions upon which these results are based. [1] The projections are based on data and information available in July 2015. It is important to stress that the Thünen Baseline is not a forecast about the future. Rather, the Baseline describes expected developments in accordance with specific assumptions about the development of exogenous drivers and provided that the current agricultural policy is continued. The Thünen Baseline thus serves as a reference scenario for analysing the impacts of alternative policies and developments. It complements the more general and highly aggregated results of the baseline reports of the European Commission (2015) and the OECD-FAO (2015) by offering a detailed picture of the projected situation of German agriculture in 2025, taking national policies into account.

The assumptions for the development of the exogenous factors and the agricultural policy conditions selected for the Baseline were chosen in close consultation with experts from the German Ministry of Food and Agriculture. Preliminary Baseline results were discussed with representatives from the federal and federal state ministries. This approach enabled the integration of expert knowledge as well as the definition of a scenario that is widely accepted as a relevant basis for further policy impact analyses.

2 Methodology

The Thünen Baseline was established using and combining several models of the Thünen Modelling network, each describing various decision-making levels (Figure 1). In the analysis, a coordinated, parallel and/or iterative implementation of the models takes place. This joint use of different models has a number of advantages. The parallel use of models allows exploitation of the comparative advantages of different model types and implementations regarding result quality, coverage or resolution (Britz, 2008). The linked use of models, which includes feedback between the models, increases the consistency of scenario definitions as well as the consistency of overall results and at different levels of aggregation, and can also improve the quality of results (Helming and Banse, 2008; Offermann, 2008). Compared to (a series of isolated) single-model analysis, the use of the Thünen Modelling network for the establishment of the Thünen Baseline has the following specific advantages:

– A wide range of trade, agricultural and environmental policies can be analysed, while in one model it would be difficult to capture all the policies' different aspects

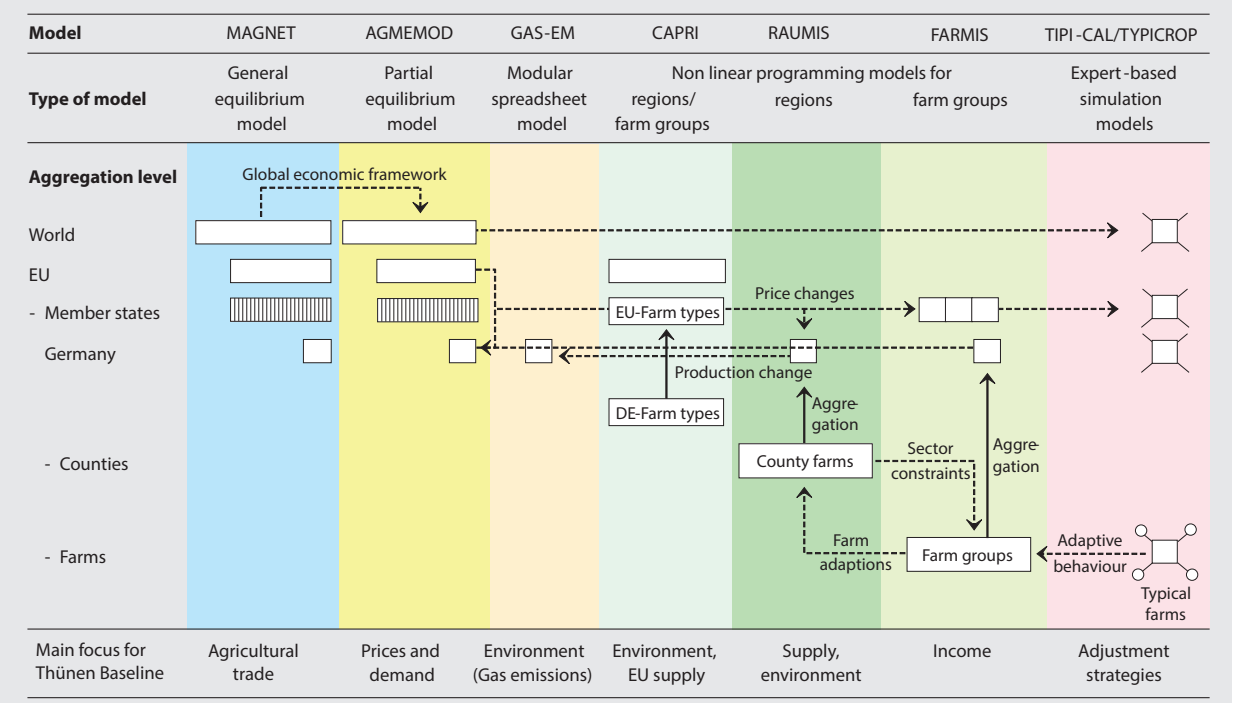


Figure 1
The use of models of the Thünen Modelling Network for the establishment of the Thünen Baseline 2015 – 2025

[1] The full report with detailed results is published in German as Offermann et al. (2016).

comprehensively and in detail. Policies can be modelled using the most appropriate model. For example, policies that target farms and whose impacts depend on farm characteristics are generally best modelled at farm level. Typical examples of such policies are the crop diversification requirement and the set-aside regulations. The upscaling of farm level impacts and the linkage to market models then allows to asses potential market effects of such policies – and to analyse the impacts of induced price effects on the farms in subsequent feedback loops.
- The impacts of policy and market changes can be analysed for a large number of various facets of the agricultural sector, e.g., trade, markets, production, environment and income, which would be difficult to incorporate comprehensively in one model.
- Projections of the development of agriculture can be presented at different levels (e.g. sector level and farm level; or national and regional level). They thus provide information on aggregate impacts, which is often important for identifying the need for political action. At the same time, information on the heterogeneity of results is provided, which is important for designing targeted and efficient policy instruments.
- The coordinated implementation allows for the alignment of important assumptions, an exchange of results between models, and the mutual monitoring and control of model results. This approach ensures a consistent overall result.

The various models [2] project different aspects relevant for the Baseline according to their individual scopes and strengths:
- The MAGNET model is a multiregional, general equilibrium model covering global economic activity as well as single countries and regions. Its specification includes a very detailed representation of agricultural trade policies and treaties. For the Thünen Baseline, MAGNET is applied to assess the development of bilateral agricultural trade flows.
- AGMEMOD is a partial, multi-national, multiple-product model which covers production, consumption, trade, inventories and prices for agricultural and processing sectors of the EU member states, accession candidates and other neighbouring countries. Its specification accounts for the specific characteristics of agricultural price formation in the individual EU member states. For the Thünen Baseline, AGMEMOD projects the prices of agricultural products in Germany, which are used as an input in the regional and farm level supply models.
- CAPRI is a comparative-static partial equilibrium model, which iteratively links regional or farm-level supply models representing the EU with a global spatial multi-commodity market model. For the Thünen Baseline 2015 – 2025, it assesses the impacts of the voluntarily coupled payments (VCS) of the Common Agricultural Policy (CAP) in the EU. The assessment uses the very detailed implementation of national CAP schemes and options in CAPRI.
- RAUMIS is based on mathematical programming models representing agricultural land use and production in Germany at regional level. The high regional resolution of RAUMIS and the integration of biophysical relations facilitate the calculation of environmental indicators. For the Thünen Baseline, it provides projections of land use, production and nitrogen surplus at regional and sectoral levels.
- Farm level aspects are covered by FARMIS, a process-analytical programming model for farm groups. The scope of the model's data basis enables providing a representative picture of farm level developments while capturing the heterogeneity of farms in Germany. For the Thünen Baseline, FARMIS projects the income of different farm groups.
- TIPI-CAL is a production and accounting model for selected typical farms, applied within the framework of the global agri benchmark network. For the Thünen Baseline 2015 – 2025, it is used to assess the impact of the reform of direct payments on suckler-cows and beef finishing farms in selected European countries, capturing the highly diverse historic payment levels, re-introduced coupled payments, and planned new schemes as well as the influence of the different production systems predominant in different regions of Europe.
- For the projection of greenhouse gas and ammonia emissions from agriculture in the Baseline scenario, the Thünen Modelling Network is linked to the model GAS-EM, a modular spreadsheet programme that uses the definitions and calculation procedures according to the current guidance documents of IPCC. The projections of gaseous emissions in 2025 build on the respective RAUMIS projections for land use and livestock numbers.

A particular strength of applying the models jointly in a network is the consistent consolidation of different areas and aspects covered by the individual models, allowing us to capture the complex interactions between the decision-making levels. For the Thünen Baseline, the core of this process is the consolidation of the price-supply relationships of AGMEMOD, RAUMIS and FARMIS.

Generally, the base year of the models is a 3-year-average around 2010 (i.e. 2009 to 2011). [3] If more recent data was available, then these are highlighted in the diagrams as observed values.

3 Assumptions

3.1 General economic framework

The Thünen Baseline 2015 – 2025 builds on external projections for macroeconomic developments from 2015 to 2025,

[2] The databases and characteristics of the models used for the establishment of the Thünen Baseline 2015 – 2025 are briefly described in the Annex.

[3] Small differences between models may occur (e.g., due to the accounting laws, the 3-year period for the farm models is 2009/10 to 2011/12). To improve readability, some table / maps refer to 2010 rather than 2009 to 2011.

as compiled in secondary sources like the USDA (USDA, 2014a; USDA, 2014b). The Baseline scenario is characterized by an annual growth of the gross domestic product of the world economy of 3.4 %, and a more modest growth in Germany (1.6 % p. a.). World population growth is projected to increase by 1 % p. a., while the population in Germany is slightly declining (-0.2 % p. a.). The Baseline scenario assumes that the Euro remains comparatively weak at an exchange rate of 1.15 $/€ in 2025 (OECD-FAO, 2015). As international trade mostly takes place in US-Dollar, a weak Euro stimulates exports and makes imports more expensive for countries of the eurozone.

Inflation in Germany remains low at 1.6 % p. a. Agricultural land in Germany is assumed to continue to decrease at an annual rate of -0.1 %, accompanied by constant structural change rates with a decline of farm numbers (-3.4 % each year; own calculations based on the Farm Structural Survey; see also Offermann et al., 2016). Yield projections are based on trends, taking into account the relation of product and input prices. For arable crops, this implies annual yield growth rates of around 1 % p. a. Dairy yields are assumed to increase by 1.1 % p. a. Autonomous technical change is driven by historical trends, while overall technical change in the agricultural sector is also influenced by structural change (especially by the increase in farm size).

The assumptions for the development of input prices in Germany are generally based on trends from 2005 to 2014. For energy inputs, the oil price projections used in the OECD-FAO-outlook (2015) are applied, which imply an oil price of 88 $/barrel in 2025. Due to the high importance of energy costs for the production of nitrogen fertilizers, fertilizer prices were linked to the price forecasts of oil. World market price projections [4] for agricultural products from the OECD-FAO (2015) are used as a calibrated basis in the AGMEMOD model to establish price developments in the EU and Germany. For the projection period international prices for livestock products, expressed in Euro, rise further (+10 % - +30 %) compared to the already high price level during 2009 to 2011 despite the downswing observed during 2011 to 2014, whereas world market prices for crop products remain constant or decrease slightly.

3.2 Policy framework

The Baseline assumes a continuation of the current policy framework and the implementation of already decided policy changes. For the Thünen Baseline 2015 – 2025, this implies that the direct payment system established by EU-Regulation 1307/2013 and its national implementation (BMEL, 2015) will be continued until the year 2025. The most important policy assumptions of the Baseline can be summarized as follows:

- Trade policy framework: The Baseline accounts for 14 trade agreements which will be implemented by the EU and its trading partners between 2015 and 2025 (e.g., with countries in South America and North Africa and the Balkan States). A graphical overview of these agreements is presented in Offermann et al. (2016).
- Price and quota policies: EU regulation No. 1308/2013 foresees a safety net with public intervention mechanisms for selected products. In addition, the EU commission has a reserve fund for crisis prevention and management measures at its disposal, to be able to react to general market disturbances. The Thünen Baseline presumes that neither these measures nor export support for milk products are applied during the projection horizon due to the prevailing world market conditions. The Baseline scenario takes into consideration the abolishment of the milk quota in 2015 and the end of the sugar quota regime in 2017 while maintaining border protection. Based on the OECD-FAO projection of world market prices, an EU-internal sugar price of 419 €/t in 2025 is assumed.
- Direct payments of the first CAP pillar: The redistribution of funds between EU member states, the national redistribution of 4.5 % of the budget to the second pillar, and support for young farmers lead to a base payment of 176 €/ha and a greening payment of 85 €/ha. To support smaller farms, a top-up of 50 €/ha for the first 30 ha and 30 €/ha for the next 16 ha is granted.
- Voluntary coupled support: With the exception of Germany, all EU member states notified their plans to make use of the option of introducing voluntary coupled support payments for specific sectors and regions. Based on these plans, 10.5 % of overall direct payments in the EU-28 are coupled to production levels.
- Greening: Eligibility for a part of the direct payments depends on the fulfilment of the so-called 'greening' requirements. These comprise protection of permanent grasslands, minimum crop diversity and provision of ecological focus areas (EFA). For the Thünen Baseline it is assumed that the share of EFA remains fixed at 5 % of arable area throughout the projection period.
- Support measures of the second CAP pillar: The reduced EU funds for second pillar measures in Germany are compensated by the national redistribution of funds from the first pillar. The baseline assumes that the national and regional rural development programmes implemented for the period 2014 to 2020 will be continued to 2025 with a constant budget and a continuation of the currently planned distribution of financial resources to individual measures.
- Support for bioenergy: Electricity stemming from biogas is supported in Germany by the Renewable Energy Sources Act (EEG), which guarantees a certain price for electricity generated from renewable energy sources. It is expected that the latest amendment to the EEG will significantly restrict the expansion of biogas plants and lead to a demand for 1.1 million ha of energy maize in 2025. Taking into account the projections for fuel demand, it is expected that the new policy framework will reduce demand for biofuels until 2015, with only a modest increase in the following years, whereas demand for ethanol from cereals remains constant.

[4] All price developments refer to nominal prices.

4 Results

4.1 Changes in agricultural trade patterns

In the Baseline, trade flows are influenced by macroeconomic developments as well as changes in agricultural and trade policies. Here, e.g., the implementation of 14 bilateral trade agreements, the end of the sugar quota regime, and the biofuel targets have effects on agricultural trade patterns. Figure 2 provides an overview of the changes in world trade between 2015 and 2025. Total agricultural exports (including EU intra trade) increase from 732 bn € in 2015 to 805 bn € in 2025. In contrast to this development, internal trade of the EU decreases from 213 bn € to 197 bn €. EU exports to non-EU countries increase slightly from 67 bn € to 76 bn €. This increase in EU exports lags behind export increases of other countries. Thus, exports of the EU (without internal trade) as percentage of exports of total agricultural trade decrease from 12.8 % in 2015 to 12.5 % in 2025.

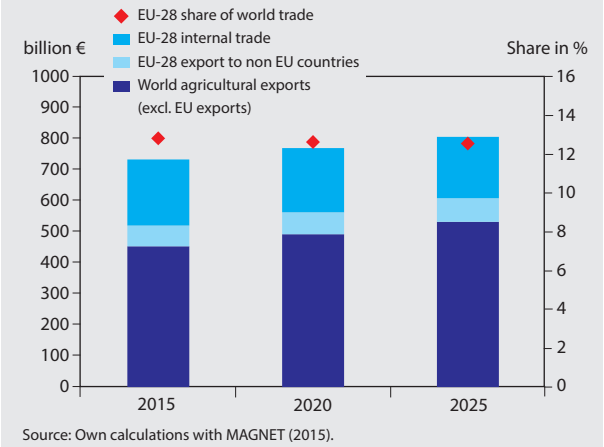


Figure 2
Agricultural world trade and share of EU-28 (exports)[1)]
[1)] *The values in 2015 are already projected.*

A regional disaggregation (Figure 3) shows that EU-exports to all regions of the world increase slightly. The situation concerning the imports into the EU is different. Here, additional imports from Central and South America are expected due to trade agreements with the EU that will be implemented in the coming years and are therefore included in the Baseline scenario. Imports from Asia are also expected to rise. The import increase can be explained in particular by an increase of imports from China. The EU imports from other Asian countries increase only slightly in the period under consideration. Japan and the Asian-LDCs (Least Developed Countries) even show a slight decrease in exports to the EU. With the growth in imports from Central and South America as well as Asia, the trade of other regions, such as Africa and North America, is diverted. A successful conclusion of the TTIP (Transatlantic Trade and Investment Partnership) with the United States as well as the ratification of CETA (Comprehensive Economic and Trade Agreement) with Canada could counteract this effect for North America in the coming years.

4.2 Farm gate prices

Important determinants of prices for agricultural products in Germany are the projected development of world market prices (OECD-FAO, 2015) and changes in domestic policies like dairy quota abolition and the politically influenced demand of biofuels and biogas. In addition, the assumed relatively weak Euro implies that in countries of the Eurozone, prices of traded goods are higher (in national currency, i.e. Euro) than they would be in a scenario with a strong Euro, which stimulates exports and makes imports more expensive.

Until 2025, wheat prices are projected to slightly increase to reach almost 210 €/t. In the short term, a steady wheat price is expected due to low export demand. Since 2013, the wheat harvest has reached top records leading to replenished wheat stocks in typical importing countries. In the long term, the German wheat price will be oriented towards world

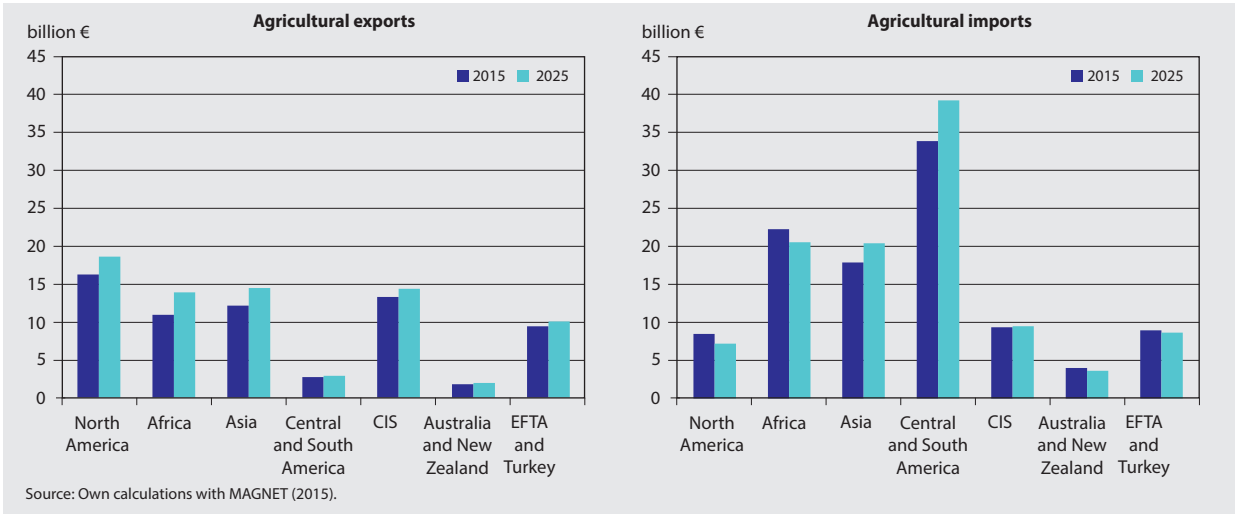
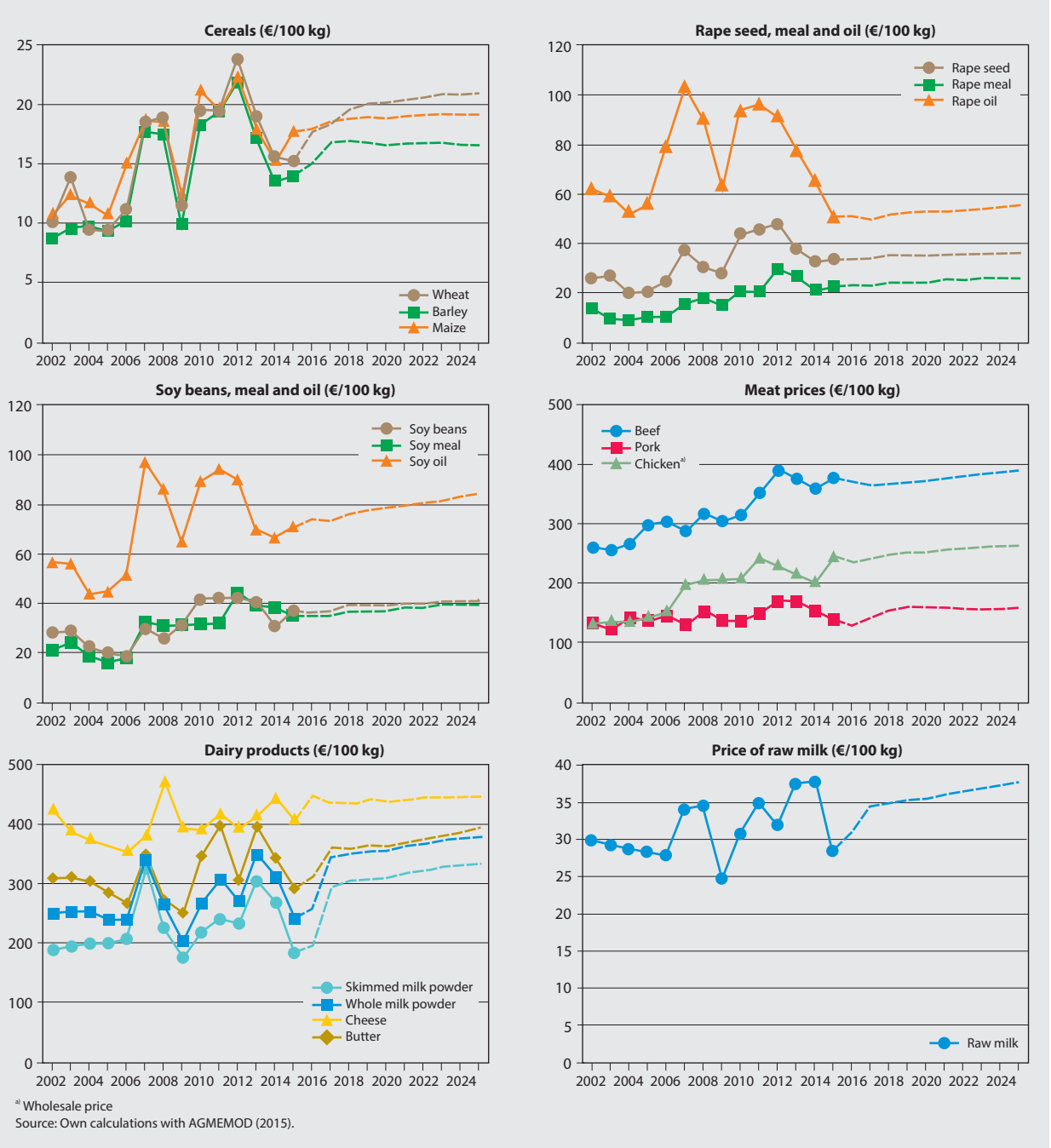


Figure 3
Agricultural exports and imports of EU-28 in 2015 and 2025[1)]
[1)] *The values in 2015 are already projected.*

prices, which are supported by the increasing demand in the Mediterranean and the Arabian Gulf region. Feed cereal crops prices stabilize at the comparatively high level of approx. 190 €/t for maize and 170 €/t for winter barley. In this projected development, a stronger demand growth for corn has been taken into account. Despite the drop in domestic demand for rapeseed for biofuels, the decrease of the rapeseed price is moderate and prices remain almost constant at 360 €/t due to favourable world market developments. This means that the rapeseed price will stay significantly lower than in the record year 2012.

Several adverse factors were observed in the years 2015 and 2016 for animal products, especially for dairy products and pig meat. High levels of milk production worldwide in 2015 and 2016 driven among other factors by high prices in the period before, the import embargo from Russia as well as the lower demand for milk from China induced a price drop. In the case of Germany, international factors met national conditions: With the end of March 2015, milk quotas were abolished leading to higher milk production in the EU market adding to low prices. Even though the milk production in Germany was relatively steady, in most of the other EU countries production considerably expanded, negatively



[a] Wholesale price
Source: Own calculations with AGMEMOD (2015).

Figure 4
Development of farm gate prices in Germany

affecting the milk prices. After the period of consolidation, milk prices are projected to catch-up again until 2025 due to backlog demand in China and Near East, which is currently curbed by a slowdown in global economic development. The German milk price is projected to almost reach 38 €/100 kg raw milk with 4 % fat and 3.4 % protein.

Similar negative conditions affect the pork meat markets. Again, the import embargo from Russia as well as a further (cyclical) rise in pork production are to be mentioned. For poultry meat, the increasing production rates will contribute to a steady meat price. The differences in prices for pork and poultry meat presented in this study are due to differences in the conception of the prices. The broiler prices shown in Figure 4 represent wholesale prices. The prices on farm gate level are expected to rise less dynamically due to an assumed substantial increase in the trade margin that could already be observed in the past.

In the case of beef meat, the close link of beef and milk production needs to be considered. Thus, if milk production is driven by productivity growth, then the beef meat production will develop in the same direction, though the potentially significant increase in live animal trade also needs to be taken into account.

4.3 Agricultural production

Table 1 provides an overview of the development of land use and agricultural production in the Thünen Baseline. Despite the projected increase of cereal prices by about 26 % in 2025, cereal area decreases slightly (-1 %) compared to the average of the period 2009 to 2011. This decrease results from an increase of energy maize to approx. 1.1 million ha, the increase of set aside to approx. 0.4 million ha and the continuing loss of agricultural land. Cereal production shifts from more extensively produced cereals like summer barley to more intensive wheat production. This intensification is complemented by crop yield increases due to technological progress. Therefore, in 2025 cereal production increases by approx. 52 million t, despite the smaller cropping area.

The oilseed production remains constant at 5.6 million tons, although the oilseed acreage is reduced by 17 % due to the unfavourable development of the price for oilseeds. The cultivation area of silage maize and other arable fodder crops is slightly reduced because fodder yield increases while cattle numbers remain more or less constant.

With the abolishment of the milk quota and rising milk prices, milk production increases to 37 million t by 2025. Compared to the period 2009 to 2011, this corresponds to a growth of milk output in Germany by 23 %. It is important to stress that this high increase of milk production is based on high price projections which are mainly driven by the assumption of increasing demand for milk on the world

Table 1
Development of production and land use in German agriculture

		1999	2007	2010	Baseline 2025	*Baseline 2025 vs. 2010 in %*
	Unit	absolute				
Land use						
Cereals	1 000 ha	6 840	6 763	6 571	6 517	*-1*
Wheat	1 000 ha	2 706	3 098	3 298	3 535	*7*
Barley	1 000 ha	2 196	1 968	1 641	1 408	*-14*
Rye	1 000 ha	851	649	627	589	*-6*
Oilseeds	1 000 ha	1 137	1 475	1 499	1 249	*-17*
Root Crops	1 000 ha	804	651	633	624	*-1*
Potatoes	1 000 ha	298	270	255	253	*-1*
Pulses	1 000 ha	112	119	91	171	*87*
Maize silage	1 000 ha	1 203	1 017	1 050	973	*-7*
Other arable fodder	1 000 ha	469	599	750	706	*-6*
Energy maize	1 000 ha	51	444	809	1 075	*33*
Set aside [a]	1 000 ha	720	593	245	367	*50*
Cattle	1 000 head	14 831	12 749	12 772	12 701	*-1*
of which: Dairy cows	1 000 head	4 765	4 123	4 191	4 443	*6*
Milk production [b]	1 000 t	26 768	28 057	30 051	37 040	*23*
Beef and veal production	1 000 t	1 396	1 136	1 221	1 130	*-7*
Pork production	1 000 t	3 863	4 019	4 908	5 116	*4*
Poultry production	1 000 t	799	959	1 588	1 909	*20*

[a] Incl. unused grasslands.
[b] Actual fat and protein content.

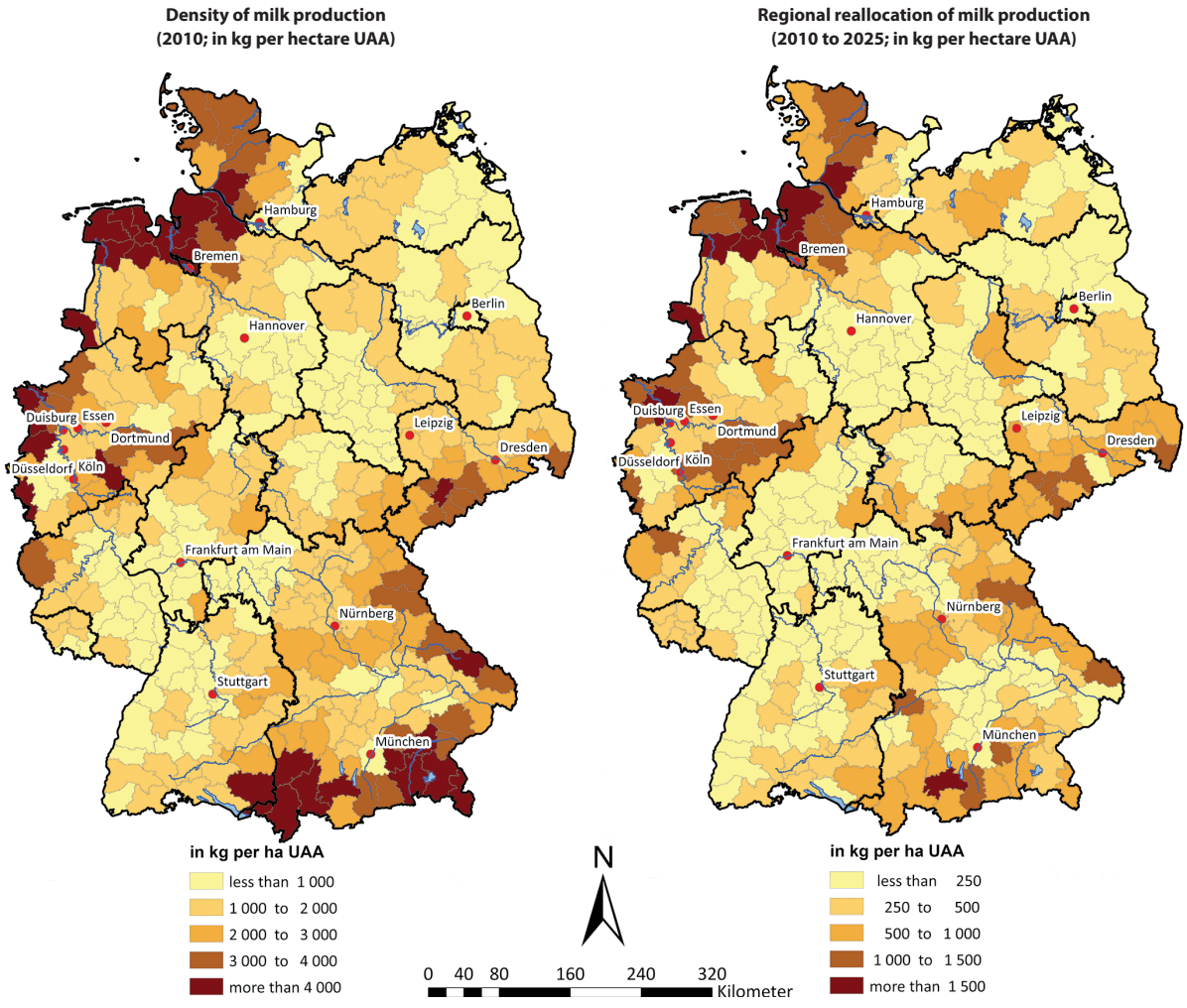
market. Breaking the historic trend, the number of dairy cows increases slightly. The total number of cattle remains almost constant. Thus changes in beef production are minor. Only moderate increases are projected for veal and pork production. In contrast, the poultry meat production is projected to increase by 20 % until the year 2025.

The trend of a regional concentration of dairy production (Kreins and Gömann, 2008) is accelerating after the end of the dairy quota system. On average, milk production increases by approx. 400 kg/ha of utilisable agricultural area (UAA) from 2009/11 to 2025. According to the model results, an above-average expansion of dairy production will take place in the coastal regions and in the lower Rhine region, in some areas of the Mittelgebirge (middle mountain areas), as well as in the Allgäu and the Voralpen (pre-Alpine regions) (Map 1). These grassland and lower-yielding arable crop areas have generally shown a particularly competitive dairy production in the past, and already exhibit high dairy production densities. A withdrawal from dairy production can particularly be observed in arable locations, such as for example the Köln-Aachener Bucht (Cologne-Aachen area), the Hildesheimer Börde (plain, fertile soils around Hildesheim) and the northeast of Brandenburg. In addition, some grassland regions lose production shares. This affects, for example, the Black Forest as well as parts of Hesse, and thus grassland regions that have proven to be less competitive for dairy production in the past and in which dairy production has been declining. These regions are often found near urban centres that offer comparatively good off-farm job opportunities.

4.4 Income

The following analysis of income developments at farm level focuses on the indicator 'Farm Net Value Added (FNVA) per agricultural working unit (AWU)'. FNVA measures the return to the factors land, labour and capital, and is put in relation to the amount of labour input to account for differences and changes in farm size. All income figures are adjusted for inflation and refer to 2010 prices.

Compared to the base period of 2009/10 to 2011/12 (Figure 5), the average FNVA/AWU once again increases slightly, and is thus higher than average income over the



Source: Own calculations with RAUMIS (2016).

Map 1
Regional relevance and reallocation of milk production in Germany

last ten years. The decrease of farm gate prices in real terms and the reduction of direct payments are partly offset by

- the continuing structural change, with high exit rates especially of small farms with below-average income potential and the resulting opportunity for growth for remaining farms;
- the reduced labour requirements as a consequence of technical change; and
- improvements in crop and dairy yields.

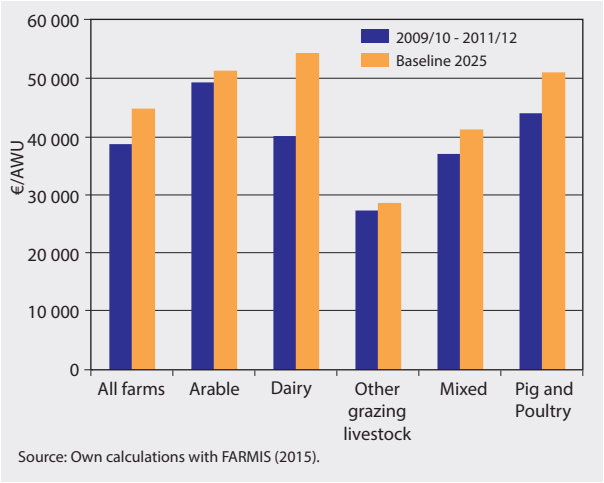


Figure 5
The development of farm net value added per agricultural work unit by farm type (in real terms in prices of 2010)

However, income developments differ by farm type. Arable farms are especially affected by significantly lower prices for sugar beet, but benefit from the still growing demand for energy maize. The average land area of arable farms increases markedly, due to the high exit rates of small arable farms with lower incomes. Income of arable farms stabilizes at the level of the base period. Dairy farms profit from projected milk prices being significantly higher than during the period 2009 to 2011, and benefit from a strong increase in the average milk production quantity. The income of dairy farms rises by 35 % and thus surpasses that of other farm types. Other grazing livestock farms, which include many smaller, part-time farms, can only slightly increase their income above the low level of the base period (+5 %).

While pork prices significantly decline in real terms, mixed and pig and poultry farms profit from rising poultry meat prices and a comparatively favourable development of prices for energy and imported feed. In addition, pig and poultry farms are less affected by the reduction and reformation of direct payments than other farm types. While on average farms receive 50 €/ha less than in the base period, the payments in pig and poultry decrease by only 7 €/ha. Compared to the base period, income increases by 11 % in mixed and 16 % in pig and poultry farms, and thus reaches the comparatively high level of the farming years 2012/13 and 2013/14. However, it should be noted that higher regulatory requirements currently under discussion, e.g., as part of the fertilizer directive, which could increase production costs for these farms in the future, have not been accounted for in the Baseline scenario.

Expenditures for land rent are not taken account of in FNVA, and the impact of changing rental prices on farm profits depends on farm specific rental shares. The projected increase of rental prices for grassland thus especially affects other grazing livestock farms due to the high share of grassland in combination with a high share of rented land. According to the model results, rents are projected to increase strongly especially in regions with intensive livestock farming.

The income of organically managed farms increases by 10 % in the Baseline compared to the base year period as shown in Figure 6. This development is mainly due to the growing size of the average farm in the wake of structural change, higher yields and higher support payments for organically managed land, which compensate for lower farm-gate prices and higher costs for labour and farm inputs. An increase in income can be observed particularly for organic dairy farms (+23 %) and organic arable farms (+12 %). In contrast to this, there is only a slight increase of FNVA/AWU in organic mixed (+4 %) and other grazing livestock farms (+7 %). These farms receive higher revenues due to an expansion of production, but have also to bear substantially higher production costs.

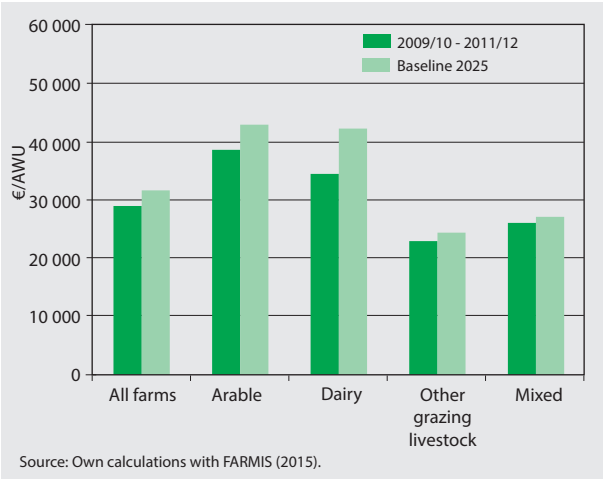


Figure 6
The development of farm net value added per agricultural work unit in organic farms (in real terms in prices of 2010)

4.5 Environmental impacts

One of the key indicators for the environmental impacts of agriculture is the N-balance, which is the difference between all nutrient inputs and outputs on agricultural land. For the calculation of the soil surface nitrogen balance, inputs include mineral and organic fertilizers (including fermentation residues), atmospheric deposition, and symbiotic and asymbiotic N-fixation, while output refers to the quantity of nitrogen in harvested crop production. A positive balance reflects inputs that are in excess of crop and forage needs. A

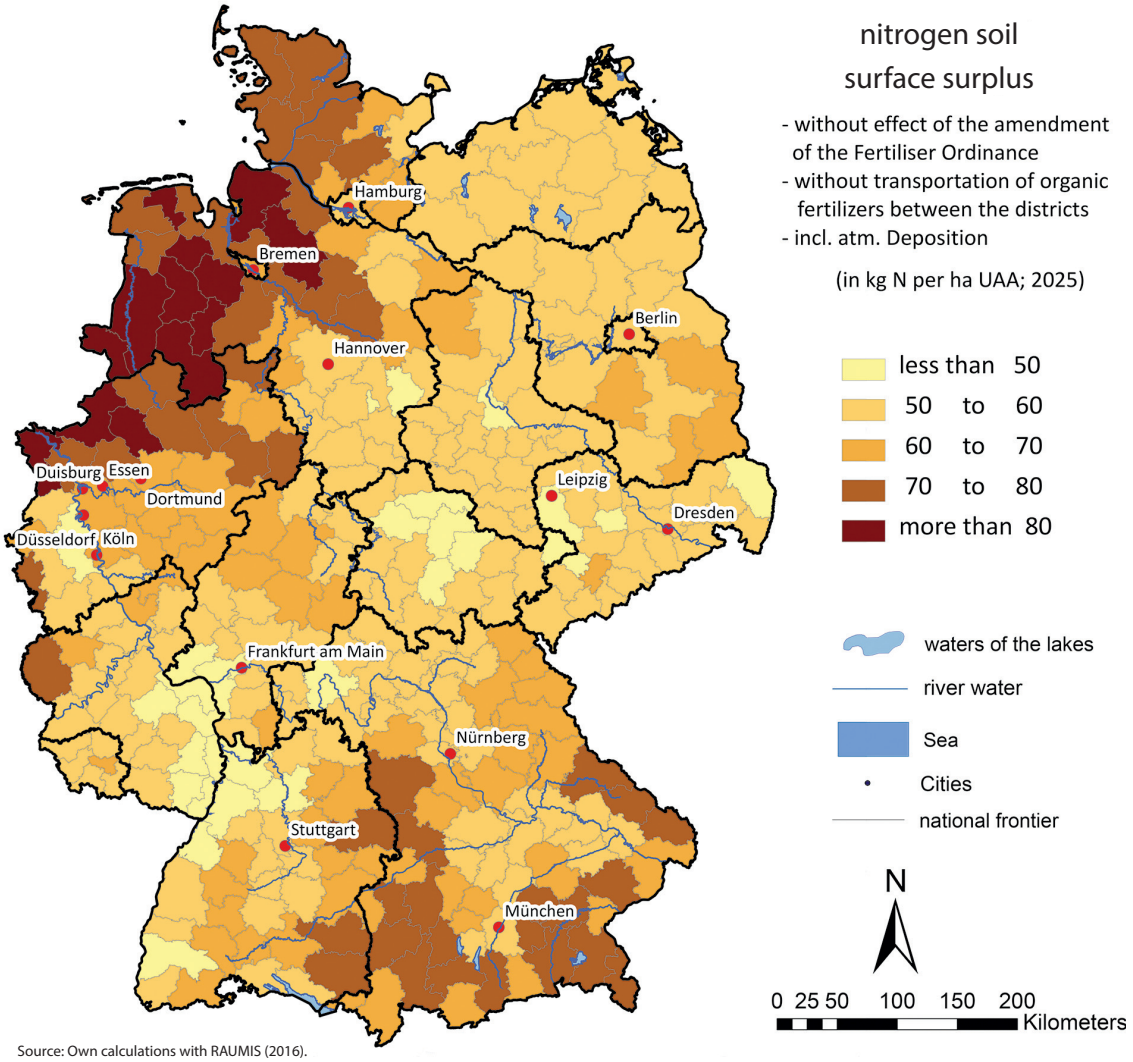
modified calculation of the N-balance is used to assess the potential impact of excess nitrogen on water: to this end, nitrogen loss through the volatilisation of ammonia to the atmosphere is subtracted from animal husbandry and stored manure.

Compared to the previous developments during the past decade, the trend of declining livestock numbers does not continue in the Baseline scenario. The increase of biogas production leads to a rise in nitrogen quantities from fermentation residues, which have a lower utilisation rate than mineral fertilizers. With an increasing efficiency of the utilization of organic fertilizer [5], the use of manure rises by 8 % until 2025 (Table 2). In addition, the use of mineral fertilizer increases by 9 % during the same period. The expected yield increase and the corresponding nutrient requirements account for the decline of the sectoral nitrogen soil surface surplus from 70 kg/ha UAA in 2010 to 64 kg/ha UAA in 2025.

Table 2
Development of the nitrogen balance

Elements of the nitrogen balance		2009/11	2025	*Change in % to 2009/11*
		in kg N/ha UAA		
Inputs	Organic fertilizer	84	92	*8*
	Mineral fertilizer	97	105	*9*
	Symbiotic fixation, asymbiotic fixation and atmospheric deposition	38	38	*0*
Total inputs		219	234	*7*
Outputs and gaseous losses	N in harvested yield and ammonia losses	-149	-170	*14*
Nitrogen balance (soil surface balance)	Denitrification, leaching and accumulation in soils	70	64	*-8*

Source: Own calculations with RAUMIS (2016).



Source: Own calculations with RAUMIS (2016).

Map 2
Regional nitrogen soil surface surplus (2025)

[5] Based on the developments during the last 20 years, the Thünen Baseline 2015 – 2025 assumes that nitrogen use efficiency of mineral fertilizers increases by 0.25 percentage points per year, and by 0.8 percentage points per year for organic fertilizers.

Map 2 provides an overview of regional nitrogen soil surface surplus until 2025. Regional nitrogen balances are to a large extent influenced by the quantities of regionally produced manure and energy maize. The livestock densities vary significantly, and while the average value is 0.9 livestock units (LU) per ha, stocking rates exceed 2 LU/ha in some areas (e.g. in the northwest of Germany). High nitrogen inputs from organic fertilizers are projected especially for the northwestern part of Germany and some regions in Schleswig-Holstein and Bavaria. While nitrogen input from organic fertilizers is on average around 94 kg N/ha UAA, values exceed 300 kg N/ha UAA regionally due to intensive livestock production (e.g., in Lower Saxony). In these regions, average nitrogen surpluses can be exceeded significantly with values of more than 80 kg/ha UAA.

Ammonia is one of the most important airborne pollutants. Directive 2001/81/EC of the European Parliament and the Council on National Emission Ceilings for certain pollutants (NEC Directive) stipulates a reduction of ammonia emissions in Germany to less than 550,000 t after 2010. The European Commission already suggested further reductions of up to 39 % until 2030 on the basis of 2005 emissions (implying a reduction of ammonia emissions to approximately 415,000 t). Figure 7 provides an overview of the past and projected development of ammonia emissions in Germany. Using new emission factors for mineral fertilizers, between 2010 and 2014 the emissions exceeded the NEC emission ceiling by 90 to 125 kt. The reduction of livestock numbers in the eastern part of Germany in the early 1990s, the continuous decrease of cattle numbers and technical progress with respect to the management of organic fertilizers all have contributed to the decrease of ammonia emissions in the past. Since 2010, emissions from livestock are slightly increasing. Emissions from biogas residues stemming from anaerobic digestion of energy plants are not considered in the NEC limit, but will be included in the 2030 objective. The projections thus highlight that additional measures for ammonia reductions will be necessary to ensure full compliance with legal emission limits. The reduction targets discussed for 2030 are even more ambitious, because the biogas sector has significantly expanded since the year 2005, the basis for calculating the new reduction targets.

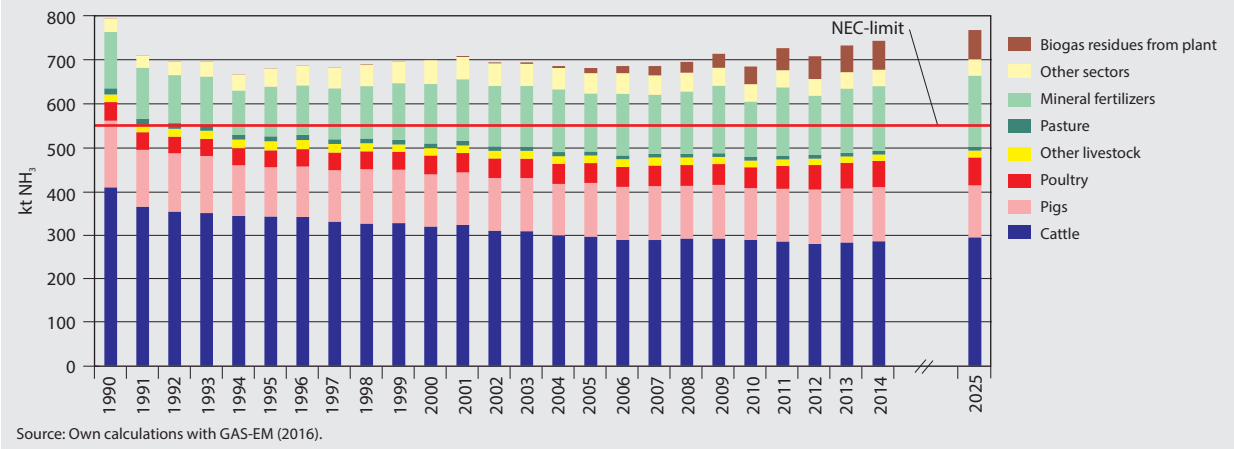
Greenhouse gas emissions will increase by 6 % compared to 2005, especially due to the rise in cattle numbers. According to the so-called 'effort sharing decision' (406/2009/EC), an average reduction of 14 % compared to 2005 emissions is required for German sectors not included in the emission trading. The projection shows that additional actions in the farm sector are required to contribute to the intended emission reductions.

5 Coupled payments and Single Farm Payment reform in other EU member states

Important elements of the latest CAP reform, like the internal convergence of direct payments within the Member States and the changes to coupled payments, do not directly affect German farmers, as the system of regional per ha payment rates was already implemented in the past, and the abandonment of coupled payments has been confirmed for the new CAP period. However, as these reforms could potentially have significant impacts on the profitability of production systems in other EU member states, this might indirectly affect the relative competiveness of Germany farmers. The next section looks in detail at beef cattle farms, which will be particularly affected by the changes in the payment schemes, followed by an analysis of the impact of an abolishment of the voluntarily coupled payments in all EU member states.

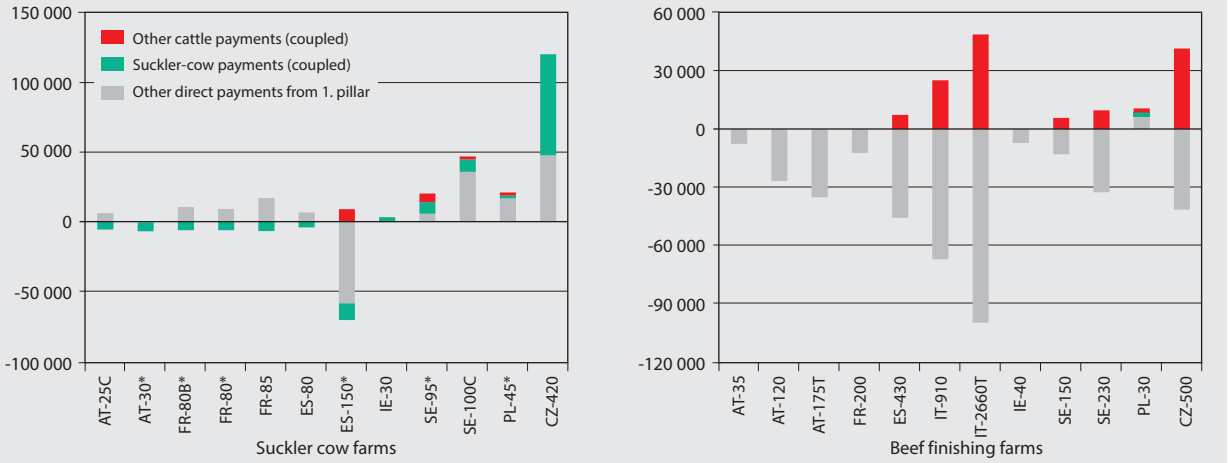
5.1 Impact of the CAP-reform on cow-calf and beef finishing farms in selected EU-member states

The previous sections were dealing with rather aggregated model results which cannot reflect differences between farm types in great detail. Due to the fact that policy changes in the European CAP can be expected to particularly affect beef



Source: Own calculations with GAS-EM (2016).

Figure 7
Development of ammonia emissions in Germany



* With finishing of own weaners.
The farm names on the y-Axis have the following syntax: country prefix plus the number of suckler cows or the number of finished beef cattle per year.
AT: Austria. FR: France. ES: Spain. IE: Ireland. IT: Italy. SE: Sweden. PL: Poland. CZ: Czech Republic.

Source: Own calculations with TIPI-CAL (2015).

Figure 8
Payment changes in EUR per farm, 2025 compared to 2014

farms (cow-calf and beef finishing), a special analysis using the typical farms from the agri benchmark Beef and Sheep Result Data Base was carried out. Farms with suckler-cows and beef finishing used to enjoy relatively high payment levels through coupled suckler-cow payments and/or decoupled Single Farm Payments (SFPs), the latter based on the historic reference from the years 2000 to 2002. With the present CAP-reform, suckler-cow payments are reduced or abolished and SFPs are transferred into per hectare payments. The change in payment type leads to significant payment losses for beef finishing farms in those countries where the decoupled payments were mainly disbursed as a SFP (Belgium, France, Greece, Ireland, Italy, Netherlands, Austria, Portugal, Spain, Scotland, Wales). In contrast to those countries where the transfer had already been completed by 2013/14 (England, Finland, Germany), it cannot be expected that rising beef prices will compensate for the loss of payments. This is the main reason why several member states re-introduced coupled payments for beef production.

As a consequence, the analysis focuses on those member states which are likely to be most affected by the changes listed above. Figure 8 shows the changes in payments in selected suckler-cow and beef finishing farms.

The following main conclusions can be drawn from the analysis:

- The changes in the payment systems tend to benefit farms with high proportions of grassland and low stocking rates and worsen the economic situation of farms with high shares of arable land and high stocking rates.
- The newly introduced voluntary coupled support payments for suckler cows and other cattle cannot compensate for the reduction of SFPs.
- The regulation on the first hectares in France result in a stabilisation of incomes in farms with less than 100 hectares.
- The development of the profit per labour unit reflects the situation described above: mainly positive in the cow-calf farms, mainly negative in beef finishing farms.
- The negative impact of the policy changes on the finishers in the EU-countries improves the relative competitive position of the German beef finishers, mainly in terms of a cash flow deficit and the delay of necessary investments on the side of their EU-colleagues.
- In contrast, the German cow-calf producers seem to lose competitiveness against at least some of the cow-calf farmers in other EU member states.
- However, it can be expected that the losses in beef finishing will be passed on to cow-calf producers in terms of lower weaner prices, reducing to a certain extent the gains shown above.

5.2 Implications of a complete de-coupling of direct payments in the EU

The implementation of measures under the voluntary coupled support scheme results in approximately 4.16 billion Euros of sector or region specific support. Almost 90 % of these payments accrue to five sectors, namely beef and veal (41 %), milk and milk products (20 %), protein crops (11 %), sheep and goat meat (12 %) and sugar beet (4 %). This sectoral focus is closely linked to the structure of the agricultural sector in the member states that make the most use of this instrument, France, Spain, Italy, Poland and Romania. Together, these five countries account for roughly 70 % of total voluntary support payments.

As the Baseline projection assumes a continuation of current policies up to the year 2025, a supplementary scenario was defined and analyzed. This scenario assumes a complete de-coupling of the voluntary coupled support

Table 3
Supply in 2025 following a complete de-coupling of direct payments

	Beef from suckler cows	Sheep and goat milk	Sheep and goat meat	Protein crops	Sugar beet
			in 1 000 tons		
EU-28	**4 782**	**4 366**	**750**	**2 027**	**112 432**
	-4.5 %	***-1.9 %***	***-1.0 %***	***-6.6 %***	***-0.9 %***
EU-15	**4 530**	**3 491**	**645**	**1 548**	**91 143**
	-4.4 %	***-2.1 %***	***-0.8 %***	***-4.7 %***	***0.1 %***
Germany	275	55	16	230	27 638
	4.7 %	*0.8 %*	*-0.4 %*	*1.0 %*	*0.1 %*
France	1 699	948	72	58	25 509
	-8.2 %	*-3.6 %*	*-0.6 %*	*-29.3 %*	*0.7 %*
Spain	782	1 059	154	499	3 030
	-8.8 %	*-3.0 %*	*-0.5 %*	*-7.4 %*	*-1.9 %*
Italy	51	254	11	105	3 671
	-4.7 %	*-0.4 %*	*-2.6 %*	*-3.3 %*	*-3.4 %*
EU-13	**252**	**875**	**105**	**479**	**21 290**
	-6.5 %	***-1.1 %***	***-2.1 %***	***-12.2 %***	***-5.0 %***
Poland	65	8	1	220	10 981
	-5.3 %	-15.0 %	-22.4 %	-7.9 %	-7.1 %
Romania	0.3	728	88	80	536
	7.4 %	-0.7 %	-1.2 %	2.3 %	-4.2 %

* Percentage deviation to the Baseline, i.e. a situation where the voluntary coupled support payments are maintained up to 2025.
Source: Own calculations with CAPRI (2015).

payments and analyzes the effects on production, prices and incomes in the EU28 for the year 2025.

Table 3 highlights the implications of a complete de-coupling of direct payments for the EU28 as well as selected countries and products. The values depicted in Table 3 reflect the supply quantity in 2025 for the scenario of a complete de-coupling, as well as the relative difference to the supply situation in the Baseline (i.e., a situation where the voluntary coupled support payments are maintained).

At the EU28 level the impacts of a complete de-coupling are moderate. For individual member states, the most discernible implications arise in France and Spain, i.e., two countries that account for roughly 41 % of total payments under the voluntary coupled support scheme. This regional focus is also reflected in the sectoral results with the most noticeable differences accruing to suckler cows and protein crops. These moderate decreases in supply result in a slight increase in prices for beef and protein crops. The funds released by the complete de-coupling of payments are transferred to the basic payment scheme, thus the increase in prices only results in a modest increase (+0.94 %) in EU incomes.

For Germany, the only member state without voluntary coupled support payments in the Baseline, effects of a complete decoupling of payments by the other EU member states are generally small and slightly positive. These effects are triggered by changes in prices at the EU level resulting from a moderate decline in production in the other member states. The greatest benefits arise in the beef sector. Nevertheless, while average agricultural incomes remain fairly stable due to the general transfer of funds to the basic payment scheme, deviations in agricultural incomes for farms specialized in beef production can be more pronounced.

6 Sensitivity of results to exchange rate developments

The assumption concerning the development of the exchange rate of Euro and US-Dollar is characterized by high uncertainty. At the same time, it has a relatively large impact on a wide range of projection results. Based on the OECD-FAO Outlook (2015), the Thünen Baseline 2015 – 2025 assumes that the Euro remains comparatively weak at an exchange rate of 1.15 $/€ in 2025. While several market observers expect a further weakening of the Euro at least in the short- to medium-term, the EU Commission (2015), based on projections by IHS Global Insight, assumes an appreciation of the Euro and an exchange rate of 1.37 $/€ in 2025 for their projection of agricultural markets development until 2025.

A sensitivity analysis was implemented to illustrate the importance of the exchange rate assumption for the results of the Thünen Baseline. The Scenario "Strong Euro" has the same assumptions and framework conditions as the Baseline, with the exception of the exchange rate, which was fixed at 1.37 $/€ in 2025. For the German agricultural sector, this implies that the prices for many products decrease, especially for those products where trade is important for the

market balance. Intermediate inputs with a high share of imports (e.g., imported feedstuff, oil-price dependent energy inputs and fertilizers) will become less expensive from the view of the German producers, while at the same time many output prices will also decrease markedly. The impact on the German agricultural sector and the extent to which individual farms are affected depends on the size of price effects and the importance of the respective cost and revenue items for individual producers.

The assumed appreciation of the Euro leads to a decrease of market and farm gate prices in the EU. The impact is strongest for crop products, where prices are strongly influenced by world market developments as import protection is relatively low (Table 4). While milk prices are also strongly affected due to the high dependency on exports, the effect on beef and pork prices is somewhat lower.

Table 4
Price development of selected products in the Scenario „Strong Euro" in comparison to the Baseline

Product	Change in % to Baseline
Wheat	-15
Milk	-13
Beef	-8
Pork	-7
Soy meal	-16

Source: Own calculations with AGMEMOD (2015).

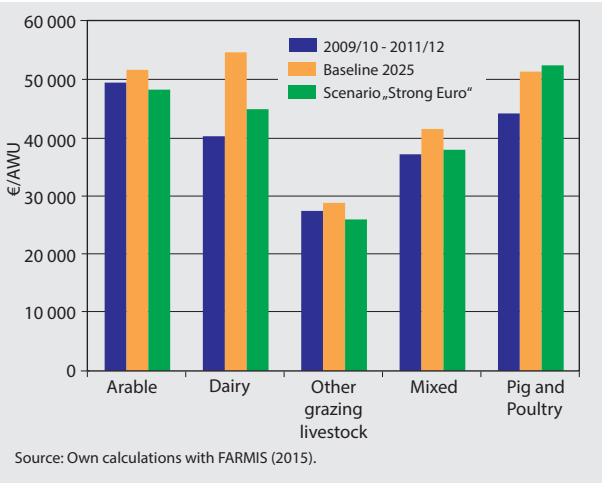
Table 5
Development of land use and production in the Scenario „Strong Euro" in comparison to the Baseline

	Unit	Scenario „Strong Euro" in 2025 absolute	*Relative change to 2010 %*	*Relative change to Baseline %*
Land use				
Cereals	1 000 ha	6.379	*-3*	*-2*
Root crops	1 000 ha	644	*2*	*3*
Pulses	1 000 ha	148	*63*	*-13*
Maize silage	1 000 ha	933	*-11*	*-4*
Other arable fodder	1 000 ha	753	*0*	*7*
Energy maize	1 000 ha	1 087	*34*	*1*
Set-aside	1 000 ha	418	*71*	*14*
Cattle	1 000 head	12 480	*-2*	*-2*
of which: Dairy cows	1 000 head	3 829	*-9*	*-14*
Milk production a)	1 000 t	31 955	*6*	*-14*
Beef and veal production	1 000 t	1 067	*-13*	*-6*

a) Actual fat and protein content.
Source: Own calculations with RAUMIS (2015).

While the level of individual crop production activities hardly changes (Table 5), significant impacts are projected for milk production. Compared to the Baseline, milk production is reduced by 14 %, and the number of dairy cows decrease by 600,000. This contributes to the decrease of beef production by 6 %.

The negative effects of lower output prices, which are not fully compensated by partly lower input prices, dominate income effects. On average, farm income in the Scenario "Strong Euro" is 10 % lower than in the Baseline. However, there are significant differences between farm types (Figure 9). Dairy farms are affected most, with FNVA/AWU decreasing by 22 % compared to the Baseline, which is still above the level of the base period. While the income of arable, other grazing livestock and mixed farms is 7 % lower than in the baseline, pig and poultry farms profit from lower prices for feedstuff and energy-intensive inputs and can expect a small increase in income (+2 %) despite lower product prices.



Source: Own calculations with FARMIS (2015).

Figure 9
Development of farm net value added per agricultural work unit in the Scenario „Strong Euro", by farm type (in real terms in prices of 2010)

7 Discussion and conclusions

The Thünen Baseline is based on a number of assumptions concerning the development of factors and variables not explicitly covered in the models. Some of the areas concerned are characterized by high uncertainties:

- The assumption concerning the development of the exchange rate of Euro and US-Dollar is characterized by high uncertainty. Its implications are illustrated and discussed in Section 6.
- Against the background of the recent decline of revenues in oil-exporting countries and the lower economic growth in China, the projections of the OECD-FAO (2015) for the development of world agricultural markets, which provide the basis for the Thünen Baseline, may prove to

be overly optimistic, especially for livestock products at least in the mid-term.
- For some time now, stricter regulations to improve the protection of water bodies (e.g., adjustments to the fertilizer ordinance) are being discussed in Germany. Such regulations could increase costs especially for farms with intensive livestock production. However, as no final policy decisions had been made at the time of analysis, the potential implications are not taken into account in the Thünen Baseline 2015 – 2025.
- Potential impacts of the current migration processes in Germany (e.g., increase in overall demand due to population growth, increase of product-specific demand, e.g., for lamb) are not accounted for.

All the models used for this study are based on a detailed depiction of policies and economic relationships and interdependencies in agricultural production, and are continuously being developed further. Still, due to specific model characteristics and restricted data availability, it is inevitable that some policy instruments or new technical developments cannot be modelled, or only in a simplified way. The most important restrictions in this respect are:
- The static models are not explicitly taking into account short-term fluctuations, e.g., of world market prices. During the last years, especially world market prices of milk fluctuated markedly within a single year, often due to climate events in some export countries. These effects are not covered.
- The end of the milk quota scheme in 2015 represents a structural break. The impacts are difficult to project, especially during the first years. Higher price fluctuations may occur, in particular if climatic events or demand shifts occur during this period. These phenomena cannot be projected with the model system applied, which simulates equilibrium markets.

In the Thünen Baseline 2015 – 2025, a favourable outlook for world agricultural markets in combination with a weak Euro contribute to the positive development of farm incomes in Germany. The projections of the Baseline scenario also indicate a number of issues that could remain or emerge as key challenges for the agricultural stakeholders and agricultural policy in the medium-term:
- A sensitivity analysis highlights the extent to which export-oriented sectors (e.g., the milk sector) depend on macro-economic developments. In addition, the developments of the dairy sector serve as a reminder of the challenges which volatility, disequilibria and adjustments processes pose for many stakeholders even if medium-term prospects are positive. This indicates the need for farmers and policy makers to further strengthen contingency planning and to implement additional measures that increase the resilience of farms.
- Farm incomes of extensive cattle production systems are projected to remain low. These systems often contribute to a number of societal objectives and public goods (e.g., landscape management, environmentally and animal friendly production systems). Therefore, careful monitoring of the evolution of these systems is needed to be able to act timely if undesired developments occur.
- While the currently planned implementation of voluntary coupled support payments in other EU member states has only small impacts on German agriculture, the increasing renationalisation of agricultural policy (via national implementation options for the CAP) bears the danger of distorting competitiveness. Policy makers should continue to watch and prevent any related developments that could endanger a level playing field within the EU.
- Ammonia emissions are projected to continue exceeding current national emission ceilings, and planned future targets will be missed by a significant margin. Additional measures for ammonia reductions will be necessary, including curbing ammonia emissions from biogas residues.
- Regional nitrogen soil surpluses remain excessively high. Significant changes to current production practices and the policy frameworks at different governance levels are required to reduce these surpluses.

The Thünen Baseline 2015 – 2025 provides the basis for subsequent policy impact analysis. Potential future studies include the analysis of the impacts of adjustments to the fertilizer ordinance, as well as the investigation of a CAP reform after 2020.

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Annex

The MAGNET model (Modular Applied GeNeral Equilibrium Tool) is a multiregional, general equilibrium model covering global economic activity as well as single countries and regions (Woltjer and Kuiper, 2014). It provides a detailed representation of the interactions between agriculture, the input sector and the food industry as well as commercial economics and the service sector, and accounts for the intra- and inter-regional linkages between markets and actors. MAGNET is based on a simultaneous system of non-linear equations, which ensures an equilibrium in the model and the identity between expenses and income. Linking supply and demand, the model endogenously determines prices and quantities that lead to balanced product and factor markets. Trade modelling differentiates products by origin, based on the Armington assumption (Armington, 1969). Additionally transport requirements and bilateral trade flows are considered (Hertel and Tsigas, 1997). MAGNET is built on the GTAP database 8.2 [6] and is updated regarding GDP, population, capital and yield growth as well as changes in the market for skilled and unskilled labour. MAGNET extends the GTAP database in the fields of grain and oilseeds and takes 66 sectors into account. Furthermore, MAGNET allows for a more detailed illustration of the common EU agricultural policy and includes, for example, milk and sugar quotas as well as the production of biofuels and associated policies. For a description of the model extension see Woltjer and Kuiper (2014) and Junker et al. (2014).

AGMEMOD (http://www.agmemod.eu) is a partial, multinational, multiple-product model based on econometrically estimated parameters and a recursive-dynamic approach. It covers production, consumption, trade, inventories and prices for 20 agricultural and 17 processing sectors of the EU member states, accession candidates and other neighbouring countries. The German model provides a detailed representation of grains and oilseed, potatoes, cattle and calves, sheep, pigs, poultry and milk as well as their processed products (Salamon and von Ledebur, 2005). Coupled with each other and to the appropriate world markets, the models create a combined EU Model for all EU Member States (van Leeuwen et al., 2011). In the present model, Version 7, the world markets are endogenous and calibrated to fit to the OECD price projections (OECD-FAO, 2015). The database covers the years 1973 to 2014.

CAPRI is a comparative-static partial equilibrium model, which iteratively links regional or farm-level supply models with a global multi-commodity market model (Britz and Witzke, 2014 [7]). It is used for regional and/or global policy impact analyses on production, incomes, supply and demand as well as trade and the environment. The supply models afford a detailed representation of the European agricultural sector and can be used at different aggregation levels. The higher aggregated level comprises 270 regional models at

[6] A detailed documentation is available on the GTAP-website: https://www.gtap.agecon.purdue.edu/databases/v8/v8_doco.asp

[7] Additional information is available at http://www.capri-model.org

NUTS2 level, whereas a more detailed level includes roughly 2500 farm-type models (Gocht and Britz, 2011). In the supply models, supply and yields are endogenous and based on different degrees of technological progress. The available arable area is calculated endogenously based on land rents with the possibility of substituting arable land and grassland. Environmental indicators are calculated at the regional level. The market model depicts agricultural trade and is based on profit and consumption maximizing behaviour of producers and consumers, respectively. Equilibrium is reached by iteration where the market model passes prices to the supply models, which in turn pass production effects back to the market model.

The regionalized agricultural and environmental information system RAUMIS (Henrichsmeyer et al., 1996) is employed to analyse medium and long-term agricultural and environmental policy impacts. The model consolidates various agricultural data sources with the national agricultural accounts as a framework of consistency. It comprises of more than 50 agricultural products, 40 inputs with exogenously determined prices, and reflects the German agricultural sector with its sector linkages. According to data availability, the spatial differentiation is based on administrative bodies, i.e., 326 regions (NUTS III level) treated as single "region farms." Production adjustments caused by changes in the general framework conditions such as agricultural policies are determined by using a comparative-static mathematical programming approach that maximizes a non-linear objective function for regional farm income. The model is calibrated to observed production decisions using a positive mathematical programming approach (Howitt, 1995; Cypris, 2000). Model base years are available in four-year intervals from 1979 to 2010.

Farm level aspects are covered by FARMIS, a process-analytical programming model for farm groups (Bertelsmeier, 2005; Offermann et al., 2005; Deppermann et al., 2014) based on information from the Farm Accountancy Data Network (FADN). Production is differentiated for 27 crop and 15 livestock activities. The matrix restrictions cover the areas of feeding (energy and nutrient requirements, calibrated feed rations), intermediate use of young livestock, fertilizer use (organic and mineral), labour (seasonally differentiated), crop rotations and political instruments (e.g., set-aside and quotas). The model is calibrated to observed production decisions and elasticities using a positive mathematical programming approach. For this study, the model specification is based on data from the accounting years 2009/10, 2010/11 and 2011/12. The farm sample was stratified by region, type, system and size, resulting in 646 farm group models (of which 90 groups represent organic farming). Results are aggregated to the sector using farm group specific weighting factors. To account for structural change, econometrically estimated farm exit probabilities were applied to the aggregation factors for the projection. Within regions, farms compete for land on rental markets (Bertelsmeier, 2005).

TIPI-CAL is an accounting model applied within the framework of the global agri benchmark network (www.agribenchmark.org). It represents in detail production systems, technology and physical interrelationships at farm level. As part of the Thünen Modelling Network, this model is mainly used to analyse the impacts of changes in policy, economic, and regulatory framework on selected farms, and to investigate the financial consequences of different alternative farm adjustments and development strategies. The database comprises typical farms, which are established based on a globally harmonised Standard Operating Procedure together with more than 40 partners in different countries. Data are collected annually, and the validation of results and specification of adjustment strategies is done in cooperation with farms and advisors.

For the projection of greenhouse gas and ammonia emissions from agriculture in the Baseline scenario, the Thünen Modelling Network is linked to the model GAS-EM. GAS-EM is a modular spreadsheet programme to estimate gaseous and particulate emissions from animal agriculture and crop production including professional horticulture. GAS-EM was first described in Dämmgen et al. (2002) and has been developed further continuously since then. The assessment of emissions within GAS-EM uses the definitions of agriculture according to the definitions of IPCC. All calculation procedures involved are based on the rules provided by the respective conventions and the current guidance documents. In addition, the German agricultural inventory uses differing methods in specific circumstances in order to improve the description of national emission conditions. The results are based on the calculation methods implemented at the end of 2015, which were also used to generate the official National Emission Inventory Reports for Germany (Haenel et al., 2016). For this study, the projections of gaseous emissions in 2025 are based on the RAUMIS projections for land use and livestock numbers in the Baseline scenario.