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Austrian Agriculture 2030 – 2040 – 2050

Scenarios and Sensitivity Analyses on Land Use, Crop and Livestock Production

Franz Sinabell, Katharina Falkner, Gerhard Streicher (WIFO), Martin Schönhart, Erwin Schmid (INWE-BOKU), Christian Fritz (HBLFA Raumberg-Gumpenstein)

Research assistance:
Dietmar Weinberger (WIFO)

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Although the agricultural sector plays a minor economic role in the national economy, macroeconomic impacts are relevant for the achievement of climate goals due to forward and backward linkages with sectors in the food value chain. Agricultural land use also has some positive external effects or spillovers to other sectors, such as tourism. The aim of the study is not only to estimate the expected adaptation and mitigation costs in the sector to achieve the specific climate policy goals, but also to quantify the economic impacts. The relevant variables are the effects on GDP, gross value added, output, land use and employment. The effects on food and energy security are assessed as complementary parameters. The results show that a significant reduction in emissions from the agricultural sector is only possible with a significant reduction in its output. This implies that economic activity in agriculture, in industries providing inputs and in industries receiving outputs will decline in such a scenario. Negative consequences for consumers can be avoided if an increase in imports compensates for the loss of production in Austria.

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1 Introduction and overview of study

The topic of this analysis is to present scenarios of the Austrian agricultural sector for the period 2020 to 2050. The main interest are projections of agricultural production and their economic consequences for other sectors in the economy. The purpose of the analysis is to inform the general public and policy makers about likely pathways of the Austrian agricultural sector in a quantitative manner. Furthermore, this information can be used to project emissions of the sector that are consistent with expected market conditions and existing climate regulations.

The report is structured as follows: The regulatory context is presented in the next chapter. Thereafter likely sector developments are outlined, followed by a short summary of the international situation on agricultural markets. Then, the agricultural sector model for the analysis is introduced before major assumptions are stated together with brief scenario descriptions. A discussion of the model results and the major findings of the sensitivity scenario are presented next.

Because there is considerable uncertainty about future situations on international markets, several scenarios are analysed. The scenario "with existing measures" (WEM) takes into account the currently existing legal and regulatory framework, anticipated changes of the agri-environmental program and assumptions about market conditions as perceived in mid 2022. In the Appendix the detailed results of the scenarios are presented along with supplementary material that helps to interpret the results of the analysis.

2 The regulatory context

2.1 The international context

The potential hazards due to emissions of greenhouse gases (GHG), among them carbon dioxide (CO_2) and methane (CH_4), have become evident during the last decades of the previous century. The UN took the initiative to save the global common atmosphere by initiating the United Nations Framework Convention on Climate Change (United Nations, 1992). Its main objective is the "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system". The Kyoto Protocol, which operationalizes this convention, was adopted on 11 December 1997 (United Nations, 1997). It entered into force on 16 February 2005 owing to a complex ratification process. The convention itself only asks those countries to adopt policies and measures on mitigation and to report periodically. In its Annex B, the Kyoto Protocol sets binding emission reduction targets for 37 industrialized countries and economies in transition and the European Union[1]. In the first "commitment period" the target was a 5 per cent emission reduction compared to 1990 levels over the period 2008–2012.

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[1] Adopted in the EU with Council Decision 94/96 EC of 15 December 1993 concerning the conclusion of the United Nations Framework Convention on Climate Change.

Complying with this convention, EU Member States make considerable efforts to reduce CO_2 and other greenhouse gas (GHG) emissions. In 2007 the EU adopted the legally binding target of reducing greenhouse gas emissions by 20 % by 2020 compared to 1990. In addition, the share of renewable energy sources of gross final energy consumption was planned to increase to 20 % EU-wide by 2020. Furthermore, energy efficiency was planned to improve by 20 % compared to a "business as usual" scenario. In the same year, Austria implemented the "Climate Strategy 2007" with a commitment to achieve the Kyoto-Targets for the period 2008 to 2012 (BMLFUW, 2007).

For the longer run, a coherent concept was presented in 2011 in the "Roadmap for the transition to a competitive low-carbon economy by 2050" by the European Commission[2]. A gradual transformation towards a low-carbon economy by 2050 is to be accompanied by an EU-internal greenhouse gas emission reduction programme with the objective to reduce emissions in all sectors by at least 80 % compared to 1990. In the agricultural sector, greenhouse gas emissions are to be reduced within the range of -42 % to -49% by 2050. Efficiency improvements, careful use of fertilisers and animal feed, biogas production and local diversification as well as product marketing were proposed as possible measures to attain the reductions. In addition, new processes should contribute to accumulating carbon in soils and forests. EU interim targets were set to reduce overall greenhouse gas emissions by 40 % by 2030 and by 60 % by 2040. The overall 2030 target was established in October 2014 in the climate and energy policy for 2030.

In order to attain the objectives defined in 2007, the EU put into force regulations on "effort sharing", the emission trading system (ETS)[3], energy efficiency, and renewable energy sources in 2009. A novelty introduced by these legal acts are specific targets. The Effort Sharing Decision[4] defines upper bounds of emissions for those sectors that are not part of the European Emission Trading System (EU-ETS). For such sources (e.g. transport, buildings, agriculture) the EU's climate and energy package sets a reduction target of greenhouse gas emissions by around 10 % by 2020 compared with 2005. Because Austria is relatively wealthy, this country was obliged to reduce greenhouse gas emissions in sectors outside of ETS by 16 % between 2013 and 2020 compared with 2005. During the 8-year commitment period, a linear target path was to be adhered to. The maximum permissible levels of emissions in the starting year 2013 were calculated on the basis of the average emissions of the years 2008-2010 from sources outside ETS.

As a follow-up to the Kyoto Protocol of 1997, the UN COP21 Climate Conference was held in Paris. Its result, the Paris Agreement is the legally binding international treaty, which sets the

[2] Communication from the commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions Brussels, A Roadmap for moving to a competitive low carbon economy in 2050 from 8.3.2011, COM(2011) 112 final.

[3] Directive 2003/87/EC of the European Parliament and of the Council of 13 October 2003 establishing a system for greenhouse gas emission allowance trading within the Community and amending Council Directive 96/61/EC.

[4] Decision No 406/2009/EC of the European Parliament and of the Council of 23 April 2009 on the effort of Member States to reduce their greenhouse gas emissions to meet the Community's greenhouse gas emission reduction commitments up to 2020

frame for global action on climate change mitigation (United Nations, 2015). It was adopted in December 2015 and has been signed by 196 countries worldwide, including Austria. Its goal is to limit global warming to well below 2°C and preferably to 1.5°C compared to pre-industrial levels as well as the reduction of global greenhouse gas (GHG) emissions to net-zero by 2050. Signing countries commit to define nationally determined contributions (NDCs) containing country-specific GHG emission reduction targets, which are reviewed and updated on a 5-year basis.

The European Union's ambitions for climate action is laid down in the European Green Deal (European Comission, 2019). It is a comprehensive roadmap, which characterizes the EU's ambitions to make its economy climate-neutral by 2050. The framework comprises several policy strategies, regulations and action plans with measures for transport, energy, agriculture, buildings, and industries. For the EU agri-food system, the Common Agricultural Policy (CAP) is considered the main policy lever to reduce its climatic and ecological footprint. To reduce the emissions from agriculture and to support the sector to adjust to changing climate conditions is among the objectives of the CAP Strategic Plan, the agricultural policy for the period 2002 to 2007 (European Parliament and Council, 2021). Furthermore, additional ambitious environmental targets for the agricultural sector were presented in the Farm-to-Fork-Strategy (European Commission, 2020a). Regarding GHG emission reduction targets, an agreement was found to implement a modified proposal of the effort sharing regulation (European Commission, 2021a) on 8th of November 2022[5]. According to this agreement, Austrian sectors that are not part of the EU-ETS – which includes agriculture – will have to reduce GHG emissions by 48 % compared to 2005 by the year 2030. For the whole EU the reduction requirement is 40 %.

2.2 The national climate policy context

In national law Austria implemented the Climate Protection Act in 2011[6]. To reach the targets defined in the Effort Sharing Decision, the Austrian Climate Protection Act developed a framework for establishing sector specific measures that are considered to contribute to lower emissions. Specific emission reduction objectives were defined for all relevant sectors – which includes agriculture – in a separate regulation (national law BGBl. I Nr. 94/2013) following the EU Decision 162/2013/EC of 26th March 2013 on determining Member States' annual emission allocations for the period from 2013 to 2020 pursuant to Decision No 406/2009/EC.

The annual maximum GHG emissions for Austrian agriculture were defined to be 8.0 mio. t CO_2eq for the period 2013 to 2015 and 7.9 mio. t CO_2eq for the period 2016 to 2020.[7] Targets

[5] https://www.consilium.europa.eu/en/press/press-releases/2022/11/08/fit-for-55-eu-strengthens-emission-reduction-targets-for-member-states/

[6] KSG, BGBL. Nr. 106/2011; a follow-up legislation is still due by time of writing this report.

[7] The original sector classification according to the Climate Strategy 2007 (BMLFUW 2007) was slightly adapted in order to improve accountability of different sectors. The sector classification according to the Climate Protection Act for the

for all non-ETS sectors (including agriculture) are set to a decline in GHG emissions from 52.6 in 2013 to 48.8 mio t CO_2eq in 2020 (national law BGBl. I Nr. 128/2015). Due to a change in the UN accounting methodology effort sharing targets are to be reduced by 1 mio t CO_2eq in 2020 to 47.8 mio t CO_2eq (according to Decision 1471/2017/EC; see Anderl et al., 2018). The target of non-ETS emissions in Austria for 2030 – according to the Effort Sharing Decision from 2009 – was 36.7 mio t CO_2eq (-36% compared to 2005 which is equivalent to -28% compared to 2016).

To achieve these targets, policy interventions at various levels including regulations and economic incentives such as information and awareness campaigns and support programmes were seen as necessary. Initiatives in Austria included a package of measures for the years 2013 and 2014 that was agreed upon by the Federal Government and the Länder (BMLFUW, 2015). The implementation of these measures was reviewed by a working group in spring 2014. Subsequently, additional measures for the period 2015-2018 were agreed by the Federal Government and the Länder and were eventually adopted by the Council of Federal Ministers (BMLFUW, 2015). Corresponding resolutions of the Provincial Governors' Conference were passed on both action plans.

A consultation process targeted at the general public was initiated in the spring of 2016 with the publication of a Green Paper. It covered key principles such as the status quo of CO_2 emissions, energy consumption and future developments (BMWFW & BMLFUW, 2016). In early 2018 a draft version of the Austrian climate and energy strategy was presented for public consultation among stakeholders and the general public. In May 2018 the Austrian Climate and Energy Strategy (dubbed "#mission2030") was adopted by the Austrian Federal Government. It aimed at setting the framework for the Integrated Energy and Climate Plan for Austria, in which specific implementation measures for decarbonisation are finally set out (BMNT, 2019).

The currently relevant program of measures was developed between federal and Länder authorities in compliance with the Climate Protection Act. Not all measures are traditional environmental policy instruments like standards or regulations. Concerning agriculture, one policy instrument is particularly important, the Agri-Environmental Programme. It is co-financed by the EU as part of the Common Agricultural Policy's Programme of Rural Development. The current programme was put into force in December 2014 and will be effective until the end of 2022. This voluntary programme offers several measures that support farmers to adopt mitigation practices.

The target for Austria's reduction of GHG-emissions of the sectors not included in the EU-ETS is minus 48 % compared to 2005, as decided in the trilogue on 8th of Nov. 2022 (see previous section). How these reduction requirements are allocated among the relevant sectors which include agriculture is not yet determined. The sector specific reduction targets and measures to support their attainment will be specified in the upcoming climate protection law.

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period 2013-2020 provides for agricultural machinery to be included in the agricultural sector (previously room heating and other small-scale consumption).

Two recent for the agricultural sector and GHG emission relevant regulations are the directive to reduce ammonia emissions[8] and an update of the nitrate action programme[9]. By the time of writing this report, the industrial air emissions ordinance and the environmental impact assessment regulation are being revised. Both regulations will bring about stricter norms for large farms which will likely involve higher investments in emission reduction equipment.

3 Framework of the quantitative analysis

The development of the agricultural sector is mainly driven by the demand for farm commodities and public services, and by technological progress. Agricultural commodity markets have traditionally been focused on domestic markets. Since two decades they have become increasingly characterized by a reduction of trade impediments. Global demand for food and technological progresses are the main driving force of sector developments. The transmission of demand and supply takes place via prices which are assumed to be set on global markets. Given the small size of Austria within EU-28, the assumption can be made that any domestic supply or demand shift does not affect equilibrium prices in the common market.

In the past, many agricultural commodity prices were either set directly by policy makers or reflected heavy policy intervention (see details in the next chapter) such as the markets for milk and sugar until very recently. A reduction of farm commodity prices, initiated in 1992 in the EU (1995 adopted in Austria, as well) with a further bold step during the Agenda 2000 reform in 1999 and a further corroboration during the 2003 reform of the Common Agricultural Policy (CAP). Domestic prices of many important markets (grains and meat) have been near world market equilibrium during 2000 to 2006. Since 2007 EU markets have been exposed to the high price volatility that had been confined to world markets in the past.

Currently there are no signs that EU farm policy will intervene in markets as heavily as it did in past decades. Nevertheless, EU farm policy is concerned about price volatility and several EU member states have implemented schemes to help farmers to confine the consequences of volatile markets. Apart from this, existing foreign trade rules restrict the flow of agricultural commodities (e.g. meat, sugar) and for many goods of the downstream sectors of agriculture (e.g. ethanol) levies raise internal market prices above world market levels.

The demand for agricultural commodities has surged in during the last two decades due to two major developments:

- several states - including the EU - have implemented very ambitious targets for biofuels which require feedstocks that are produced on agricultural land;
- economic growth at a global scale has been relatively high during recent years (apart from the dip in 2008 and 2009) and a larger share of world population can afford more livestock products.

[8] Ammoniakreduktionsverordnung BGBl. II Nr. 395/2022

[9] Änderung der Nitrat-Aktionsprogramm-Verordnung BGBl. II Nr. 386/2022

Apart from demand for farm commodities, there is a significant demand for public goods which are provided by agriculture. This demand is still increasing and relevant for most production decisions in Austria. There are aspects that fall in two classes:

- the active provision of goods and services for which private markets do not exist (like open landscape, biodiversity), and
- the reduction of production intensities and emissions below the legally binding level of standards (e.g. support for organic farming, cultivation of winter cover crops).

To the extent that discretionary policy interventions in farm commodity markets were reduced over the last decade, programmes to stimulate the support of public goods which addressed the farm sector, have proliferated.

The framework of the analysis is given by four major assumptions

- The development on farm commodity prices is mainly driven by the demand for farm commodities and technological progresses. In affluent societies with low population growth, the overall volume of food consumption will be relatively constant. Therefore, changing demand trends affect mainly the composition of food components (e.g. substitution of red meat by white meat). The demand from domestic market is only one determinant in agricultural markets. Due to a growing global population with higher incomes the demand for food will be increasing, however at a slower pace than in the previous decade (OECD and FAO, 2022). Given that EU markets are globally integrated this development will have an impact on EU agriculture.
- Society in the EU will be willing to pay for non-commodity outputs of the agricultural sector in the future, however, the large increase in such a public demand that was observed at the begin of the century will come to a halt.
- Technical progress will further increase productivity, however, likely at a lesser scale than previously observed due to environmental programmes and regulations that limit the use of many inputs (including fertilizer, plant protection substances, seeds). New technologies such as those emanating from digitization (e.g. artificial intelligence, digital smart farming) will mainly safe labor, improve quality and reduce inputs such as fertilizer and pesticides. Its output increasing effect will be minor.
- In Austria, population and economy are likely to grow in the coming decades. One consequence is that more and more affluent people need more housing. The observed pressure to use agricultural land for residential and commercial purposes and the related infrastructure will therefore prevail.

These assumptions are made operational in using an agricultural sector model for Austria which was developed to evaluate farm policy changes. Given the partial character of the model, further assumptions must be made concerning the actual price levels. These are taken from publications focussing on market trends at EU-level.

4 Modelling the Austrian Agricultural Sector

In this chapter, we present an approach that strives to meet these challenges of forecasting agricultural production in a very detailed manner. The Positive Agricultural Sector Model for Austria (PASMA) was developed to estimate the impact of the 2003 CAP reform on selected agricultural and environmental indicators to measure rural/agricultural development. The model has been continuously improved since then (Kirchner et al., 2015). PASMA depicts the political, natural, and structural complexity of Austrian farming in a very detailed manner (Figure 1).

The structure ensures a broad representation of production and income possibilities that are essential in comprehensive policy analyses, i.e., development analysis. Data from the Integrated Administration and Control System (IACS), Economic Agricultural Account (EAA), Agricultural Structural Census (ASC), Farm Accountancy Data Network (FADN), the Standard Gross Margin Catalogue, and the Standard Farm Labour Estimates provide necessary information on resource and production endowments for 35 regional production units (i.e. NUTS-3) in Austria.

Consequently, PASMA is capable to estimate production, labour, income, and environmental responses for each single unit. Most production activities are consistent with EAA, IACS and ASC activities to allow comparable and systematic policy analyses with official, standardised data and statistics.

The model considers conventional and organic production systems (crop and livestock), relevant management measures from the Austrian Agri-Environmental Programme ÖPUL, and the support programme for farms in less-favoured areas (LFA). Thus, the two most important components of the programme for rural development are covered on a measure-by-measure basis. Apart from major components of the programme for rural development the complete set of CAP policy instruments is accounted for, as well. Both, the set of instruments before and after the 2013 reform can be modelled explicitly.

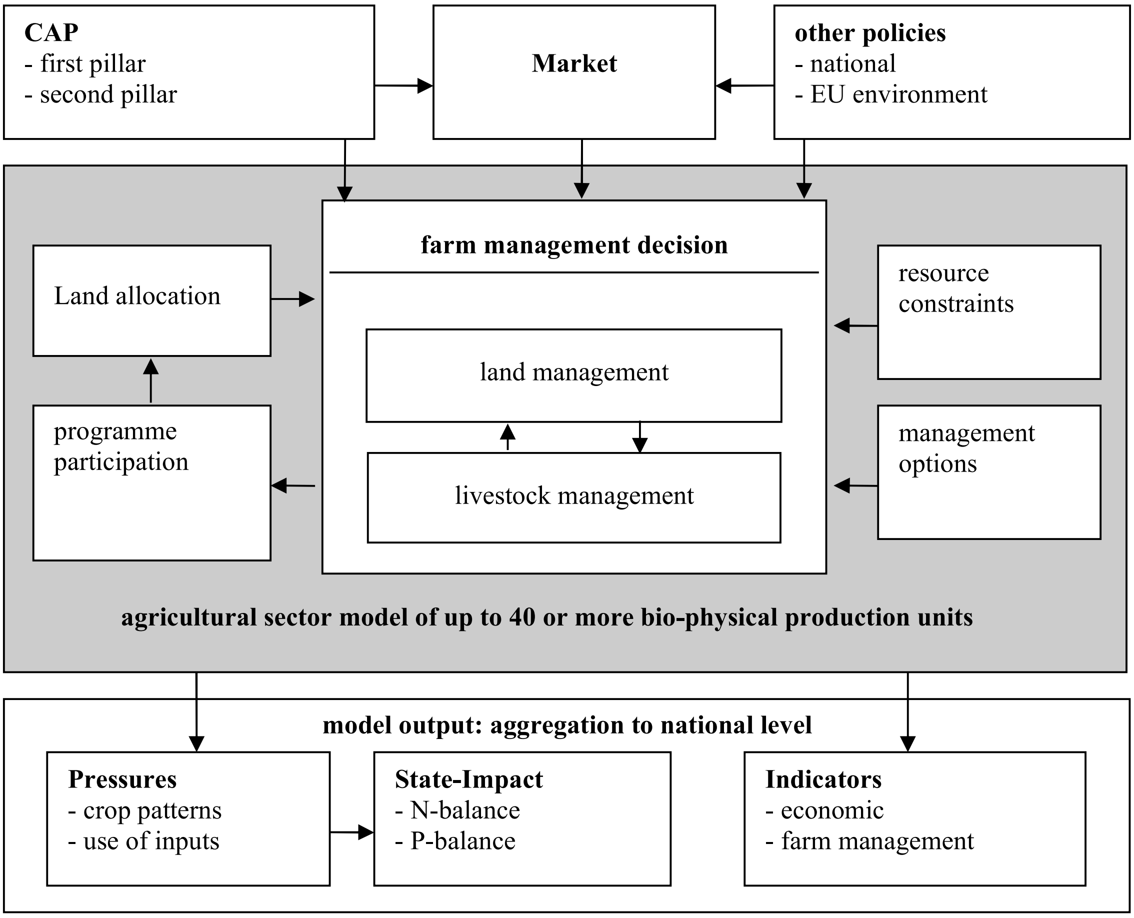

Figure 1: Structure of the agricultural sector model PASMA

Source: own construction.

The model maximises sectoral farm welfare and is calibrated to historic crop, forestry, livestock, and farm tourism activities by using the method of Positive Mathematical Programming (PMP). Howitt (1995) has initially published PMP and since then it has been modified and applied in several models e.g., Lee and Howitt (1996), Paris and Arafini (1995), Heckelei and Britz (1999), Cypris (2000), Röhm (2001), Röhm and Dabbert (2003). This method assumes a profit-maximizing equilibrium (e.g. marginal revenue equals marginal cost) in the base-run and derives coefficients of a non-linear objective function on the basis of observed levels of production activities.

Three major conditions need to be fulfilled:

(i) the marginal gross margins of each activity are identical in the base-run, and

(ii) the average PMP gross margin is identical to the average LP gross margin of each activity in the base-run. These conditions imply that the PMP and LP objective function values are identical in the base-run.

(iii) Another important condition needs to be made by assigning the marginal gross margin effect to either marginal cost, marginal revenue or fractional to both. In PASMA, the marginal gross margin effect is completely assigned to the marginal cost and consequently coefficients of linear marginal cost curves are derived.

In PASMA, linear approximation techniques are utilized to mimic the non-linear PMP approach (Schmid and Sinabell, 2005). Thus, large-scale models can be solved in reasonable time. In combination with an aggregation procedure, i.e., building convex combinations of historical crop and feed mixes (Dantzig and Wolfe, 1961; McCarl, 1982; Önal and McCarl, 1989, 1991), the model is robust in its use and results.

Therefore, PASMA consists of a set of three almost identical programming models. The purpose of the first one is to assign all farm activity levels i.e., crop, forestry, livestock, and farm tourism, and remaining cost shares and to define feed and manure balances. For instance, the area of meadows is recorded in various data sources listed above. However, information on which activities are actually carried out and to what extent are not available (e.g., grazing, hay, silage, or green fodder production activities). In the model, these activities and remaining cost shares (i.e., fertilizer and feed) are accordingly assigned using historical livestock records and detailed feed and fertilizer balances (phase 1). Phase 2 is the second LP, the perturbations coefficients (Howitt, 1995) are incorporated to compute the calibration coefficients of a linear marginal cost curve primarily following the approach of Röhm and Dabbert (2003). The third non-linear model (phase 3) is the actual policy model. Calibration coefficients are built in using linear approximation techniques that allow calibration of crop, forestry, livestock, and farm tourism activities to observed and estimated shares. Other model features such as convex combinations of crop and feed mixes, expansion, reduction and conversion of livestock production, a transport matrix, and imports of feed and livestock are included to allow reasonable responses in production capacities under various policy scenarios.

5 The macro-economic model ASCANIO

ASCANIO is part of a family of models at different geographical levels. What these models have in common is a theoretical core, which is supplemented by detailed statistical information at the respective regional level. The structure of this model family has a scheme as shown in *Figure 2*.

ASCANIO models the interdependencies between the economic sectors at the level of the Austrian provinces; the basic structural information is based on the Austrian input-output table of 2017, which was supplemented by behavioural equations based on economic theory. These behavioural equations describe the

- private consumption (as a function of income and prices);

- factor demand for labor, capital and intermediate inputs (as a function of wages, prices and output as well as - in the case of capital and the investments derived from it - the interest rate level), and
- price formation; this includes production prices as well as a model for wage formation. From output prices, all other prices are derived in a consistent manner, taking into account transport and trade margins, taxes on goods, etc. The interdependencies between sectors are also taken into account.

The linkages between sectors are reflected in the regional input-output tables; these define the intermediate input linkages between economic sectors. The origin of these intermediate inputs - from one's own region, from other states or from the "rest of the world" - is mapped by the trade model implemented in the model. For the base year, this model trade matrix is derived from statistical sources and business consultations; however, price reactions in the model can also change the structure of these trade flows.

In the course of the project, the existing model framework will be adapted by integrating translog production functions, whose parameters are estimated econometrically, into the model in order to be able to make statements about the price pass-through, specifically the sensitivity to changes in energy costs.

As a federal-state model, however, ASCANIO has some special features that represent mechanisms that can be described as "regional redistribution processes."

- Commuting linkages: For example, about 250,000 people employed in Vienna live in other federal states (primarily in Lower Austria and Burgenland). Conversely, about 80,000 Viennese commute to workplaces outside their region of residence. This has the effect of redistributing disposable income from the region of work (where the income is generated) to the region of residence (where the resulting consumption is primarily made).
- Domestic tourism: Similar to commuting, tourism causes a redistribution from the place of residence to the vacation region. If the vacation region is also in Austria, this implies a domestic transfer of consumption expenditure (important provinces in domestic tourism are Burgenland, Carinthia, Styria and Salzburg. For the "big" tourism regions of Tyrol and Vorarlberg - as well as for Vienna - foreign guests are more important than domestic tourism).
- Interregional shopping: Finally, "institutionalized" shopping facilities such as shopping centers result in a systematic - and not inconsiderable - regional dispersion of consumer spending. Here, too, the Vienna metropolitan area offers several examples of such "shopping institutions," with Shopping City Süd as the first and still largest, though for some time no longer the only, example.
- Other mechanisms that systematically decouple demand from the region of residence (or work) exist, for example, in the school and health sectors; however, these are not relevant for the present work.

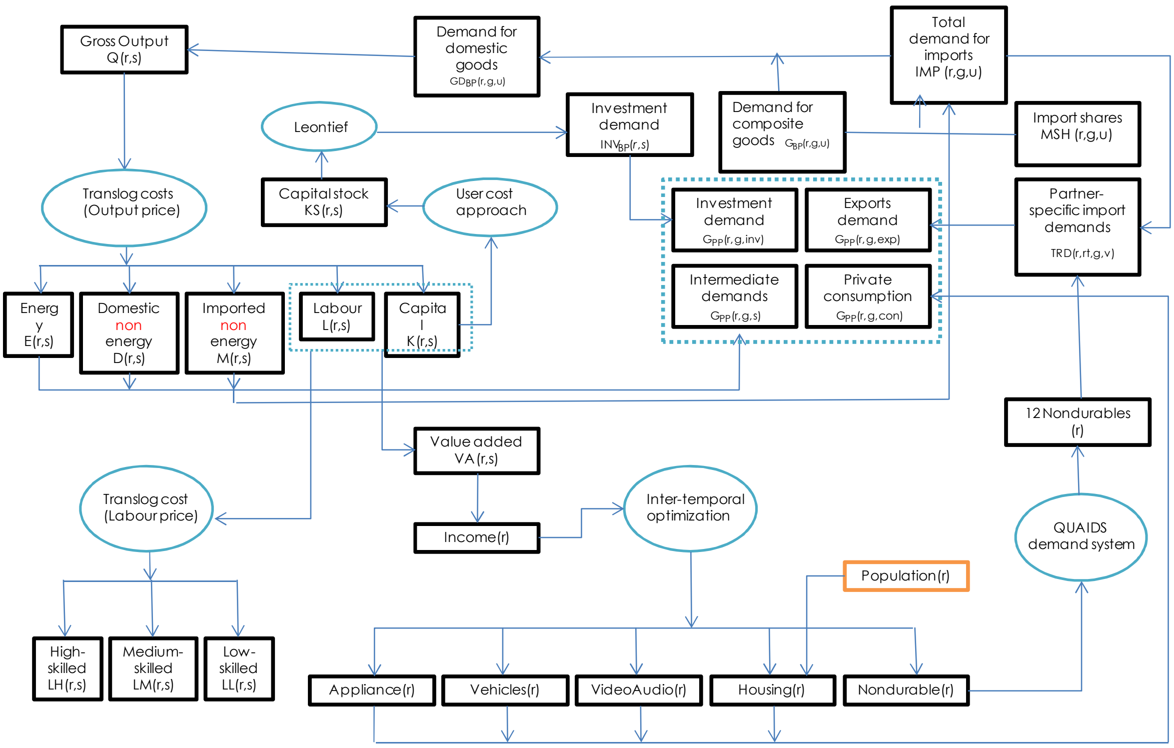

Figure 2: Structure of the macro-economic model ASCANIO

Source: Q: ECORYS, WIFO und National Institute of Economic and Social Research (NIESR) for the Directorate- General for Internal Market, Industry, Entrepreneurship and SMEs (European Commission), 2018: Competitiveness of the European cement and lime sectors; Contribution G. STREICHER: Modelling chapter; https://publications.europa.eu/en/publication-detail//publication/07d18924-07ce-11e8-b8f5-01aa75ed71a1/language-en/format-PDF/source-65040600

The model levels of ASCANIO consist of:

- nine Länder (plus a "rest of the world"),
- 63 goods or economic sectors,
- the final demand categories of private and public consumption, investment, and exports.

The main variables modelled by ASCANIO are value added and employment by sector and region. These can also be estimated separately according to the aforementioned impact types (direct, indirect and induced):

1) the *direct effects*, which represent gross value added and employment (as well as production value) of the Austrian universities themselves.
2) the *indirect effects*, which result from the subcontracting triggered by the demand impulse of the direct effects and run through several levels of the production system (supplies of third companies to the direct contractors, supplies to these suppliers, etc.).
3) the *induced effects*, which result from the creation of additional income (in the form of wages, salaries and profits) in the economic sectors related to the direct and indirect effects, and which, on the one hand, have an impact on private consumption; on the other

hand, can stimulate investment activity if the additional production causes capacity bottlenecks (expansion investments) or the additional liquidity is used for replacement investments; and, last but not least, can also increase the public budget, i.e. government spending, via additional tax revenue. Finally, additional tax revenue can also influence the public sector balance, i.e. government spending or the public sector's net lending/net borrowing.

ASCANIO also provides results on tax revenues and social security contributions.

6 Farm policy in Austria – two decades of efforts to reduce greenhouse gas emissions

6.1 The CAP Reform in 2003

In 1992, farm commodity prices that had been kept at high levels via government intervention were reduced significantly with a view to controlling excess production. In order to restrict to a minimum, the resultant effects on farm incomes, premiums were introduced which were linked to the amount of land used for production and the number of livestock raised. Direct production incentives of higher prices were reduced, but it is still necessary to produce some crop such as wheat in order to get a crop premium. Additional premiums are granted when specified animals are slaughtered (bulls, oxen, calves, cows, heifers) or reared on the farm (suckler cows and heifers) and an extensification premium is granted when the number of livestock per hectare of land is below a specified limit.

In mid 2002, the European Commission published a mid-term review of the Agenda 2000 reform. The European Commission planned to decouple these premiums from production and to grant a transfer for the farm instead (dubbed "single farm payment"). This subsidy would be paid even if a farmer chose to produce nothing, as long as "land is maintained in good agronomic condition". The transfers which would be subject to decoupling (dubbed "crop premiums" or "livestock premiums" or "CAP premiums") are equivalent to more than half of the EU funds spent on agriculture

A final compromise on the proposals of the reform was reached on 26th June 2003. The key element is the introduction of a single farm payment (Greek Presidency, 2003; Fischler, 2003). This payment will replace premiums formerly linked to output or land.

When the reform proposals were drafted, it was anticipated that decoupled premiums have considerable impact on production incentives. Farmers will not need to plant certain crops or raise bulls in order to obtain financial support. In future, production decisions are expected to be based on market signals (i.e., prices) and consequently resource allocations are likely to improve.

The policy change has become effective on 1st January 2005. Payment entitlements are calculated on the basis of direct payments received in the reference period 2000-2002, they are transferable with or without land and between farmers within a region or a country. They can be only received if accompanied by eligible hectares and agricultural land is maintained in good ecological conditions.

Member States may choose to introduce the single farm payment in full or they may opt to keep some premiums attached to output or factor usage or to retain up to 10 % of direct payments for measures that have a positive environmental effect or improve the quality and marketing of agricultural products. In addition, they may implement the single farm payment at regional level. This implies a redistribution of money between farm enterprises (this option is chosen by Germany) and may lead to redistributions between regions.

Farm operators (but not the owners of land if they have rented it) are entitled to premiums based on historic payment entitlements (average of 2000 to 2002). These entitlements are weighted by premiums and will be adjusted during the reform period. The total of premiums per farm is divided by the sum of the relevant crop and forage area, thus obtaining the average farm premium per hectare. Premiums per hectare will therefore vary among farms.

All farmers receiving direct payments must set aside part of their land (small farms and organic farms are exempt) and will be subject to compulsory cross-compliance. Recipients of farm payments must abide by a list of 18 statutory European standards in the field of environment, food safety, and animal health and welfare (cross compliance). Direct payments to larger farms (above a threshold of € 5,000) were reduced by 3 % in 2005, 4 % in 2006 and 5 % from 2007 to 2013 (modulation). Channelling expenditure away from market policies will make more than € 1.2 billion available for rural development.

For cereals (apart from rye), the intervention price remains the same with some modifications. Other crop regulations were simplified, but some production related premiums (notably those for durum wheat, protein crops, and energy crops) have been introduced by the reform. A reformed milk quota system will be maintained until the 2014-15 marketing year (see Sinabell and Schmid, 2008). Regulated prices of butter and skimmed milk powder have been cut asymmetrically in four stages. The quota expanded moderately in 2006 and a decoupled milk quota premium was added to the single farm payment.

6.2 The CAP Reform in 2008

As decided in the 2003 reform, a "health check" was carried out 5 years later. The objective was to make adjustments to guarantee that the intended objectives of the reform will be met.

On 20 November 2008 the EU agriculture ministers reached a political agreement on the Health Check of the Common Agricultural Policy. Among a range of measures, the following agreements are of major importance for agricultural market today (EC, 2011):

- Phasing out milk quotas: Milk quotas were planned to expire by April 2015. A 'soft landing' was ensured by increasing quotas by one percent every year between 2009/10 and 2013/14. For Italy, the 5 percent increase was introduced immediately in 2009/10.

In 2009/10 and 2010/11, farmers who exceed their milk quotas by more than 6 percent had to pay a levy 50 percent higher than the normal penalty.

- Decoupling of support: The CAP reform "decoupled" direct aid to farmers, i.e. payments were no longer linked to the production of a specific product. However, some Member States chose to maintain some "coupled" – i.e. production-linked - payments. These remaining coupled payments were planned to be decoupled and to be moved into the Single Payment Scheme (SPS), except for suckler cow, goat and sheep premia, where Member States may maintain current levels of coupled support. Eventually several Member States maintained support schemes also for sugar beet.
- Assistance to sectors with special problems (so-called 'Article 68' measures): Up to 2008, Member States could retain by sector 10 percent of their national budget ceilings for direct payments for use for environmental measures or improving the quality and marketing of products in that sector. This possibility became more flexible and was used by some Member States to implement risk mitigation programmes.
- Using currently unspent money: Member States applying the Single Payment Scheme were allowed either to spend money from their national envelope for Article 68 measures (which finance measures to control income volatility in some EU member states) or to transfer it into the Rural Development Fund.
- Shifting money from direct aid to Rural Development: All farmers receiving more than € 5,000 in direct aid had their payments reduced by 5 percent and the money was transferred into the Rural Development budget. This rate was increased to 10 percent by 2012.
- Abolition of set-aside: The requirement for arable farmers to leave 10 percent of their land fallow was abolished.
- Cross Compliance: Aid to farmers is linked to the respect of environmental, animal welfare and food quality standards. Farmers who did not respect the rules faced cuts in their support. This so-called Cross Compliance was simplified, by withdrawing standards that were not relevant or linked to farmer responsibility. New requirements were added to retain the environmental benefits of set-aside and improve water management.
- Intervention mechanisms: Intervention was abolished for pig meat and set at zero for barley and sorghum. For wheat, intervention purchases were maintained during the intervention period at the price of € 101.31/tonne up to 3 million tonnes. Beyond that, interventions were planned to be done by tender. For butter and skimmed milk powder, limits will be 30,000 tonnes and 109,000 tonnes respectively, beyond which intervention will be implemented through tender.
- The energy crop premium was abolished.

6.3 The CAP Reform in 2013 and the Multiannual Financial Framework 2014-2020

The most recently implemented reform of the CAP was initiated by the Commission in 2011. For the first time the entire CAP was reviewed all at once and the European Parliament acted as co-legislator with the Council. This new role was due the Lisbon Treaty that gave more power to the European Parliament.

The current CAP maintains the two-pillar structure, but introduces a new architecture of direct payments. The objective is to have payments better targeted, more equitable and greener. The role of direct payments as a safety net that strengthen rural development has become more important.

During the phase of the debate on the reform, scenarios which would have implied substantial reductions of farm payments were considered realistic. To the surprise of many observers, the overall budget for agriculture did not change very much. The instruments of the CAP and how they are implemented was decided by the farm ministers in co-operation with the parliament (see Hofreither and Sinabell, 2013 for a detailed account of the debate). For the allocation of funds available, the heads of Member States and the European Parliament had to find and agreement. The Commission had proposed that, in nominal terms, the amounts for both pillars of the CAP for 2014-2020 would be frozen at the level of 2013. Compared to the Commission proposal, the amount for pillar 1 was cut by 1.8% and for pillar 2 by 7.6% (in 2011 prices). A total amount of EUR 362.8 billion for 2014-2020, of which EUR 277.9 billion is foreseen for Direct Payments and market-related expenditure (Pillar 1) and EUR 84.9 billion for Rural Development (Pillar 2) in 2011 prices.

The reform aimed at improving sustainability by the combined and complementary effects of various instruments:

- there is a simplified cross-compliance requirement which is a compulsory basic layer of environmental requirements and obligations to be met in order to receive direct payments from Pillar 1;
- on top of this 30% of direct payments are reserved, from 2015 onwards, for a new policy instrument in Pillar 1, the Green Direct Payment (for the maintenance of permanent grassland, ecological focus areas and crop diversification);[10]
- at least 30% of the budget of each Rural Development programme were reserved for voluntary measures that are beneficial for the environment and climate change.

Equity concerns were addressed in the CAP reform as well. A more balanced, transparent and more equitable distribution of direct payments among countries and among farmers was agreed upon. The outcome of the agreement is not a uniform payment throughout the Union but a reduction in disparities of the level of direct payments between Member States, known as *external convergence*. Agricultural policy makers hope to reinforce the credibility and legitimacy of the support system at EU level by this step.

[10] Several studies analysed the effectiveness of this instrument, among them EC 2016, EC 2017, European Court of Auditors, 2017.

The level of direct payments per hectare, which is currently based on historic parameters in many countries including Austria, is progressively adjusted with the introduction of a minimum national average direct payment per hectare across all Member States by 2020. This element of the reform is called *internal convergence* within the Member States. Payments will no longer be based on uneven historical references of more than a decade ago but rather on a fairer and more converging per hectare payment at national or regional level.

In addition, Member States have further possibilities to rebalance payments with the introduction of the redistributive payment, voluntary capping and degressivity (reduction) of payments, beyond the mandatory cuts which will apply to the Basic Payment above a certain threshold.

In a nutshell, the most important changes compared to the previous CAP reforms from an Austrian perspective were:

- The annual volume of direct payments (1st Pillar) in Austria was set to 693 Mio. EUR until 2020 (compared to 733 Mio. EUR (2007-2013).
- The annual volume of the Program of Rural Development (2nd Pillar) is practically the same as in the previous phase with EUR 1.1 billion financed by the EU by 50% and federal funds and funds of Länder.
- Young farmers will qualify for special support financed from the 1st pillar – this will make investments in new production facilities more likely.
- A very small part of the support from the 1st pillar is granted as "coupled support". In order to qualify for such payment, farmers have to produce farm products. In the case of Austria 2% of direct payments will be channeled to Alpine farming which will make cattle and milk production in alpine region more profitable.
- The internal convergence of direct payments brings about considerable changes of the distribution of farm payments in Austria. The consequence will be that regions in which cattle and milk production prevails will benefit (Kirner and Wendtner, 2012 and Kirner, 2011).

For the preparation of the follow up reform published in 2018, the EC carried out several evaluation studies. Regarding GHG emission reduction Pérez Domínguez et al. (2016) identified a positive impact. Its extent, however, was difficult to determine and quantify. The findings regarding greening were unambiguous: "It is clear that the 'greening' measures have not fully realised their intended potential to provide ambitious benefits for climate and environment" is a major conclusion of EC's impact assessment (SWD(2018) 301 final).

6.4 The proposals of the CAP reform in 2018 and the Austrian CAP Strategic Plan implemented in 2022

6.4.1 The EU agricultural policy reform initiated in 2018

In June 2018 the European Commission published legislative proposals for a reformed Common Agricultural Policy (CAP) that are consistent with the proposals of the Multi-Annual Financial Framework for the period 2021-2027.[11]

According to the proposal, the reformed CAP will pursue nine policy goals:

1. to ensure a fair income to farmers
2. to increase competitiveness
3. to rebalance the power in the food chain
4. climate change action
5. environmental care
6. to preserve landscapes and biodiversity
7. to support generational renewal
8. vibrant rural areas
9. to protect food and health quality

In its proposal, the European Commission puts a priority on environmental and climate change. Mandatory requirements include

- preserving carbon-rich soils through protection of wetlands and peatlands;
- obligatory nutrient management tool to improve water quality, reduce ammonia and nitrous oxide levels;
- crop rotation instead of crop diversification.

According to the proposal, farmers will have the possibility to contribute further and be rewarded for going beyond mandatory requirements. EU countries will develop voluntary eco-schemes to support and incentivize farmers to undertake agricultural practices beneficial for the climate and the environment (see next chapter for previous implementations in Austria).

The policy will shift the emphasis from compliance and rules towards results and performance. Member States are becoming responsible to develop strategic plans, that set out how they intend to meet the nine EU-wide objectives using CAP instruments while responding to the specific needs of their farmers and rural communities. The new way of working will also entail

- streamlining administrative processes: countries shall submit only one strategic plan covering direct payments, rural development and sectoral strategies
- making environmental protection easier: through a set of standards and objectives at EU level, each country shall adapt environmental and climate actions to the reality on the ground

[11] The text in the following paragraphs is based on the materials presented at and linked to the following web-page: https://ec.europa.eu/info/food-farming-fisheries/key-policies/common-agricultural-policy/future-cap_en (retrieved 12 Nov 2018).

Figure 2 provides an overview of key aspects of the current green architecture of the CAP, based on three different layers of measures: cross-compliance, green direct payments and rural development measures, strengthened by other tools (EC, 2018). *Cross-compliance* is a mechanism that links the CAP to farmers' compliance with various basic standards, as well as to their application of fundamental good practice. This is essential for a sustainable development of the agricultural sector and to improve the link between the CAP and other EU policies, including environmental and climate topics:

- Statutory Management Requirements (SMRs): These are 13 requirements arising from non-CAP EU legislation, in the field of the environment, food safety, animal and plant health and animal welfare.
- Good Agricultural and Environmental Condition (GAEC): GAEC standards have their legal basis within the CAP and are specified by Member States. The seven EU standards relate to management of water, soil and landscape features – in the last case, with explicit reference to habitats. EU standards are translated into national standards, taking into account local needs and specific situations.

If farmers do not comply with the standards related to their received CAP payments, the payments under these schemes can be reduced. Cross-compliance thus helps to provide a foundational level of action with regard to the environment and climate.

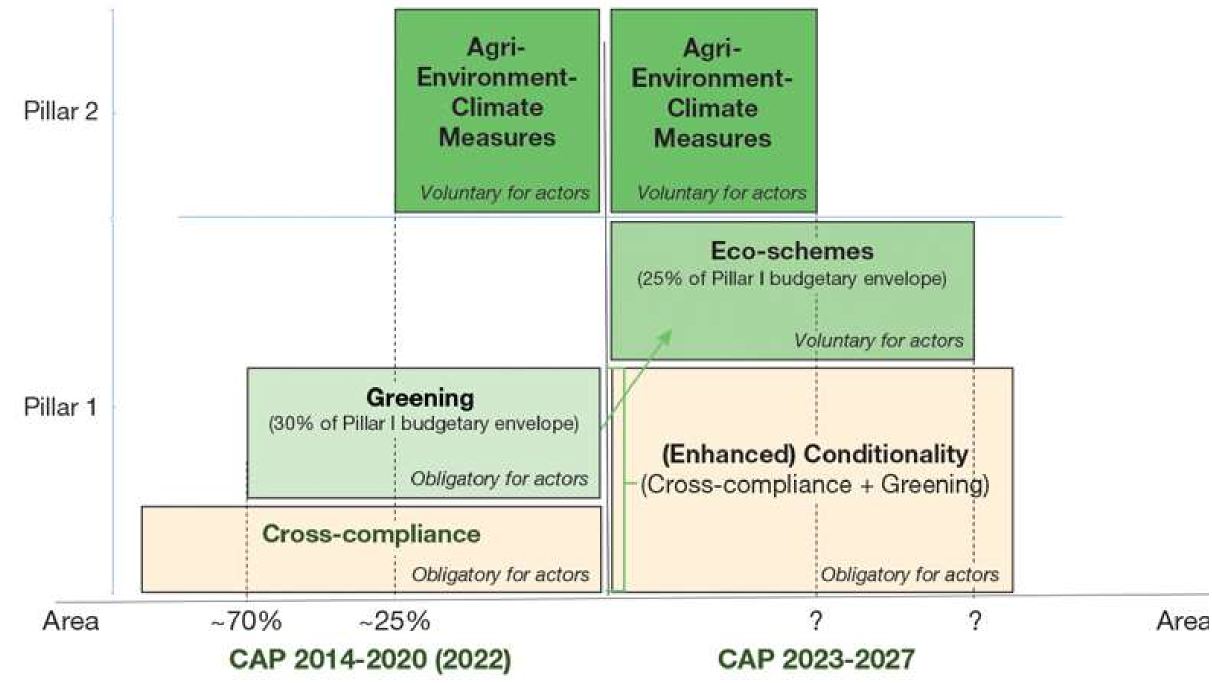

Figure 3: Green Elements of the CAP

Source: Détang-Dessendre and Guyomard, 2022.

Direct area based payments to farmers are necessarily conditional on *cross-compliance*. An additional type of payments, *Payments for agricultural practices beneficial for the climate and the environment* (also known as "green direct payments", "greening"), have the explicit mission of enhancing farming's environmental performance.

The greening architecture introduced by the 2013-20 CAP reform will be replaced by a 'more targeted, more ambitious yet flexible approach'. Member States will have more flexibility to choose the options most suited to local needs, involving a mixture of mandatory and voluntary measures to meet the environmental and climate objectives defined at EU level (McEldowney, 2018).

Farmers may receive CAP payments when they:

- maintain a certain level of crop diversity on their arable land;
- maintain permanent grassland;
- devote a certain portion of their arable land (labelled "ecological focus area - EFA") to biodiversity-friendly practices and features – including landscape features, fallow land, buffer strips, use of catch crops and nitrogen-fixing crops, and others.

Various measures available through the EU's rural development policy (indicated by the dark green area in Figure 3) can be used for environment- and climate-related purposes.

The new Common Agricultural Policy (CAP) was adopted on 2nd December 2021. It is based on a performance- and results-based approach that takes into account local conditions and needs, while increasing the EU's ambition in terms of sustainability. The new CAP will be a key tool in reaching the ambitions of the Farm to Fork strategy (European Commission, 2020a)and biodiversity strategy (European Commission, 2020b). By March 2022 all EU Member States had submitted their CAP Strategic Plans to the EU Commission (European Comission, 2022). Each EU country designed a national CAP strategic plan, combining funding for income support, rural development, and market measures. When designing their strategic plans, EU countries identified contributions to the ten specific objectives through a toolbox of broad policy measures provided by the Commission, which are shaped around national needs and capabilities.

6.4.2 The Austrian CAP Strategic Plan

Austria's CAP Strategic Plan was submitted to the European Commission in December 2021. Fundamental decisions on important elements, such as the reduction of direct payments to larger farms, were only taken in Austria shortly before. After several consultations and minor changes, the plan was approved by the European Commission on 13th September 2022[12].

The Austrian CAP Strategic Plan is structured according to the detailed and extensive requirements of the EU digital platform, the so-called System for Fund Management in the European Community (SFC) 2021. It is very detailed and comprises 45 "needs", i.e. prioritised

[12] https://info.bml.gv.at/themen/landwirtschaft/eu-agrarpolitik-foerderungen/nationaler-strategieplan/gsp-approval.html.

objectives. The achievement of these sub-objectives is to be ensured by 98 interventions, whereby the spectrum of instruments includes direct payments, sectoral interventions, area-based interventions and project-based interventions in the field of rural development. To monitor success in the performance framework, 26 output indicators (e.g. number of beneficiaries of certain measures) and around 36 result indicators (e.g. reduction of greenhouse gas emissions) are used.

Accompanying the CAP strategy process, a strategic environmental assessment and an ex-ante evaluation (Bachtrögler-Unger et al., 2021) were carried out. In the course of the ex-ante evaluation, a strategic assessment of the allocation of financial resources was made, focusing on the long-term development of financial resources.

In 2000, the EU had disbursed almost 1.6 billion € to Austria's agriculture from market organisation and rural development funds. By 2027, the payments will fall by almost one third to about 1 billion €. In addition, the loss of value due to inflation also contributes to the decrease in CAP subsidies over time, as the nominal amounts were fixed in the Multiannual Financial Framework. At the same time, the CAP Regulation has increased the number of objectives addressed (e.g. to include the bioeconomy). In view of the budget decline, either fewer objectives will have to be addressed or reductions will have to be made, affecting either all or only the additional objectives.

At the beginning of the 21st century, climate change and adaptation to it, ecosystem services and societal demands (such as ensuring animal welfare) did not yet have the same weight in agricultural policy as they do in 2022. Moreover, due to the price policy that was still predominant at that time, the administrative requirements for farms were significantly lower. The increased complexity of the CAP can be partly mitigated by digitalisation and better training, and the Austrian strategic plan addresses both areas. At the same time, however, the demands placed on farms by the market and by product and environmental regulation are continuously increasing. Therefore, agricultural policy should be transparent, comprehensible, easy to communicate and involve as little administrative burden as possible for the beneficiaries.

As the evaluation of the Austrian CAP Strategic Plan shows (Bachtrögler-Unger et al., 2021), the planned funds are not distributed equally across the needs or the targeted objectives. With almost 50 percent, a large part of the funds is earmarked for specific objective 1 (promotion of sustainable agricultural incomes as well as the resilience of the agricultural sector to increase food security).

On 28th Ocotber 2022, the CAP Strategic Plan Application Regulation (GSP-AV) was published in the Official Gazette[13]. This replaces the previous Direct Payments Regulation, Horizontal CAP Regulation, Regulation on Market Organisation Measures in the Wine Sector and parts of the Producer Framework Conditions Regulation. The Austrian CAP Strategic Plan (BML, 2022)

[13] BGBl. II Nr. 403/2022 from 28.10.2022, GAP-Strategieplan-Anwendungsverordnung

defines the agricultural policy measures that will be implemented in order to achieve reductions of GHG emissions of that sector (see Appendix VI for the list of relevant measures).

6.5 The Multiannual Financial Framework and the NextGenerationEU funds

In early summer 2018 the European Commission also presented the proposal for the Multiannual Financial Framework (MFF) for the period 2021 to 2027. The European Commission also published a proposal for a regulation establishing rules on support for strategic plans to be drawn up by Member States under the Common agricultural policy (CAP Strategic Plans) and financed by the European Agricultural Guarantee Fund (EAGF) and by the European Agricultural Fund for Rural Development (EAFRD) (COM (2018) 392 final) with annexes that contain proposals for country specific allocations of CAP funds for the period 2021 to 2027. Effectively the budget allocated for agriculture is smaller than in the previous financing period (mainly explained by BREXIT). Depending on the relative shares of payments for the first and second pillar of the CAP the country specific consequences for transfers to the farm sector are different.

A decision on the EU MFF was reached only in 2020. When the agreement on the budget was made, Member States decided to add additional resources in order to help overcome the Covid-19-crises. The EU's COVID-19 Recovery Plan includes the 750 billion € NextGenerationEU (NGEU) temporary recovery package – the most important instrument of which is the 672.5 billion € Recovery and Resilience Facility (RRF) – and the 1,074.3 billion € Multiannual Financial Framework (MFF) 2021-2027. While the spending structure of the MFF has only been moderately modernized, the NGEU and especially the RRF are explicitly future-oriented: 37% of RRF funds are to be used for climate protection, and 20% for digital transformation. New own resources are to support important European projects in the future: a plastic-based own resource will be added to the existing own resources used to finance the MFF. A digital tax, an own resource based on the EU Emissions Trading Scheme and a carbon border adjustment mechanism (CBAM), among others, are to contribute to the repayment of the debt taken on for NGEU (Bachtrögler-Unger et al., 2021).

The European Agricultural Guarantee Fund (EAGF) and the European Agricultural Fund for Rural Development (EAFRD) are the two pillars of the CAP. In the new financing period, the spending structure of the Common Agricultural Policy remains practically unchanged compared to the 2014-2020 program period. In the 2014-2020 MFF, 308 billion € was allocated to market-related expenditures and direct payments (EAGF) and just under 100 billion € for structural and environmental measures (EAFRD). In the MFF 2021-2027, the share of agricultural spending is 31% if NGEU funds are excluded. The relative weight of agricultural spending in the EU budget has thus been reduced slightly less than in the original Commission proposal (Bachtrögler-Unger et al., 2021).

6.6 Focus on the Programme for Rural Development – an important policy tool to mitigate greenhouse gas emission of agriculture

After the Agenda 2000 reform in 1999, the programme for rural development (dubbed "second pillar of the CAP") was introduced in the EU. A volume of 91 billion € from EU funds was allocated for the programme period 2007-2013 (EK, 2009) but was reduced to 85 billion € for the period until 2020. This amount has been topped by contributions of Member States up to 50% depending on the level of development. For the period 2021 to 2027 the planned nominal allocation for Pillar 2 payments by the EU is 78 billion € (COM(2018) 392 final Annex IX). Member States may top up such payments at a larger scale than in the current period.

The programme for rural development is of eminent importance for the Austrian agricultural sector, because transfers from this source outweigh transfers from the "first pillar of the CAP", e.g. instruments that have been commodity related.

The previous programme ended in 2014 and the current programme started in 2015. The main elements of the previous programme which are also prevalent for the current period were:

- a genuine EU strategy for rural development will serve as the basis for the national strategies and programmes;
- less detailed rules and eligibility conditions allow Member States more freedom in implementing their programmes;
- a strengthened bottom-up approach will better tailor rural development programmes to local needs.

The Agri-Environmental Programme 2015-2020 which was in operation until end 2022 was not organized in axes as was the case with the previous programme. Goals were bundled according to priorities and focal points. Climate protection goals were already ranking high in this programme. Specific targets are set in priority 1, 4, and 5 because climate mitigation (and adaptation) was a horizontal issue that had to be addressed in every programme (see details in European Commission, 2013).

The CAP Strategic Plan (CAP-SP) for Austria 2023-2027 was submitted by the end of 2021 and approved by the EU Commission in September 2022. It includes interventions that enable participants to receive direct payments (former 1st pillar of the CAP), and measures financed by the EAFRD (former 2nd pillar of the CAP). In addition, sector programmes (fruit and vegetables, bees, wine, hops) were implemented. Since the CAP period started with a delay of three years, it can be assumed that the programme will continue until 2030.

In the Austrian CAP-SP (BML, 2022), a total of 98 interventions, based on 45 needs, are jointly programmed and implemented. According to the intervention logic, the climate-relevant interventions are assigned to objective 4 (climate) by corresponding relevant outcome indicators (the numbers indicate the reference code in the programme):

- 31-01 Greening catch crop
- 31-02 Greening permanent green cover
- 31-03 Erosion control

- 31-04 Animal welfare pasture
- 47-13 Sustainable energy
- 47-18 Sustainable logistics
- 70-01 UBB: Environmentally sound management that promotes biodiversity
- 70-04 Hay management
- 70-14 Groundwater protection, arable land
- 70-15 Humus conservation and soil protection
- 70-16 Nature conservation
- 70-17 Results orientation
- 70-18 Animal welfare, cattle
- 70-02 Organic farming
- 70-03 EBB: Restriction of yield-increasing operating inputs
- 70-07 Erosion control, arable land
- 70-08 Near-soil slurry application
- 73-01 Agricultural investments
- 73-02 Processing and marketing
- 73-12 Renewable energy sources
- 73-13 Climate and energy projects
- 73-14 Klimaaktiv mobil (a special programme for climate friendly mobility)
- 73-03 Forest infrastructure
- 73-04 Forest management
- 73-06 Flood protection
- 73-07 Water ecology

Classification of climate-relevant interventions by funding (Art. 100 "Tracking of climate-related expenditure") are (the articles refer to Regulation (EU) 2021/2115):

- Rural development:
    - Art. 70+72 Austrian Agri-Environmental Programme (excl. eco-scheme, incl. N2000 and WFD).
    - Art. 71 Payments for areas disadvantaged for natural or other specific reasons (compensatory allowance, AZ)
    - Art. 73 Investments
        - 73-7 Investments in water ecological improvement
        - 73-12 Investments in construction, extension and improvement of all types of small-scale infrastructure including investments in renewable energy sources
        - 73-13 Implementation of climate and energy projects at the local level
        - 73-15 Investments for the conservation, restoration and improvement of the natural heritage
- Direct payments (incl. eco-scheme)

Compared to the previous CAP period (2014-2020 which was in operation until 2022) both climate mitigation and climate change adaptation measures have gained more weight compared to other measures. However, one must consider that the volume of funds has not changed significantly, and inflation has been very high from 2022 on. The implementation of measures therefore depends less on financial incentives and more on the personal motivation of farmers.

6.7 Air and water pollution control legislation

Two recent regulations which affect production processes in agriculture are the Directive to Reduce Ammonia Emissions[14] and an update of the Nitrate Action Programme[15] which are both relevant to the agricultural sector and GHG emission.

Because ammonia emissions to air are hazardous to human health and the environment further efforts are needed to reduce them. The National Emissions Reduction Commitments (*NEC*) *Directive* (2016/2284/*EU*) entered into force on 31st December 2016. It regulates national emission ceilings for certain air pollutants. These pollutants include sulphur dioxide, nitrogen oxides, volatile organic compounds, ammonia, and particulate matter. The reduction targets refer to the year 2005 and are divided into various emission sectors. Emission reductions have been binding since 2020. The reduction targets are to be achieved by 2030.

Over 93% of ammonia emissions come from agriculture. Animal husbandry is the main emitting activity. In Austria, ammonia emissions are to be reduced by 12% by 2030 compared to 2005. Ammonia is responsible for soil acidification, but particulate matter can also form through reaction with other air pollutants. Ammonia emissions mainly come from animal husbandry in stables, the storage and application of farm manure, and mineral fertilisation. Reducing ammonia is difficult in a situation where animal welfare concerns are becoming more important. Due to the trend towards larger areas per animal and loose housing of cattle, there are more polluted areas where emissions can occur.

In order to reduce agricultural ammonia emission additional investments are needed: better slurry tanks that tend to emit less, better stable systems, and slurry application techniques. Part of these investments are supported by the CAP-SP.

In accordance with the requirements of the Nitrates Directive 91/676/EEC, the effectiveness of action programmes to reduce nitrate emission must be reviewed regularly. The following changes have been made in the latest revision of the Austrian Nitrate Action Programme and came into effect on 1st of January 2023:[16]

- Increased consideration of the preceding crop effect of catch crops, legumes, and crop residues as well as the N content in irrigation water in the fertiliser assessment.

[14] Ammoniakreduktionsverordnung BGBl. II Nr. 395/2022

[15] Änderung der Nitrat-Aktionsprogramm-Verordnung BGBl. II Nr. 386/2022

[16] Transcript and shortened text of: https://info.bml.gv.at/themen/wasser/wasser-oesterreich/wasserrecht_national/recht_gewaesserschutz/APNitrat2012.html (accessed 3 Jan 2023)

- Revision of the fertiliser ceilings for vegetable crops according to the guidelines for appropriate fertilisation, taking into account the Nmin content (with exceptions for small plots), as well as setting fertiliser ceilings for wine.
- Obligation to check the plausibility of yields for farms obliged to keep records in the case of fertilisation after high yields by means of weighing receipts (harvest quantities) or determination of yields by (silo) cubic capacity (grassland and arable fodder areas excluded).
- Fertiliser ban in autumn on arable land after harvest of the main crop, except for winter rape, winter barley and catch crops.
- Clarification of the storage of farm manure on technically impermeable areas as well as technically impermeable storage rooms for leachates with special regulations.
- There must be a buffer strip of at least 3 metres along water bodies, covered with living plants all year round, with the possibility of ploughing up once within 5 years.
- At least 1.5% of the farms that are obliged to keep records must be inspected by the Water Inspectorate.

Additional changes will be implemented in designated areas:

- Reduction of fertiliser ceilings by about 10 to 15%, limitation of the fertiliser ceiling for wine with 50 kg N/ha.
- Obligation to check the plausibility of yields for all farms obliged to keep records by means of weighing receipts (harvest quantities) or determination of yields by means of silo cubage (exceptions for grassland, arable forage areas and small plots).
- Determination of the N-balance based on the ÖPUL measure "field-related balancing".
- Inspections for at least 1.5% of the farms are to be carried out by the Water Inspectorate.

As in the case of stricter ammonia emission legislation, the CAP-SP provides for measures to support famers adapt to the new situation.

At the time of writing this report, the Industrial Air Emissions Ordinance and the Environmental Impact Assessment Regulation are being revised. Both regulations will bring about stricter norms and regulations for large farms, which will likely result in increased investments in emission reduction equipment.

7 Markets and economic development

7.1 International food markets

European farm commodity markets are interlinked with international food markets in many ways. Given the imbalances between supply and demand in many markets, the EU is a major exporter, in particular of cereals, milk and white meat. The policy efforts to bring domestic market prices closer to equilibrium prices (see above) brings about that the gap between domestic prices and world market prices is narrowing. Domestic supply therefore is increasingly determined by the fluctuation of world market prices. Global demand for food and technological progresses (e.g., the adoption GMO crops in major producing countries, organic food production) will be major driving forces of agricultural production in the next decade. In the medium-term, world agricultural markets are projected to be largely supported by rising food demand driven by an improved macro-economic situation, a higher population, urbanization and changes in dietary habits (OECD & FAO, 2022). Widespread economic growth and an expanding livestock sector are projected to set the stage for an increase in global demand and the maintenance of a low stock-to-use ratio.

Cereal trade would also expand, particularly in developing economies, driven by rising income, diet diversification and higher demand for livestock products and feeds, allowing for a gradual, albeit moderate, price increase in the medium term. The medium-term outlook for the oilseed sector is expected to be characterized by increasing demand due to increasing growth of the biofuel market.

Meat markets are projected to be characterized by an expansion in production, consumption and trade with world meat prices rinsing/increasing moderately. Prospects for rising meat demand would mainly emerge from a favourable macro-economic environment of sustained income growth, notably in Asia and Latin America. World meat trade would increase, and prices remain firm over the medium term as growing consumption is mostly expected to take place in countries that are net importers with limited possibilities to proportionally and competitively increase domestic supply (in quantity and quality).

The medium-term outlook for the dairy sector is expected to remain dominated by a strong growth in global demand for dairy products. The latter would reflect not only income growth in many regions of the world, but also changing consumer preferences for dairy products.

7.2 Baseline assumptions

Several assumptions have to be made to run the model outlined above. These are essentially input prices derived from international sources.

Table 1: Assumptions on macro-economic variables in Austria

		2020	2025	2030	2040	2050
real GDP (2015) prices	bn €	349.2	391.4	411.3	469.9	530.1
consumer price index	%	1.4	1.7	2.0	2.0	2.0
GDP deflator	%	1.1	1.7	2.2	2.0	2.0
working age population	mn	5.9	5.8	5.7	5.6	5.6
price of Diesel	€/GJ	28.6	37.1	39.8	47.4	69.0

Source: Umweltbundesamt, Kaniovski et al., 2021

The price projections are based on assumption about the development of key indicators on global agricultural commodity and food markets (OECD & FAO, 2022). Forecasts on key economic indicators are based on Kaniovski et al. (2021) and energy prices are based on Umweltbundesamt (see Table 1).

Several sources of market data are available which can be used as a basis of price projections. In this study, all prices but energy prices are derived from OECD-FAO outlooks on agricultural markets (OECD & FAO, 2022). A comparison of this OECD-forecasts with projections of the European Commission (European Commission, 2022) shows that international bodies have very similar assumptions about the future development of key economic indicators. Due to the type of farm sector model used in this analysis, assumptions on the Austrian economic context (e.g., GDP growth, population dynamics) are not required directly. However, they are included in the exogenous price assumptions (mainly the consumer price index). Other driving forces (prices, technology, constraints) are referenced in of the following sections.

7.3 Specific assumptions on farm commodity prices and input prices

The assumptions about future policy variables and future prices of farm commodities are provided in Appendix II. The forecast period in this study covers the period 2030 to 2050. No OECD-FAO forecasts are available for the period after 2031. Therefore, the assumption is made that prices will follow the previous development from this year onwards for most activities.

All price projections, except diesel prices, are based on OECD-FAO 2022 forecasts. Prices of diesel and other energy carriers were provided by Umweltbundesamt (2022). Price estimates of farm outputs are specific for the Austrian market situation, the observed price wedge between Austrian and EU markets is assumed to prevail in the future. In Austria, the market for organic products is very important and many organic products are sold at a premium price. Price premia are based on five-year average observations reported by LBG (various years)[17].

7.4 Assumptions on technical coefficients, yields and productivity in production

For this report a detailed set of assumptions was developed in a stakeholder process, including the expertise of farm production experts from the Austrian Chamber of Agriculture, the Austrian Agency for Health and Food Security (AGES) and participants of three meetings of the project board established for this study. This survey covered technical coefficients such as the feed conversion ratios in livestock production and average crop yields. The coefficients documented in Appendix II are expert judgements that can be summarised as follows: productivity in livestock farming, particularly in milk production, will increase in the coming years, but at a slower pace than in the past. With regard to crop yields, the consensus was that climate change is likely to lower country averages after 2030.

A proposal for assumptions was developed in mid-2022. An online survey was conducted in summer 2022 to collect the views of agricultural experts in Austria. The proposed assumptions shared with the experts via the online survey are presented (in German) in the appendix, where

[17] See issues of all years at: https://gruenerbericht.at/cm4/jdownload/category/4-buchfngsergebnisse

a summary of responses can also be found. A workshop was organized to discuss the assumptions for prices and technical coefficients. One outcome of the discussions was that the expected yields of crops should be lowered after 2030 and that the cost of stables for livestock would be significantly more expensive than in 2020. To assume higher prices is justified by the fact that compliance with environmental legislation will make investments more expensive.

8 Mitigation measures and their costs

In this chapter, we define the procedure for the selection of mitigation measures and a number of boundary conditions. Subsequently, we describe the method for the calculation of potential abatement volumes and their costs. Sections 4, 5 and 6 show the results of the calculations.

The first step of defining the measures and boundaries is crucial for the calculation of mitigation costs, because parameters such as the volume and extend of measures, the timeframe for implementation, the underlying abatement strategy and others take a substantial effect on the mitigation costs. Both steps were rested on a more detailed investigation for Austria carried out in the course of Dafne Project No. 101324 / 2.[18]

8.1 Boundary conditions for the selection of measures

The boundary conditions for selecting the measures include

(a) technological readiness,

(b) scientific validation,

(c) economic feasibility, and

(d) environmental synergies.

With the criterion of technological readiness (a), we aimed to ensure that the proposed mitigation measures are already available, or that they are likely to be ready within the next 10 years. This includes that not only experimental field studies have been conducted, but that a scientific proof of mitigation performance is available now or in the near future.

More generally, the criterion of scientific validation (b) requires that there is a common scientific understanding of the effectiveness of a measure. This includes that a reduction in the volume of greenhouse gases is relevant and likely, and that no (or only little) contrary effects in terms of greenhouse gases occur. Contrary effects include trade-offs between greenhouse gases or territorial (domestic) and foreign emissions, amongst others. We based the proof of effectiveness on national studies whenever available and we referred to international literature, if applicable to Austrian conditions. We avoided mitigation options with no unanimous scientific verification.

[18] https://dafne.at/projekte/thg-effizienz (retrieved 20 Feb 2023)

Economic feasibility (c) describes a twofold criterion. First, mitigation measures are only taken into account, if they do not substantially influence national production volumes. That is, because policy interventions for greenhouse gas reductions by a direct change in production volumes are unlikely to result in economically efficient allocations. Second, implementing mitigation measures also requires economic feasibility at the farm level. This includes both monetary and practical issues, e.g. that sufficient means of production (including labor) are available. Monetary feasibility can include a carrying of costs by the farms and/or it can draw on future funding schemes.

Looking at synergies in ecology (d) and beyond, we aimed to include measures with positive side effects, specifically regarding other environmental areas besides climate change. For example, a measure is not taken into account, if it would go along with a substantial increase in pesticides. With this category, we also consider the societal acceptance of mitigation strategies. Measures with potentially negative side effects were included only, if they are expected to be manageable.

Regarding the goal and scope for the measure selection, we also want to emphasize that the focus is on greenhouse gas mitigation from an emission point of view, as opposed to a national inventory point of view. We of course considered the mitigation of territorial (national) emissions as a central objective. Yet from a climate protection point of view, the entirety of emissions from a production system has to be considered, which requires also accounting for upstream emissions.

8.2 Selection of measures

For the selection of the measures, we first created a longlist of measures potentially relevant for greenhouse gas reduction based on a literature review. We analyzed the measures based on the criteria stated in 8.1 (readiness, validation, feasibility, synergies) and selected appropriate measures to be included in the further calculations.

The measures are divided into three categories:

- Measures within the regulatory framework (including GHG-relevant measures in CAP)
- Additional options for adaptions of production/management techniques
- Additional demand side options and options for structural/systematic changes at sector level

The first category represents production side measures, which are either included in the existing regulatory framework (continued CAP 2014-2020) or to be implemented under the regulatory framework after 2022. Here, we also included GHG-relevant modules of the CAP-strategic plan, e.g. UBB. Already existing options under the category "within regulatory framework" are included in the scenario WEM, options of the new regulatory framework are included in the scenario WAM.

The additional options of the categories two and three are either included in both, the WAM+ and WAM++ scenarios, or in WAM++ only. All options with the header "additional options" might be fostered by futures subsidies/incentives or taxes/discentives, but no elaborated measures are available yet. The category of "additional options for adaptions of production/management techniques" encompasses options related to production and management, which can be analyzed at farm-level. The third category includes additional options, which are demand-oriented or induce structural changes amongst farms, as opposed to a change of production techniques at farm level.

8.3 Calculation of abatement potential and costs

For this report, we analyse the achievable potential of defined mitigation options and their abatement costs. The concept of greenhouse gas abatement costs is used to get an understanding of the relation between emission reductions and costs of the options or measures at hand. Marginal abatement costs (MAC) are defined as the ratio of the change in costs/revenues and the change in emissions per production unit (e.g. per hectar of land).

$$\left[\left\langle MAC\ [€to_{GHG}^{-1}] = \frac{\Delta \cos t\ \ or\ revenue\ [€ha^{-1}yr^{-1}]}{\Delta emissions\ [to_{GHG}ha^{-1}yr^{-1}]}\right\rangle\right]$$

In order to determine the abatement potential of specific measures, a reference scenario for future target years is required. Here, we use the scenario WEM as a reference to derive figures on emissions based on expected future animal numbers, nitrogen amounts, cultivated areas, production techniques, yields, and other data. The base year refers to 2020 or, where available, a five-year average.

For most mitigation options, we calculated the greenhouse gas reduction potential via an estimation of the unitary abatement potential, i.e. the amount of reduction per production unit (e.g. per ha cropland, per kg milk) and the extent of affected units (e.g. farms, ha, LU). When estimating the affected units, we accounted for practical feasibility, considering a weighted distribution of farms, which are typical for the respective production process and for implementing the relevant mitigation option. We calculated mitigation options specific to carbon sequestration separately, as they refer to a temporary time-horizon only, and included them later with an average value for the time-period 2020 to 2050.

The calculation of mitigation costs rests on a profitability assessment. This is based on a differential cost calculation if only the production process itself is concerned, or on full cost calculations if investments and/or farm strategies are affected by a mitigation option. We include opportunity costs and account for both, effects on costs and on revenues. This means, if overall positive effects occur, the results have a negative sign. Furthermore, transaction and information costs were included. We based the analysis on the prices of 2020.

The used data sources for the calculations include:

- Premium payment schemes (Federal Ministry of Agriculture, Forestry, Regions and Water Management)
- Standardized gross margins, online catalogue (Federal Institute for Agricultural Economics, Rural and Mountain Research)
- Statistical data and prices from Statistics Austria and EUROSTAT
- Data from national studies or data points from international studies, if applicable
- If no data from national or international studies were available, we performed an extended analysis with data from previous farm-level assessment studies (FarmLife data, Herndl et al. 2015)

The calculation of mitigation costs is depicted for a single year and based on multi-year average statistical values and prices in 2020. Changes in commodity prices alter the costs of mitigation. Thus, the calculations show the relative costs when comparing different options, but to transfer them into measures, calculations with future prices have to be conducted. When discussing the results, we give a range for the estimated mitigation potential and a point estimate for the medium mitigation costs at medium mitigation potential.

In general, along with the method description, we want to point out, that an assessment of reduction potentials and mitigation costs over a long-term period is subject to uncertainties. Changes in parameters such as farm structure, input prices, or sales premium affect the choice of production processes. However, especially the volume of greenhouse gas abatement, defined implicit via the scope of measures (as noted in the initial section of this chapter), takes a major influence and hence contributes to the sensitivity of the results.

8.4 Mitigation measures – arable land and grassland

The numbers in the brackets refer to the mitigation measures matrix (cf. annex)

Reducing tillage on arable land (#31, 32, 110)

Reducing tillage includes the options "mulch seeding" and "direct seeding", amongst other options. It saves fuel and thus also greenhouse gases. Depending on the location and crop, there are several variants (e.g. cultivator). Potential risks of a drop in yields require adequate management measures. We estimate the additional abatement potential to amount for 1 to 20 kt CO2eGWP100 per year. If C-sequestration is also taken into account, the savings can be even higher but for a limited number of years.

Undersowing (beans, pumpkin, soy beans, sun flower) (# 34)

Undersowing may bring advantages in terms of a temporary potential for C-sequestration. A mixture of legumes and grains may increase N-efficiency and productivity, bring a slower mineralization and thus reduce N-leaching. We estimate the additional abatement potential to amount for 1 to 10 kt CO2eGWP100 per year (for a limited number of years).

Greening, cover crops (#37, 38)

Aim of the greening incentives is to improve carbon stores and resilience to climate change by improving soil and water conditions and soil fertility. Cover crops and a permanent greening may bring advantages in terms of productivity and erosion control. We estimate the additional abatement potential to amount for 5 to 30 kt CO2eGWP100 per year (for a limited number of years).

Reducing N-fertilizer application in lanes (# 120)

An avoidance of the application of fertilizers in the driving lanes becomes possible by use of exact fertilizer application methods such as trailing shoe, band application, and manure injection. This allows for twofold GHG reductions. First, cultivation requires less fertilizer without yield losses, and second, it reduces the risk of N2O losses from compacted soils under the driving lanes. We estimate the additional abatement potential to amount for 5 to 30 kt CO2eGWP100 per year.

Reducing soil compaction from wheel traffic (# 130)

A combination of waterlogging and high nitrate availability can favor N2O emissions. Measures against soil compaction reduce emissions and improve soil quality. Implementation includes driving in dry conditions and with adjusted tire pressure. We estimate the additional abatement potential to amount for 5 to 30 kt CO2eGWP100 per year.

Optimizing N-fertilization (# 140)

An optimization of manure and mineral fertilizer N-application according to plant nutrient requirements has positive effects on greenhouse gas emissions. Adjusted fertilization results in lower N-losses and increased N-efficacy. Practical means include fertilization planning, and optimizing fertilization time and spreading technology (arable and grassland farming). Needs-based and site-adapted fertilization reduces N2O emissions by avoiding a high N-surplus in the soil. Upstream, CO2 and N2O emissions in energy-intensive N-fertilizer production can be reduced. Accompanying management has to ensure continuous, stable yields. We estimate the additional abatement potential to amount for 10 to 100 kt CO2eGWP100 per year.

Optimizing legumes in crop rotations (# 160)

Increased cultivation of fodder legumes in crop rotations can reduce the need for mineral fertilizers and (based on cattle feeding) the need for imported protein fodder. A potential risk of reduced domestic yields has to be managed, because depending on single-farm circumstances an increase of legumes in crop rotations might reduce total yields. We estimate the additional abatement potential to amount for 10 to 60 kt CO2eGWP100 per year.

Reducing cultivation of organic soils (# 180)

Soils with drainage and a high content of organic matter emit greenhouse gases due to organic decomposition processes. With higher water levels greenhouse gas emissions can be reduced. This might especially be the case for low-yielding locations. Both the amount of land affected and the future conditions for participation are rather unclear. We estimate the additional abatement potential to amount for 1 to 100 kt CO2eGWP100 per year, depending on the area included.

Fostering of hedges (# 190)

Hedges offer benefits for yield security as they can protect against erosion, wind and drought. They can act as a carbon sink in the medium term and offer other advantages in terms of biodiversity. Planting hedges includes costs and workload and can make cultivation more burdensome, but also offers a yield-stabilizing effect. We estimate the additional abatement potential to amount for 1 to 50 kt CO2eGWP100 per year for a temporary timespan, depending on the area included.

Reducing conversion of grassland (# 17, 210)

Conversion of grassland by ploughing implies a degradation of soil organic carbon. Grassland preservation and options for a no-till renewal of grasslands allow for an avoidance of CO2 and N2O emissions. The extent of the abatement depends on soil characteristics and on the permanence of the measure. Here, we calculated two variants, a temporary grassland conversion restriction for about five years (UBB) and long-term grassland conversion restriction. The calculation of the temporary measure takes into account that a share continues for more than five years. We estimate the additional abatement potential to amount for 1 to 30 kt CO2eGWP100 per year.

Optimizing forage production (site-adapted) (# 220)

An optimization of forage production based on soil and plant requirements of the different plots allos for adapted varieties and plant communities and increases resilience and productivity in crop production. This should be combined with harvesting chains with a low potential for yield losses (quantity, energy, protein) to allow for high forage yields. Potential disadvantages in terms of fuel consumption should be minimized, including site-adapted mechanization. As a result, closer N-cycles can help to reduce N2O-emissions, less purchased feed is required (reducing upstream emissions), and good quality forage reduces CH4 emissions from enteric fermentation. This option could yield positive effects related to the area of production and per unit of output alike. We estimate the additional abatement potential to amount for 30 to 120 kt CO2eGWP100 per year.

8.5 Mitigation measures – livestock, manure, equipment

Optimizing herd composition and feed turnover (# 230)

A ruminant production, and especially a milk production, which is adapted to the locally available feed resources and coupled with an efficient supply of nutrients to the animals, can make a contribution to reducing greenhouse gases. For this, herd composition and production levels should be determined by the farms own forage supplies. Depending thereupon, more or less concentrate feed can be used. Specific means include adapted animal genetics, calculation of feed rations tailored to forage availability and performance of the animals, and optimal herd management. We estimate the additional abatement potential to amount for 10 to 70 kt CO2eGWP100 per year.

Optimizing fertility and lifetime production (cows) (# 240)

Improving health and fertility data of dairy cows and reducing the rearing phase helps to increase productive time and reduces feed turnover. Practical means for realizing this goal include genetics for fitness, health, and persistence of milk production, but also optimizing the number of heads for rearing according to demand. We estimate the additional abatement potential to amount for 30 to 150 kt CO2eGWP100 per year.

Increasing share of pasture (# 250)

Grazing of ruminants has advantages in terms of animal welfare and also offers a chance for climate protection. With a high volume of grazing hours and feed intake especially for dairy cows, offspring, suckler cows, heifers and oxen, farmers can reduce the effort for forage harvesting, forage storage and feeding. This saves fuel and/or electricity and reduces greenhouse gas emissions in the energy sector. Moreover, greenhouse gas emissions from manure storage are also reduced. Especially during the warm summer months high methane conversion factors apply. We estimate the additional abatement potential from an increase in pasture to amount for 10 to 100 kt CO2eGWP100 per year.

Direct reduction of enteric methane production (# 50, 260)

A direct reduction of enteric methane production can be realized via three pathways. First feedstuff composition, second breeding measures, and third the use of feed additives. The use of feedstuffs should be well-tested to rule out side effects, such as negative effects on feed conversion, animal health and food quality. We estimate the additional abatement potential to amount for 30 to 150 kt CO2eGWP100 per year.

Optimizing protein intake of bulls (# 270)

Protein-adapted feeding contributes to reduced greenhouse gas emissions via lower feedstuff requirements, which implies lower feedstuff production and reduced amounts of imported feed. Implementation could imply phase feeding und the use of more different feed rations (via adapted mixing of feed components). Outcomes include improved N-efficiency and animal health. We estimate the additional abatement potential to amount for 10 to 100 kt CO2eGWP100 per year.

Increasing phase feeding (pigs, poultry) (# 49, 310)

Protein-adapted feeding contributes to reducing the need for producing/ purchasing/importing protein-rich feedstuff. Greenhouse gas advantages result from reduced amounts of N, which particularly reduces emissions from manure storage and manure spreading. Practical means include phase feeding technologies for an adjusted feeding of pigs and poultry. Effects on performance can be manageable and costs for investments in feeding technology have to be taken into account. We estimate the additional abatement potential to amount for 30 to 100 kt CO2eGWP100 per year.

Covering existing manure storage (# 420)

Covering manure storage facilities decreases NH3 emissions and, indirectly, reduces induced N2O emissions. Reducing N-losses in storage increases the risk of N-losses from spreading or in the soils. However, if the N-level and spreading losses are kept constant, demand for concentrated feed and/or mineral fertilizers decreases, resulting in lowered greenhouse gas emissions upstream. Remark: As this technique mostly reduces NH3 emissions, only a part of the costs is included here. We estimate the additional abatement potential to amount for 1 to 10 kt CO2eGWP100 per year.

Close to the ground application of slurry (# 44, 45, 430)

Improvements in spreading technologies can lead to improvements in N-efficacy by reducing N-losses. This is dependent upon an improved fertilizer distribution and a concurrent reduction of used mineral fertilizers. Remark: As this technique mostly reduces NH3 emissions, only a part of the costs is included here. We estimate an effect in the range of 10 to 50 kt CO2eGWP100 per year for both, close to ground application on arable land and on grassland.

Slurry digestion in biogas plants (# 410)

Fermentation of manure can reduce methane emissions and contribute to energy production. This reduces climate-relevant emissions from liquid manure storage (CH4) and the produced energy is a substitute for fossil energy carriers. Calculations have to account for additional emissions from the construction of the biogas plant and, depending on the substrate mix, from the cultivation and harvesting of the biomass. We estimate the additional abatement potential of slurry digestion to amount for 10 to 50 kt CO2eGWP100 per year.

Increasing energy efficiency in traction (# 51, 510)

A reduction in fuel volumes and an increase in fuel efficiency for tractors, machines and agricultural vehicles reduces greenhouse gas emissions. Application requires an increased focus efficiency and activity planning and includes improved machine configurations, e.g. working at optimal engine speeds and increased effort for maintenance. We estimate the additional abatement potential to amount for 10 to 100 kt CO2eGWP100 per year.

Energy efficient plants (electricity/heating/cooling) (# 52, 530)

An increase in the energy efficiency of buildings, stationary machinery, devices for heating/cooling and electrical equipment reduces energy requirements. This in turn lowers greenhouse gas emissions associated with energy production. Depending on the agricultural branch, farms require relevant amounts of energy for heating and electric devices (e.g. heat demand at rearing farms, electricity for automation in dairy farms). Practical solutions include energy-efficient building construction and mechanization (e.g. housing insulation, milk cooling, drying technology). We estimate the additional abatement potential to amount for 30 to 120 kt CO2eGWP100 per year.

Optimizing utilization and service life of machinery (# 52, 550)

A long service life and high utilization of agricultural machinery allows for lower machinery investments and therefore saves greenhouse gas emissions from production at factory plants. One solution aims at the shared use of machinery to reduce the total amount of machinery. Another aspect is the increase in service life, especially through fostering of repair and maintenance work. We estimate the additional abatement potential to amount for 5 to 30 kt CO2eGWP100 per year.

Introduction of systematic farm-level climate check (# 560)

A "climate check" is a tool for analysing the climate impacts caused by operations. A farm-level management instrument could enable farmers to analyse their operations in terms of greenhouse gas emissions. Thus, climate-efficient opportunities would become visible and emission savings tangible. Currently, some approaches and tools for a climate check are in place, but no educational and advisory roll-out is in reach yet. We estimate the additional abatement potential to amount for 20 to 100 kt CO2eGWP100 per year.

8.6 Overview on mitigation options and abatement costs

The following table lists the mitigation options described above. The second and third column give an interval estimate of the mitigation potential and the last column a point estimate of the costs at an average mitigation potential. The mitigation options are ranked according to the costs per unitary abatement. Thus, the upper rows of the table indicate measures with preferable mitigation-cost-relations. The costs of abatement options below or close to zero are marked as <+/- 0>. The mitigation options shown here can be combined to a large degree. However, due to some overlapping, we expect the overall mitigation potential to be below the sum of the individual measures.

Table 2: Cost range of mitigation measures

Mitigation option	**Interval estimate of national abatement potential [kt CO_2eq yr^{-1}]**		**Marginal costs of abatement [EUR to^{-1} CO_2eq]**
reducing conversion of grassland	1	30	+/- 0
optimizing utilization and service life of machinery	5	30	+/- 0
optimizing forage production (site-adapted)	30	120	+/- 0
optimizing fertility and lifetime production (cows)	30	150	+/- 0
increasing phase feeding (pigs, poultry)	30	100	+/- 0
introduction of systematic farm-level climate check	20	100	+/- 0
optimizing legumes in crop rotations	10	60	31
increasing share of pasture	10	100	48
optimizing herd composition and feed turnover	10	70	92
increasing energy efficiency in traction	10	100	92
optimizing protein intake of bulls	10	100	120
greening, cover crops	5	30	146
direct reduction of enteric methane production	30	150	153
reducing N-fertilizer application in lanes	5	30	172
fostering of hedges	1	50	187
undersowing (beans, pumpkin, soy beans, sun flower)	1	10	215
energy efficient plants (electricity/heating/cooling)	30	120	237
slurry digestion in biogas plants	10	50	275
close to the ground application of slurry	10	50	333
reducing tillage (mulch seeding, direct seeding)	1	20	339
reducing cultivation of organic soils	1	100	394
optimizing N-fertilization	10	100	559
reducing soil compaction from wheel traffic	5	30	621
covering existing manure storage	1	10	867

Source: Fritz, 2022

9 The scenarios 'with existing measures' WEM and 'with additional measures' WAM

9.1 General assumptions

The agricultural sector model PASMA is very detailed and specific. It covers more activities than the economic accounts of agriculture and differentiates between various types of management (organic farming, high intensive farming, reduced input farming). This level of detail is necessary to model effects of agri-environmental policies, such as support for organic farming. The model therefore needs many input data which can only partially be derived from publications. Assumptions on many aspects need to be made explicitly that are based on expert judgement and not on rigorous data analysis (in more detail listed in the previous section).

The scenarios analysed in this study are cumulative. This means that the WEM scenario is based on a set of assumptions and the scenario WAM contains additional assumptions that are simulated together with those of WEM.

An important scenario assumption is that only prices and technological parameters (like milk production per cow, crop yields, piglet per sow) are assumed to change after 2030. The set of policy instruments, i.e., the way in which environmental programmes work, is fixed after this year.

A consequence of this assumption is that a certain outcome indicator that shows a downward trend until 2030 may rebound thereafter. Such model results are due to combinations of prices and technological parameters in later periods that are assumed to change, while policy instruments are assumed to remain constant until 2050. PASMA is a programming model that does not include results from earlier periods for the calculation of results of later periods.

The advantage of building scenarios in such a manner is that the model shows how indicators of interest might change if policy is fixed, while market conditions and technology are constantly changing. In the context of agricultural policy, such results are meaningful. Premiums for agri-environmental measures are kept constant in nominal terms, while prices for outputs and inputs are generally increasing, though moderately. The premiums reflect opportunity costs around the year 2020, but over time they change and therefore their effectiveness diminishes more and more after 2030.

9.2 Assumptions for the scenario WEM

In the WEM scenario commodity price projections are based on the OECD-FAO 2022 outlook for the EU, the 2022 legal framework regarding regulations in agriculture (air, water, animal welfare, land use), farm policy according to the CAP-SP[19] that is implemented in 2023 and

[19]https://info.bml.gv.at/themen/landwirtschaft/eu-agrarpolitik-foerderungen/nationaler-strategieplan/gsp-einreichung.html

climate policy measures as implemented in Austria in 2022 (which includes the eco-social tax reform with the national emission trading system for the non-ETS sectors which make fossil fuels more expensive in several steps). Projections of OECD-FAO end in 2031 and a new multi-annual financial framework and another agricultural policy reform is planned to be implemented in 2028.

In the following overview the most important assumptions are summarized. All elements must be considered when the results of this report are compared to projections from 2018 (Sinabell, Schönhart and Schmid, 2018):

- prices**:**
  - agricultural output and input prices used in WEM are in line with the OECD-FAO 2022 outlook to 2029-2031, except the price of diesel which is based on Umweltbundesamt (2023);
  - prices after 2030 follow the trend in most cases; in the other cases strongly increasing prices were flattened in a discretionary manner;
- technological parameters:
  - agricultural, climate and environmental policies will not change after 2028 but remain in place until 2050 without further changes;
  - technology assumptions are made explicit for crop yields, milk yields per cow and other parameters that capture technical change;
  - milk yield per cow is expected to remain permanently relatively low (compared to yields in countries like the Netherlands or Denmark) because of the high share of organic farms and animal welfare considerations;
  - productivity in livestock sectors (mainly feed requirements) is assumed to change as well, particularly with regard to nutrient requirements;
- climate change and adaptation of farmers:
  - crop yields are expected to be lower in 2050 than in 2030;
  - climate change adaptation is assumed to be captured in the expected price changes and in technological changes which includes efficiency gains in irrigation such that future droughts can be handled with incremental investments;
- resources and agricultural land:
  - the assumption is made that all necessary resources (labour, water, capital) are available and are financed either by revenues or subsidies granted from agricultural policy;
  - the loss of agricultural land is following the long term trend.
- policy measures:
  - sector specific measures implemented according to climate and energy policies in place in 2022 (most importantly this includes an incremental increase of diesel prices);
  - agricultural policy according to CAP-SP as implemented in 2023; this includes the agri-environmental programme and subsidies for climate relevant investments;

- over the projection period, the programme for rural development is assumed to be maintained.

9.3 Additional assumptions for the scenario WAM

In the scenario WAM additional measures are considered compared to the scenario WEM. Their rationale is to integrate policies that will become effective after the introduction of the CAP-SP in 2023 or are anticipated to be effective in 2030.

When the scenario WEM was designed it became evident that neither market conditions nor planned policies are such that significant reductions of ruminants are likely to happen until 2030. The most important reason for this assumption is that Austria has a comparative advantage in milk production because of the large grassland share on total agricultural land and that OECD-FAO forecasts indicate favourable prices for milk. The major share of agricultural emissions is from ruminants and manure management. The CAP-SP with its climate ambition was assumed not to provide incentives enough for a drastic reduction of livestock as is necessary to come close to a reduction of 48% compared with 2005 (the target for the non-ETS sectors in Austria).

The regulations relevant for emission that are in place by 2023 and those expected to become effective until 2030 are expected to increase the costs of agricultural production by making investments more expensive. This assumption was discussed in a stakeholder workshop and the consensus opinion from experts on agriculture. In the scenario WAM the assumption is made that support for agriculture is the same as in WEM.

In the PASMA model higher investment costs are implemented via a higher present value for leasing stable capacity. This makes livestock production more expensive and therefore other activities (such as crop production) become more profitable for farmers. The factor of higher costs in the scenario WAM compared to WEM is 10%. This increase seems reasonable to finance construction such as slurry tank covers, slurry separators, and improved air conditioning for new investment.

An overview of measures and regulations considered in the scenarios WEM and WAM is presented in Table 3. In Table the additional measures analysed in scenarios WAM+ and WAM++ are presented. An "X" indicates that a given measure/regulation was taken into account in the model run.

Table 3: Scenario – Measures – Matrix for scenarios WEM and WAM

##		WEM		WAM
		2020	2030	2030
	existing regulatory framework			
01	national emission trading (NEHG)		X	X
02	CAP 2014-2020 with extension to 2022	X		
03	nitrates directive action programme up to 2016	X	X	
04	national air pollution control programme up to 2018	X	X	
05	effort sharing regulation – climate protection act 2011	X	X	
06	animal protection act 2004 up to 2021	X		
	to be implemented regulatory framework after 2022			
07	animal protection act 2022 (potential impact on manure management)		X	X
ß8	nitrates direction action program – to be implemented 2023			X
09	national air pollution control programme – to be implemented 2023			X
10	national energy and climate plan – to be implemented			X
11	climate protection act – to be implemented			X
12	measures from energy efficiency law			X
13	measures from renewable heating law			X
	CAP-Strategic Plan GHG relevant measures		X	X
14	new: capping of DP, young farmers, redistribution		X	X
15	more land for biodiversity (UBB)		X	X
16	crop-rotation on arable land (UBB)		X	X
17	grassland conversion restriction (UBB)		X	X
18	arable land: erosion control (UBB)		X	X
19	arable land: additional premium for more land for biodiversity		X	X
20	arable land: basic module		X	X
21	arable land: top-up biodiversity		X	X
22	regulation for organic farming (pasture for cattle)		X	X
	grassland			
23	grassland land: basic module		X	X
24	grassland: basic module LU < 1.4 ruminant LU/ha		X	X
25	grassland: basic module LU > 1.4 ruminant LU/ha		X	X
26	top-up biodiversity		X	X
	reduction yield increasing substances / herbicides /pesticides			
27	arable land		X	X
28	vineyards		X	X
29	orchards		X	X
30	hops		X	X

Table 3: Scenario – Measures – Matrix – cont.

#		WEM 2020	WEM 2030	WAM 2030
	arable land: erosion control / water quality			
31	mulch seeding		X	X
32	direct seeding		X	X
33	mounding in potatoes production		X	X
34	undersowing (soybeans, cucumber, sunflower, beans)		X	X
35	green ditches on arable land		X	X
36	intermediate crop (variants)		X	X
37	active greening (variants)		X	X
38	evergreen system		X	X
	other land: erosion control			
39	hops: erosion control		X	X
40	vineyards: erosion control (variants)		X	X
41	orchards: erosion control (variants)		X	X
	nitrate leaching controls			
42	arable land in programme regions		X	X
43	maintenance of grassland (variants – slope dependent)		X	X
	slurry management		X	X
44	arable land: close to the ground application of slurry		X	X
45	grassland land: close to the ground application of slurry		X	X
46	slurry separation and biogas usage		X	X

Source: own elaboration; version from 25th August 2022.

In the scenarios WAM+ and WAM++ additional measures are analysed such as a reduction of food waste and circular economy measures and a shift to a healthier and climate-friendly diet by a larger share of the population. In order to further limit emissions from agriculture, a mix of incentives (in WAM+) and disincentives (WAM++) is implemented in the model simulations (see Table 4).

Table 4: Scenario – Measures – Matrix for scenarios WAM+ and WAM++

		WAM+	WAM++
		2030	2030
	Reduction of food waste and circular economy measures		
47	Reduction of food waste and consequently reduction of food demand	X	X
	Public health measures and information campaigns		
48	Shift to a healthier and climate-friendly diet by a larger share of the population	X	X
	incentives and subsidies		
49	*Optimisation of feeding systems*	X	X
50	*CH4-reducing feed additives*	X	X
51	*Higher variable costs due to additional GHG reduction measures*	X	X
52	*Investments for additional GHG reduction*	X	X
53	*100% biofuel for tractors*	X	X
54	*Soil carbon sequestration integrated into EU ETS*	X	X
55	*Premiums for ruminant reduction*	X	X
56	*Premiums for reduction of other animal categories*	X	X
57	*Demand shift towards plant-based food (= low price for animal products)*	X	X
58	*Premiums for fallow land with high carbon content*	X	X
	taxes and negative incentives		
59	*Higher consumer taxes on animal products (milk, meat)*		X
60	*Tax on CH4 emissions from enteric fermentation*		X
61	*Tax on GHG emissions from manure*		X
62	*Tax on GHG emissions from farm manure*		X
63	*Tax on soil management causing GHG emissions*		X
64	*Tax on mineral fertilisers depending on GHG emission potential*		X
65	*Tax on herbicides and insecticides for conventional farms*		X
66	*Regulation of land use / reduction of conversion of land to residential use*		X

10 Results of the model analysis of scenarios WEM, WAM, WAM+ and WAM++

10.1 Results of the agricultural sector model of scenarios WEM and WAM

The detailed results of the model analysis of the scenarios WEM and WAM are presented in Appendix II. Before turning to the results, one important assumption needs to be highlighted. It is assumed that arable land will decrease (from 1.325 million hectares in 2020 to 1.218 million hectares in 2050). This applies for both scenarios, WEM and WAM. The cultivation of arable crops (including cereals, field fodder, sugar beet, oil and protein crops, field vegetables) will consequently decrease. There are varying degrees of decline between the different crops, as changing prices and different yield developments per hectare influence the advantageousness of individual crops. The land that becomes available is used for other purposes (forests, infrastructures, housing, etc.), as observed in the last 20 years. How the land is used is not the subject of PASMA modelling.

The main results for the agricultural sector are:

- In the scenario WEM the size of the **cattle** herd declines from 1.86 mil. head in 2020 to 1.63 mil. head (-12.4%) in 2030 (Table 13 and Table 17). After 2030, the number of cattle continues to decline, but at a lower rate, i.e., to 1.55 mil. head in 2050 (-16.2% compared to 2020). This is because only the output and input prices and technical coefficients change. No further increment in investment costs is assumed. In its latest outlook on agricultural markets, the European Commission also anticipates lower beef production and a declining number of dairy cows at EU level.
- In the scenario WAM the size of the cattle herd declines from 1.86 mil. head in 2020 to 1.59 mil. head (-14.1%; Table 21) in 2030. After 2030, the number of cattle continues to decrease at higher rate than in the scenario WEM, to 1.46 mio. Head in 2050 (-21.4% compared to 2020). This is because not only output and input prices and technical coefficients change in WAM, but also a further increment of investment costs is assumed and makes milk and beef production less profitable. Milk yield per cow and other parameters are the same in the scenarios WEM and WAM.
- In the scenario WEM, the number of **pigs** decreases at a much higher rate than the number of cattle in all periods studied. For instance, by 17.4% between 2020 and 2030. The reason is that output price and input cost relations are less favourable. Compared to the current trend, this result is in line with expectations. In its most recent outlook on agricultural markets the European Commission expects lower production of pork as well at EU level.
- In the scenario WAM the number of pigs decreases at a similar rate as in the scenario WEM in all periods studied, e.g., by 18.9% between 2020 and 2030. This is because higher investment costs to reduce emissions make pork production less favourable.
- The number of **poultry** declines at a similar rate as the number of pigs until 2030 in both scenarios WEM and WEM (-17.7% and -20.7%, respectively). After 2030, the number of poultry decreases at a lower rate than the number of pigs. The modelled development of the poultry population is in contrast to the observed production trends, as in Austria the number of chickens and turkeys has increased in recent years. However, a declining number of heads is not implausible, as competition for poultry meat and eggs from imports from Ukraine was a big concern for producers in Austria after the free trade agreement was implemented in 2014. Time series going back to 1990 show that the number of heads of poultry decreased sharply after Austria's accession to the EU and the introduction of stricter production regulations.
- In both scenarios WEM and WAM the results indicate that more commercial **fertilizer**, in particular nitrogen, will be applied to agricultural land. The increase in mineral nitrogen fertilizer consumptions is higher in the scenario WAM, because **manure** production also

decreases due to the reduction in livestock. The nutrient deficit is compensated by higher sales of commercial fertilizer to the agricultural sector.

- Overall, **total cropland** declines steadily over each study period through 2050 in both scenarios (WEM and WAM). Similar developments are modelled for **grassland** areas. The results show that both cropland and grassland decrease slightly more in the scenario WAM.
- The **cropping area** for cereals declines at about the same rate in both scenarios WEM and WAM and over all study periods (cf. Table 15 for observed data, Table 19 for WEM, and Table 23 for WAM results). The same is true to maize and other arable crops. This result also applies to legumes which is notable because the PASMA model accounts for the fact that these crops accumulate nitrogen during the vegetation period. The decrease in cropping area is mainly due to the assumption that the land used for other purposes (e.g., forest, infrastructure, housing) will change as observed in the last 20 years, affecting agricultural land use and cropping areas.
- According to the model results, the **crop yields** decline at a similar rate in both scenarios, however following a different pattern than the reduction of land allocated to various crops (cf. Table 16 for observed data, Table 20 for WEM, and Table 24 for WAM results). Modelled crop yields per hectare decrease slightly more than corresponding cropping areas until 2030, then remain relatively stable until 2040, before decreasing again until 2050.
- **Organic soils** are assumed to stabilise at the observed level throughout the period of the analysis.

10.2 Results of the agricultural sector model of scenarios WAM+ and WAM++

The results of scenario WAM+ are compared with the WEM scenario. This provides a uniform reference with the scenario WAM. According to the assumptions, a stronger decline in livestock farming is to be expected and crops with high nitrogen demand become less profitable. The most important results are in detail:

- In the WAM+ scenario, the cattle population decreases to 1.59 million head (-14.5 %) by 2030. The number of dairy cows is about 11,000 head below that in WEM in that year and about 15,000 head below that in 2050. There are also further decreases in the other cattle categories.
- The pig population in WAM+ develops similarly to that in WEM, with -17.5% by 2030.
- The number of poultry decreases with -20.8% in WAM+ more strongly than in WEM (roughly corresponds to the decrease in WAM). By 2050, the model results for the poultry population show a similar decline as in WEM.

- In the WAM+ scenario, the use of mineral fertiliser is significantly lower compared to the WEM scenario. While in WEM more than 111,000 t N are used in 2030, this amount is reduced to less than 90,000 t N in WAM+ (-18.4 % compared to 2020).
- In arable farming, less cereals will be cultivated in WAM+ in 2030 on about 67,000 hectares, which corresponds to a decrease of 8.1 % compared to the cereal area in 2020. Legumes will also be cultivated to a lesser extent in WAM+ than in WEM in all periods examined. However, the difference is smaller than for cereals.
- The amount of arable crops harvested also decreases, as can be expected from the decrease in area. This also reduces the amount of nitrogen contained in plant residues.

The results of scenario WAM++ are now compared with the WAM+ scenario. According to the assumptions, on the one hand a stronger decline in livestock farming, especially in the number of cows, is to be expected. On the other hand, crops with high nitrogen demand become even less profitable. The most important results are in detail:

- In the WAM++ scenario, the cattle population declines significantly more compared to the WAM+ scenario, i.e. in 2030, about 325,000 (20.5 %) and in 2050 about 424,000 (28.1 %) fewer cattle are kept than in WAM++ in the respective year. The stronger decline can be observed for all cattle categories, as the number of births is significantly lower. For example, in 2030 (2050) there will be about 100,000 (126,000) fewer dairy cows.
- The pig population is also lower in Scenario WAM++ than in Scenario WAM+. However, the decline of about 10.9 % in 2030 is comparatively limited.
- For the poultry stock, the model results show a stronger decline in 2030 than for the pig stock (-16.2% compared to WAM+). As in WAM+, the poultry stock in WAM++ decreases further after 2030.
- In WAM++, the use of mineral fertilisers continues to decrease over all study periods compared to WAM+. For example, in 2030, about 87,000 t N are used in WAM+, whereas in WAM++ about 74,000 t N are used, which corresponds to a decrease of 15.2 %. After 2030, the use of mineral fertiliser remains relatively constant in both scenarios.
- In arable farming, the area of cereals decreases by more than 40,000 hectares in 2030 in the WAM++ scenario compared to WAM+, and the cultivation of legumes also decreases further.
- The amount of arable crops harvested also decreases, as can be expected from the decrease in area. This also further reduces the amount of nitrogen contained in plant residues compared to WAM+.

10.3 Results of the macro-economic model

The change of agricultural production was used as an input to shock the model ADAGIO which represents the Austrian economy in a very detailed manner. The effects on value added and employment are presented in Table 5. The effect on gross value added is relatively low given the size of the economy. This reflects the fact that the agricultural sector's share on the national economy is less than one percent. Having this small share in mind, the absolute changes are remarkable. The decline in employment is significant.

In Input-Output simulations, three main groups of effects can conceptually be distinguished, corresponding to different boundaries of the system under consideration:

- **Direct effects** originate in the agricultural sector itself. They describe in how far the agricul-tural sector is economically different in the simulation run when compared with the base run. These direct effects are taken directly from PASMA.
- **Indirect effects** show the impact of changes in the agricultural sector on the "rest of the economy", both upstream and downstream (as forward and backward linkages): changes in the level and the structure of input use directly affects other sectors of the economy (e.g., the petrochemical industry); these are the upstream effects (backward linkages). The downstream effects (forward linkages), on the other hand, affect sectors that buy products from the agricultural sector. Together with the direct effects, the indirect effects constitute the so-called "Type1-effects".
- Contrary to the first two effects, which are exclusively production-oriented (i.e., they affect only other sectors along the value chain), **induced effects** arise from changes in value add-ed: changes in economic activity will also lead to changes in wages, profits, and taxes. These will lead to changes in final demand: higher wages will lead to higher consumption (or, in the case of lower wages, lower consumption); changes in profits give rise to changes in capital owners' income (as well as investment in the case of retained profits), also feeding into consumption. Rising tax receipts can lead to rising public spending (at constant budget deficit) or lead to lower budget deficits (with constant public spending). The simulations in this project are done under the assumption of constant public deficits. All these induced effects constitute multiplier effects (also called "Type2" effects): by working via value added, they augment the initial (direct and indirect) effects.

In the "real world", these three effects cannot be observed separately; using an economic model like ADAGIO, however, allows the separation of effects. In this application, we will concentrate on production-related effects, to highlight the effects that can unambiguously be traced back to the changes in the agricultural and food sector. However, there is one aspect of induced effects that also pertains to production, viz replacement investment: in the production process, capital is "used up" (depreciated), leading to replacement investment. As depreciation is part of value added, this constitutes an "induced effect". However, it is an integral part of the production process, so we set the boundaries of our analysed system accordingly. We will call this setup "Simulation of Type2i" (for investment).

Table 5: Scenario results of the macro-economic model

Scenario	Year	Value Added Mil. € 2020 prices	Employment 1,000 persons
WEM	2020	0	0.0
	2030	-209	-9.0
	2040	-249	-8.9
	2050	-511	-14.0
WAM	2020	0	0.0
	2030	-234	-10.5
	2040	-295	-11.1
	2050	-597	-17.6
WAM+	2020	0	0,0
	2030	-267	-13,2
	2040	-313	-13,9
	2050	-586	-19,6
WAM++	2020	0	0,0
	2030	-973	-34,8
	2040	-1,066	-35,0
	2050	-1.462	-42,7
biogas plant	construction	1,798	20
	operation	354	,.9

Source: own calculations.

11 Conclusions

The report presented the numerous policy efforts to limit the emissions of the agricultural sector. Both, European and national policies are regulating agricultural production and therefore affect its emissions. The scenario WEM simulates the consequences of the policies implemented in 2023 and the anticipated prices in 2030. The results show that agricultural activities and agricultural output will decline compared to the situation observed in 2020. However, the reduction of livestock and other emission causing factors will not be sufficient to curb emissions in such a manner that emissions drop by more than 10%. Even further emission reductions are necessary however, to attain a level that is consistent with the goal of the effort sharing regulation of -48% in 2030 compared to the year 2005. In order to reach such an amount of reduction a scenario such as WAM++ needs to be put in practice. However, this means that many farmers will have to look for other sources of income because activities such as milk and beef production will no longer be economic viable for them.

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Appendix I: Price and parameter assumptions for the model PASMA

Table 6: Price projections for the European Union, 2022 – 2031 (June 2022)

Groupe	Commodity	Unit	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
CEREALS	Wheat	€/t	204.16	280.98	271.06	219.86	199.12	194.19	192.01	193.48	193.89	194.27	194.94	195.39
	Maize	€/t	243.12	269.65	279.07	224.30	203.14	197.14	195.17	197.43	197.68	197.65	197.79	197.86
	Other coarse grains	€/t	179.00	219.74	231.30	185.71	167.90	162.74	160.39	162.37	162.92	163.50	164.00	164.35
	Rice	€/t	662.20	663.25	627.61	616.43	623.38	627.03	630.14	631.38	634.27	635.66	638.32	635.05
	Distiller's dry grains	€/t	281.98	248.64	252.00	240.81	234.98	227.31	224.13	226.12	226.80	227.27	227.31	226.72
OILSEEDS	Soybean	€/t	401.49	364.46	363.76	318.64	299.22	297.83	298.58	302.13	305.91	306.75	308.96	312.96
	Other oilseeds	€/t	479.03	435.21	404.09	329.85	319.30	305.68	305.72	310.12	311.87	313.87	316.28	318.82
	Protein meals	€/t	368.35	331.14	334.34	294.35	277.13	272.07	271.93	276.86	278.98	281.25	283.79	284.99
	Vegetable oils	€/t	1,149.28	1,322.42	1,134.04	1,002.14	1,011.95	988.64	997.10	1,001.44	1,009.75	1,016.14	1,024.83	1,033.69
SUGAR	Sugar	€/t	419.58	452.83	476.23	408.85	377.85	367.49	362.71	366.40	368.44	370.56	372.79	374.49
	White sugar	€/t	419.58	452.83	476.23	408.85	377.85	367.49	362.71	366.40	368.44	370.56	372.79	374.49
	High fructose corn syrup	€/t	225.00	281.45	295.56	253.85	235.04	228.86	226.33	228.01	229.12	230.15	230.97	231.48
	Sugar beet	€/t	28.79	29.48	31.50	27.80	25.95	25.39	25.17	25.46	25.81	25.99	26.15	26.28
	Molasses	€/t	198.00	235.62	245.98	206.45	187.76	178.52	175.56	177.41	180.31	182.72	184.36	185.34
MEATS	Beef and veal	€/t	3,534.50	3,880.00	4,581.30	4,017.00	3,672.03	3,660.43	3,656.14	3,662.67	3,656.80	3,662.65	3,665.27	3,661.26
	Pigmeat	€/t	1,601.00	1,505.00	1,633.01	1,462.43	1,496.29	1,487.53	1,489.32	1,495.50	1,490.33	1,490.12	1,477.17	1,464.67
	Poultry meat	€/t	1,874.84	1,842.95	2,163.63	2,054.59	2,061.68	2,083.06	2,103.14	2,124.41	2,124.37	2,118.49	2,114.54	2,110.68
	Sheepmeat	€/t	5,802.20	6,320.00	5,718.33	5,590.40	5,568.37	5,555.85	5,573.98	5,602.80	5,604.47	5,634.12	5,643.73	5,634.52
DAIRY	Milk	€/t	322.19	370.88	370.92	363.34	350.33	343.38	343.21	345.58	347.84	352.06	354.93	357.79
	Butter	€/t	3,359.97	3,950.00	3,910.33	3,664.38	3,497.62	3,431.40	3,434.35	3,472.86	3,482.33	3,529.67	3,555.66	3,583.61
	Cheese	€/t	3,036.72	3,150.00	3,209.74	3,132.60	3,071.15	3,043.39	3,053.23	3,076.82	3,097.22	3,128.25	3,152.87	3,176.96
	Skim milk powder	€/t	2,207.04	2,480.00	2,494.57	2,509.36	2,443.62	2,394.50	2,391.65	2,400.42	2,424.40	2,450.33	2,474.79	2,497.08
	Whole milk powder	€/t	2,786.79	3,509.74	3,493.29	3,446.13	3,346.41	3,293.24	3,297.17	3,316.87	3,349.54	3,391.43	3,427.59	3,462.99
	Whey powder	€/t	705.89	951.70	865.02	848.41	821.89	806.86	806.59	810.09	816.37	823.64	830.72	838.20
	Casein	€/t	7,177.03	7,025.31	7,079.51	7,130.77	6,931.35	6,783.69	6,770.71	6,786.17	6,844.48	6,905.03	6,965.15	7,019.22
BIOFUEL	Ethanol	€/hl	60.44	72.60	77.84	56.61	56.66	57.45	56.99	57.39	57.63	57.86	57.44	57.70
	Biodiesel	€/hl	74.59	126.55	110.56	95.05	93.15	92.89	93.07	93.40	93.95	94.07	94.28	94.50
FISHERIES	Fish	€/t	2,982.57	3,099.82	3,910.90	3,494.82	3,500.19	3,414.63	3,450.33	3,510.96	3,702.14	3,536.15	3,557.62	3,583.09
	Fish from aquaculture	€/t	3,375.11	3,233.17	4,139.78	3,556.56	3,591.27	3,498.59	3,563.10	3,647.29	3,884.28	3,682.75	3,734.82	3,786.38
	Fish meal	€/t	1,255.76	1,248.27	1,377.56	1,295.42	1,336.16	1,179.86	1,199.75	1,263.29	1,344.84	1,280.32	1,302.12	1,324.58
	Fish oil	€/t	1,865.50	1,795.60	2,156.79	1,867.70	1,749.47	1,567.17	1,559.56	1,573.30	1,856.20	1,728.49	1,761.61	1,795.14
COTTON		€/t	871.20	841.68	936.02	871.65	880.62	887.34	890.36	891.95	892.56	889.31	883.23	874.80
ROOTS AND TUBERS		€/t	511.66	549.78	587.59	593.49	589.06	593.54	593.49	600.80	601.90	606.14	610.58	612.24
PULSES		€/t	123.43	207.26	181.63	147.52	132.50	127.67	126.14	126.99	127.49	128.09	128.62	128.84

Source: OECD-FAO, 2022, Agricultural Outlook 2022-2031.

Table 7: Observed and projected nominal farm prices for crop products in Austria

Product	Unit	ø2019/2021	ø2016/2020	2020	2021	2030	2040	2050
Milling wheat	EUR/t	189.66	161.92	165.16	241.60	165.09	168.04	171.14
Feed wheat	EUR/t	162.17	133.94	141.82	203.86	141.16	143.67	146.32
Durum wheat	EUR/t	256.71	202.50	243.46	313.84	223.45	227.43	231.63
Milling rye	EUR/t	161.75	147.01	124.75	215.57	141.95	144.80	147.71
Fodder rye	EUR/t	134.64	119.15	111.57	171.69	118.16	120.53	122.96
Spring barley	EUR/t	138.73	119.82	120.79	172.25	121.75	124.19	126.69
Malting barley	EUR/t	184.55	165.28	180.86	191.53	161.96	165.21	168.54
Winter barley	EUR/t	138.73	119.82	120.79	172.25	120.76	122.91	125.18
Oats	EUR/t	162.85	150.10	152.20	186.46	142.91	145.78	148.72
Triticale	EUR/t	159.35	124.40	129.09	218.74	139.84	142.65	145.52
Spelt	EUR/t	320.89	253.13	304.33	392.31	279.31	284.29	289.54
Grain corn	EUR/t	154.48	133.05	130.64	204.95	135.57	138.30	141.08
Field beans	EUR/t	322.18	266.44	277.44	441.05	291.70	315.77	340.32
Grain peas	EUR/t	160.01	155.09	159.78	168.44	144.87	156.82	169.01
Soybeans	EUR/t	407.54	337.03	350.95	557.90	368.98	399.43	430.48
Sunflowers	EUR/t	362.12	288.53	316.36	476.87	286.26	308.76	330.84
Sugar beet	EUR/t	26.29	26.29	26.29	26.29	24.83	26.55	28.30
Table potatoes	EUR/t	190.32	194.32	135.71	178.86	167.02	170.37	173.80
Starch potatoes	EUR/t	97.58	96.54	92.66	94.32	85.63	87.35	89.11
Winter rapeseed	EUR/t	397.50	338.59	353.63	495.10	314.23	338.92	363.16
Poppy	EUR/t	2,351.73	2,250.40	2,297.50	2,030.00	2,345.67	2,438.23	2,531.96
Hops	EUR/t	8,213.71	7,915.43	7,953.21	8,662.63	8,731.32	9,187.72	9,643.97
Spice plants	EUR/t	3,634.57	3,634.57	3,634.57	3,634.57	3,813.76	4,000.54	4,187.39
Fiber hemp	EUR/t	45.08	45.07	45.09	45.09	47.31	49.63	51.95
Oil pumpkin	EUR/t	2,934.22	2,803.91	2,998.18	3,180.44	3,176.09	3,348.89	3,520.78
Oil flax	EUR/t	300.00	300.00	300.00	300.00	314.79	330.21	345.63
Seeds	EUR/t	180.00	180.00	180.00	180.00	188.87	198.12	207.38
Strawberries	EUR/t	3,703.52	3,120.26	3,852.27	4,509.20	4,193.84	4,455.24	4,713.80
Fruit	EUR/t	638.67	492.31	705.40	787.51	733.73	780.29	826.17
Wine	EUR/t	413.50	517.49	400.00	550.50	479.57	512.31	544.71

Source: own calculations based on OECD-FAO, 2022.

Table 8: Observed and expected nominal farm prices for livestock products in Austria and milk yields

Product	Unit	ø2019/2021	ø2016/2020	2020	2021	2030	2040	2050
Cowmilk	€ per kg	0.38	0.36	0.38	0.39	0.39	0.42	0.45
Veal	€ per kg SW	6.01	5.92	5.83	6.15	6.00	6.01	6.02
Heifer for breeding	€ per head	1,741.51	1,808.70	1,768.81	1,782.64	1,740.77	1,742.84	1,746.36
Heifer for suckler cow	€ per head	1,163.17	1,151.49	1,154.14	1,202.98	1,162.67	1,164.06	1,166.40
Beef of heifer	€ per kg SW	3.59	3.50	3.43	3.83	3.59	3.60	3.60
Mutton	€ per kg SW	4.89	4.66	4.72	5.31	4.76	4.88	5.00
Beef (oxen)	€ per kg SW	4.14	4.03	4.08	4.36	4.14	4.15	4.16
Sheep cheese	€ per kg	0.71	0.69	0.70	0.74	0.73	0.78	0.83
Pork	€ per kg SW	1.70	1.63	1.71	1.61	1.57	1.53	1.50
Beef	€ per kg SW	3.82	3.79	3.70	4.04	3.82	3.83	3.84
Turkey	€ per kg LW	1.54	1.50	1.51	1.60	1.73	1.76	1.79
Fallow deer	€ per kg SW	2.72	2.68	2.50	2.90	2.72	2.72	2.73
Wool	€ per kg	0.30	0.50	0.28	0.29	0.30	0.29	0.29
Goat meat	€ per kg SW	1.67	2.76	1.56	1.57	1.62	1.66	1.70
Goat cheese	€ per kg	0.79	1.31	0.74	0.75	0.81	0.87	0.93
Male calves	€ per kg LW	4.09	4.19	4.03	4.22	4.09	4.09	4.10
Male calves for beef	€ per kg SW	471.31	482.49	464.56	486.27	471.11	471.67	472.62
Female calves	€ per kg LW	3.11	3.04	3.03	3.36	3.11	3.11	3.12
Female calves for beef	€ per kg SW	449.74	439.04	437.73	486.28	449.55	450.09	450.99
Eggs	€ per unit	0.19	0.19	0.19	0.19	0.21	0.22	0.22
Chicken	€ per kg SW	1.01	1.04	1.01	1.01	1.13	1.15	1.17
Young chicken	€ per head	3.84	3.98	3.84	3.84	4.31	4.39	4.47
Piglet	€ per kg LW	2.41	2.34	2.49	2.16	2.22	2.17	2.12
Gilt	€ per head	315.11	309.46	323.00	294.16	291.12	284.35	277.44
Cow	€ per kg SW	2.65	2.59	2.48	2.96	2.65	2.66	2.66
Sow	€ per kg SW	1.16	1.18	1.25	1.00	1.07	1.05	1.02
Sheep meat	€ per kg SW	0.61	0.62	0.59	0.65	0.60	0.61	0.63
average milk yield per cow	kg per cow			7,286		8,024	8,762	9,500

Source: own calculations based on OECD-FAO, 2022.

Table 9: Revenue per unit of quantity organic versus conventional

		2015	2016	2017	2018	2019	2020	2021	**Ø 2019-21**
Product	Einheit				conventional production				
Common wheat	€/100kg	15.33	12.62	16.61	16.60	16.03	15.42	21.35	**17.60**
Durum wheat	€/100kg	27.48	17.72	18.96	18.43	19.83	22.70	30.26	**24.26**
Rye	€/100kg	13.40	12.86	15.87	16.24	14.85	13.41	18.25	**15.50**
Winter barley	€/100kg	13.92	12.11	13.05	14.87	14.79	14.07	17.54	**15.47**
Spring barley	€/100kg	14.63	12.54	13.87	14.39	14.94	16.19	17.56	**16.23**
Oats	€/100kg	13.49	13.54	14.69	15.61	17.37	15.06	17.91	**16.78**
Grain corn	€/100kg	16.47	14.71	15.04	16.56	15.42	14.31	21.24	**16.99**
Food Potatoes	€/100kg	17.76	16.16	17.05	19.27	19.09	16.14	15.78	**17.00**
Starch	€/100kg	8.27	8.54	8.78	9.35	9.00	9.08	9.38	**9.15**
Sugar beet	€/100kg	3.17	3.17	2.87	2.64	3.05	2.87	2.90	**2.94**
Grapes	€/kg	0.72	0.94	0.80	0.59	0.65	0.61	0.76	**0.67**
Wine	€/l	2.82	3.03	3.38	3.02	2.66	2.51	2.65	**2.61**
Milk delivered to dairies	€/100kg	32.10	29.50	39.60	35.42	35.28	35.17	37.23	**35.89**
					organic production				
Common wheat	€/100kg	31.94	32.41	36.73	35.63	28.60	25.49	32.44	**28.84**
Durum wheat	€/100kg	42.64	42.86	42.09	28.17	34.46	37.25	39.52	**37.08**
Rye	€/100kg	22.25	25.22	30.92	30.44	22.85	19.98	28.83	**23.89**
Winter barley	€/100kg	24.04	22.63	24.68	26.34	19.28	19.04	26.82	**21.71**
Spring barley	€/100kg	24.84	23.61	21.94	25.57	28.75	25.40	29.18	**27.78**
Oats	€/100kg	18.74	18.85	24.10	24.35	21.51	24.78	29.76	**25.35**
Grain corn	€/100kg	33.40	32.92	31.69	29.36	32.06	27.03	41.18	**33.42**
Food Potatoes	€/100kg	42.66	40.29	37.12	44.59	48.93	37.84	52.47	**46.41**
Starch	€/100kg	15.48	15.85	16.12	18.51	19.66	13.52	12.06	**15.08**
Sugar beet	€/100kg	7.97	8.19	7.55	8.42	8.10	8.00	6.68	**7.59**
Grapes	€/kg	0.86	1.08	0.88	0.71	0.63	0.71	0.72	**0.69**
Wine	€/l	2.34	3.26	3.93	3.42	3.55	2.96	2.54	**3.02**
Milk delivered to dairies	€/100kg	40.60	41.58	47.61	44.57	44.61	45.45	47.55	**45.87**
					organic in relation to conventional production				
Common wheat	%	2.1	2.6	2.2	2.2	1.8	1.7	1.5	**1.6**
Durum wheat	%	1.6	2.4	2.2	1.5	1.7	1.6	1.3	**1.5**
Rye	%	1.7	2.0	2.0	1.9	1.5	1.5	1.6	**1.5**
Winter barley	%	1.7	1.9	1.9	1.8	1.3	1.4	1.5	**1.4**
Spring barley	%	1.7	1.9	1.6	1.8	1.9	1.6	1.7	**1.7**
Oats	%	1.4	1.4	1.6	1.6	1.2	1.7	1.7	**1.5**
Grain corn	%	2.0	2.2	2.1	1.8	2.1	1.9	1.9	**2.0**
Food Potatoes	%	2.4	2.5	2.2	2.3	2.6	2.3	3.3	**2.7**
Starch	%	1.9	1.9	1.8	2.0	2.2	1.5	1.3	**1.6**
Sugar beet	%	2.5	2.6	2.6	3.2	2.7	2.8	2.3	**2.6**
Grapes	%	1.2	1.2	1.1	1.2	1.0	1.2	0.9	**1.0**
Wine	%	0.8	1.1	1.2	1.1	1.3	1.2	1.0	**1.2**
Milk delivered to dairies	%	1.3	1.4	1.2	1.3	1.3	1.3	1.3	**1.3**

Source: Own calculations based on LBG, Buchführungsergebnisse.

Table 10: Observed and expected yields per hectare as a national average

product	Ø 1999/01	Ø 2009/11	Ø 2019/21	Ø 1999/01 / Ø 2019/21	Ø 2009/11 / Ø 2019/21	% Average	2030 [1]	2040 [1]
	100 kg/ha			annual change %			100 kg/ha	
Cereals (including seeds)	**57.4**	**63.9**	**71.6**	**+1.1**	**+1.1**	**+1.1**	**74.9**	**76.0**
Wheat and spelt	50.5	52.7	57.6	+0.7	+0.9	+0.8	60.2	61.1
Common wheat and spelt	51.1	53.1	58.3	+0.7	+0.9	+0.8	60.9	61.9
Durum wheat	38.5	45.1	47.2	+1.0	+0.4	+0.7	49.0	49.6
Rye	38.5	39.0	47.8	+1.1	+2.0	+1.6	50.0	50.7
Barley	44.0	49.4	61.6	+1.7	+2.2	+2.0	64.5	65.4
Oats	39.8	40.1	38.7	–0.1	–0.3	–0.2	37.5	36.5
Winter meslin	43.7	43.3	51.7	+0.8	+1.8	+1.3	54.1	54.9
Summer meslin	39.8	38.6	41.2	+0.2	+0.7	+0.4	43.1	43.8
Maize (incl. CCM)	95.2	106.2	109.7	+0.7	+0.3	+0.5	113.0	113.8
Other cereals	49.4	48.4	52.9	+0.3	+0.9	+0.6	55.3	56.1
Triticale	50.1	49.5	55.5	+0.5	+1.1	+0.8	58.0	58.9
Millet, buckwheat, etc.	40.0	42.4	43.3	+0.4	+0.2	+0.3	44.2	44.2
Commercial crops	**163.0**	**174.9**	**129.1**	**–1.2**	**–3.0**	**–2.1**	**98.2**	**83.5**
Oilseeds, oilfruits (incl. seed)	23.5	25.1	24.5	+0.2	–0.2	–0.0	24.0	23.4
Rapeseed and turnip rape	26.6	31.8	30.6	+0.7	–0.4	+0.2	29.6	28.7
Sunflowers for oil production	25.3	27.3	28.0	+0.5	+0.3	+0.4	28.7	28.8
Soybeans	23.0	28.1	30.4	+1.4	+0.8	+1.1	31.8	32.3
Other oilseeds	6.0	5.5	7.3	+1.0	+2.9	+1.9	7.6	7.7
Poppy seed	9.6	7.7	7.7	–1.1	+0.0	–0.5	7.7	7.7
Oil pumpkin dried seeds	5.8	5.3	6.5	+0.6	+2.1	+1.3	6.8	6.9
Protein crops (incl. seeds)	27.5	25.7	23.9	–0.7	–0.7	–0.7	22.4	21.4
Grain peas	27.7	25.7	23.4	–0.8	–0.9	–0.9	21.5	20.3
Field beans	25.8	26.1	24.4	–0.3	–0.7	–0.5	23.0	22.0
Sugar beet	642.5	714.4	769.4	+0.9	+0.7	+0.8	804.7	816.8
Other commercial crops	19.6	21.2	20.1	+0.1	–0.5	–0.2	19.3	18.6
Hops	14.3	16.5	17.8	+1.1	+0.7	+0.9	18.1	18.1
Other legumes	21.0	21.4	20.2	–0.2	–0.6	–0.4	19.2	18.5
Forage crops	**91.1**	**103.7**	**109.6**	**+0.9**	**+0.6**	**+0.7**	**114.6**	**116.4**
Fodder corn (silage and green corn)	461.7	467.2	474.8	+0.1	+0.2	+0.2	481.8	480.8
Fodder root crops	491.9	615.1	545.2	+0.5	–1.2	–0.3	489.2	456.0
Fodder beets	492.2	615.1	545.2	+0.5	–1.2	–0.3	489.2	456.0
Other forage crops	64.1	73.7	74.2	+0.7	+0.1	+0.4	74.7	74.3
Red clover incl. other clovers	77.9	68.6	66.5	–0.8	–0.3	–0.5	66.9	66.5
Clover grass	79.6	76.9	75.1	–0.3	–0.2	–0.3	75.6	75.1
Alfalfa	74.9	69.4	64.6	–0.7	–0.7	–0.7	65.0	64.6
Egart	65.7	72.2	66.6	+0.1	–0.8	–0.4	67.1	66.7
Meadows one-mowed	30.7	37.6	36.6	+0.9	–0.3	+0.3	36.8	36.6
Litter meadows	35.1	35.0	31.9	–0.5	–0.9	–0.7	32.1	31.9
Multi-mowed meadows	65.5	75.9	77.0	+0.8	+0.2	+0.5	77.6	77.1
Fresh vegetables	**396.7**	**404.5**	**351.3**	**–0.6**	**–1.4**	**–1.0**	**352.9**	**350.2**
Potatoes (incl. seed potatoes)	**300.0**	**329.3**	**339.9**	**+0.6**	**+0.3**	**+0.5**	**349.8**	**351.9**
Early and medium-early table potatoes	254.0	288.9	293.7	+0.7	+0.2	+0.4	298.1	297.6
Late potatoes	357.1	384.3	398.7	+0.6	+0.4	+0.5	412.1	415.5
Fresh fruit (including strawberries)	**386.1**	**498.7**	**374.3**	**–0.2**	**–2.8**	**–1.5**	**289.2**	**248.0**
Wine	**55.0**	**52.0**	**51.7**	**–0.3**	**–0.1**	**–0.2**	**39.9**	**34.2**

Source: Statistik Austria, Feldfrucht- und Dauerwiesenproduktion. Verfügbar unter: https://www.statistik.at/statistiken/land-und-forstwirtschaft/pflanzenbau/ackerbau-dauergruenland. –[1]) Trend.

Table 11: Yields from organic production compared with conventional productions

Product	Einheit	2015	2016	2017	2018	2019	2020	2021	**Ø 2019-21**
		organic in relation to conv entional production							
Common wheat	dt/ha	60.6	63.8	54.1	53.0	59.9	62.5	61.1	**61.2**
Durum wheat	dt/ha	52.1	54.3	45.3	37.4	47.8	51.5	47.5	**48.9**
Rye	dt/ha	47.4	48.0	47.0	50.7	50.7	56.9	50.9	**52.9**
Winter barley	dt/ha	59.5	64.5	67.6	61.2	66.9	68.0	67.1	**67.4**
Spring barley	dt/ha	49.6	52.8	43.1	36.3	46.2	49.7	49.8	**48.6**
Oats	dt/ha	43.1	42.8	41.2	44.2	41.6	43.8	40.1	**41.8**
Meng cereals and triticale	dt/ha	53.7	53.1	55.3	52.7	54.0	58.4	55.2	**55.9**
Grain corn	dt/ha	81.8	104.0	97.3	95.7	100.1	108.7	105.2	**104.6**
Grain pea	dt/ha	29.5	23.4	28.1	28.8	26.0	34.7	27.3	**29.3**
Field bean	dt/ha	26.3	21.4	21.6	14.0	21.3	27.3	27.0	**25.2**
Soybean	dt/ha	23.9	30.2	29.5	27.4	29.3	30.1	30.1	**29.8**
Oilseed rape	dt/ha	28.9	34.4	30.7	30.0	29.1	28.7	26.6	**28.1**
Sunflower	dt/ha	22.8	30.9	23.2	28.1	26.4	22.9	26.3	**25.2**
Oil pumpkin seeds	dt/ha	5.9	7.3	7.3	6.6	6.6	7.5	6.8	**7.0**
Food potatoes	dt/ha	325.6	386.5	325.4	297.7	312.0	339.9	326.9	**326.3**
Sugar beet	dt/ha	643.1	837.0	725.7	714.5	751.3	806.0	839.7	**799.0**
Wine	hl/ha	51.6	49.9	57.6	61.9	54.5	57.5	58.4	**56.8**
Milk	kg/Jahr	6,980.0	7,230.0	7,413.0	7,660.0	7,534.0	7,676.0	7,651.0	**7,620.3**
		organic production							
Common wheat	dt/ha	37.0	38.5	33.5	31.8	36.5	36.9	35.7	**36.4**
Durum wheat	dt/ha	37.2	33.2	23.5	21.4	30.1	31.6	35.9	**32.5**
Rye	dt/ha	25.6	23.7	25.9	25.6	25.7	26.5	24.4	**25.5**
Winter barley	dt/ha	34.5	36.7	42.5	32.5	40.2	43.0	39.3	**40.8**
Spring barley	dt/ha	32.9	27.0	31.3	31.1	30.3	29.2	24.1	**27.9**
Oats	dt/ha	31.8	27.1	30.2	29.1	25.6	30.2	21.9	**25.9**
Meng cereals and triticale	dt/ha	31.7	32.3	33.6	33.7	35.1	36.7	31.2	**34.3**
Grain corn	dt/ha	54.9	77.1	55.3	71.5	58.0	71.7	58.4	**62.7**
Grain pea	dt/ha	17.1	7.9	18.7	10.9	18.1	16.1	16.0	**16.7**
Field bean	dt/ha	17.0	14.3	13.9	9.9	14.1	17.9	17.3	**16.4**
Soybean	dt/ha	18.1	26.1	22.8	24.3	22.1	24.8	28.3	**25.1**
Oilseed rape	dt/ha	13.4	14.3	11.8	5.3	8.0	3.5	19.1	**10.2**
Sunflower	dt/ha	18.8	30.5	21.8	23.4	19.8	20.4	24.5	**21.5**
Oil pumpkin seeds	dt/ha	4.0	6.1	5.6	4.6	5.5	4.8	4.6	**5.0**
Food potatoes	dt/ha	139.1	153.6	133.6	159.6	172.2	215.9	178.1	**188.7**
Sugar beet	dt/ha	741.3	599.2	549.6	410.2	349.1	422.1	566.8	**446.0**
Wine	hl/ha	48.7	31.1	44.3	54.6	39.6	43.9	60.4	**48.0**
Milk	kg/Jahr	5,883.0	6,058.0	6,150.0	6,342.0	6,230.0	6,096.0	6,167.0	**6,164.3**

		organic in relation to conventional production							
Common wheat	%	0.61	0.60	0.62	0.60	0.61	0.59	0.58	**0.59**
Durum wheat	%	0.71	0.61	0.52	0.57	0.63	0.61	0.75	**0.66**
Rye	%	0.54	0.49	0.55	0.51	0.51	0.46	0.48	**0.48**
Winter barley	%	0.58	0.57	0.63	0.53	0.60	0.63	0.58	**0.61**
Spring barley	%	0.66	0.51	0.73	0.86	0.66	0.59	0.48	**0.57**
Oats	%	0.74	0.63	0.73	0.66	0.61	0.69	0.55	**0.62**
Meng cereals and triticale	%	0.59	0.61	0.61	0.64	0.65	0.63	0.57	**0.61**
Grain corn	%	0.67	0.74	0.57	0.75	0.58	0.66	0.56	**0.60**
Grain pea	%	0.58	0.34	0.66	0.38	0.69	0.46	0.58	**0.57**
Field bean	%	0.64	0.67	0.64	0.71	0.66	0.65	0.64	**0.65**
Soybean	%	0.75	0.86	0.77	0.89	0.75	0.83	0.94	**0.84**
Oilseed rape	%	0.46	0.41	0.38	0.18	0.28	0.12	0.72	**0.36**
Sunflower	%	0.82	0.99	0.94	0.83	0.75	0.89	0.93	**0.86**
Oil pumpkin seeds	%	0.69	0.85	0.77	0.70	0.84	0.63	0.67	**0.71**
Food potatoes	%	0.43	0.40	0.41	0.54	0.55	0.64	0.54	**0.58**
Sugar beet	%	1.15	0.72	0.76	0.57	0.46	0.52	0.68	**0.56**
Wine	%	0.94	0.62	0.77	0.88	0.73	0.76	1.03	**0.84**
Milk	%	0.84	0.84	0.83	0.83	0.83	0.79	0.81	**0.81**

Source: Own calculations based on LBG, Buchführungsergebnisse.

Table 12: Average yields according to Statistics Austria compared to the yields from the Farm accountancy data network

		2015	2016	2017	2018	2019	2020	2021	**Ø 2015-20**	**Ø 2019-21**
Product	Einheit	yields from Statistik Austria versus yields from the Farm accountancy data network								
Common wheat	%	1.1	0.8	0.9	1.2	1.1	1.0	1.0	**1.00**	**1.03**
Durum wheat	%	1.1	0.7	0.9	1.3	1.0	0.9	1.2	**0.99**	**1.04**
Rye	%	1.3	1.0	1.1	1.1	1.3	1.0	1.2	**1.14**	**1.17**
Winter barley	%	1.0	1.1	1.0	1.0	1.0	1.1	1.0	**1.03**	**1.04**
Spring barley	%	1.0	1.0	1.0	1.0	0.9	1.0	0.9	**0.99**	**0.95**
Oats	%	1.1	0.9	1.0	1.0	1.3	1.0	1.4	**1.04**	**1.19**
Meng cereals	%									
Triticale	%									
Maize (incl. CCM)	%	1.4	1.0	1.1	1.1	1.2	1.1	1.0	**1.13**	**1.08**
Grain pea	%	1.0	1.3	1.0	1.1	1.0	1.0	1.2	**1.06**	**1.07**
Field bean	%	1.3	1.3	1.3	2.0	1.5	1.3	1.3	**1.41**	**1.34**
Soybean	%	1.4	1.0	1.0	1.2	1.1	1.1	0.9	**1.11**	**1.04**
Oilseed rape	%	1.2	0.8	1.0	1.0	1.1	1.1	1.2	**1.03**	**1.12**
Sunflower	%	1.5	0.8	1.2	1.1	1.0	1.4	0.9	**1.12**	**1.06**
Oil pumpkin seeds	%	1.4	1.0	0.9	1.1	1.0	1.0	1.1	**1.04**	**1.03**
Food potatoes	%	1.1	0.7	0.9	1.0	1.1	0.9	0.9	**0.95**	**0.99**
Sugar beet	%	1.3	0.8	1.0	1.0	1.1	1.0	0.9	**1.03**	**1.00**
Wine	%	0.8	1.1	1.0	0.8	1.0	1.0	0.9	**0.95**	**0.98**
Milk	%	1.0	1.0	1.0	1.0	1.0	1.0	1.0	**0.99**	**1.01**

Source: Statistics Austria, Crop production and production of permanent grasslands; LBG, Farm accountancy data network.

Appendix II: Observed activity levels and detailed model results

Table 13: Observed data – Animal population size and Milk yield

	Observed data				
Category	2000	2005	2010	2015	2020
Bovine animals					
Bovine animals, less than 1 year old, for slaughter [head]	68,049	61,039	170,272	159,512	150,996
Male bovine animals, less than 1 year old, not for slaughter [head]	281,040	276,974	191,189	184,944	175,616
Female bovine animals, less than 1 year old, not for slaughter [head]	306,279	290,413	272,591	280,027	271,986
Male bovine animals, 1 to less than 2 years old [head]	187,520	174,134	169,282	166,034	155,744
Heifers, 1 to less than 2 years old, for slaughter [head]	32,582	32,295	86,984	78,554	79,533
Heifers, 1 to less than 2 years old, not for slaughter [head]	246,382	229,874	187,386	194,493	179,120
Male bovine animals, 2 years old or over [head]	22,900	16,908	17,587	17,878	20,392
Heifers, 2 years old or over, for slaughter [head]	8,405	7,277	21,657	19,270	18,945
Heifers, 2 years old or over, not for slaughter [head]	128,496	116,884	102,715	98,452	87,632
Dairy cows [head]	621,002	534,417	532,735	534,098	524,783
Non dairy cows [head]	252,792	270,465	260,883	224,348	190,685
Pigs					
Piglets, live weight of under 20 kg [head]	853,315	762,585	764,542	683,354	664,105
Young pigs, from 20 kg to less than 50 kg [head]	948,350	867,172	839,543	744,004	739,942
Breeding pigs, gilts not yet covered [head]	27,258	28,161	23,281	24,497	22,217
Breeding pigs, gilts covered for the first time [head]	32,735	31,181	28,334	23,837	23,996
Breeding pigs, sows covered [head]	189,562	189,348	169,927	147,545	138,277
Breeding pigs, sows not covered [head]	74,622	59,317	57,331	49,091	42,348
Breeding boars [head]	10,101	7,724	5,818	4,685	3,743
Fattening pigs, from 50 kg to less than 80 kg [head]	663,270	646,165	636,542	559,556	558,323
Fattening pigs, from 80 kg to less than 110 kg [head]	478,432	498,487	502,762	484,332	463,374
Fattening pigs, live weight 110 kg or over [head]	70,286	79,401	106,076	124,550	150,136
Poultry					
Chicken [head]	11,077,343	12,801,345	13,918,813	16,189,796	19,064,900
Layer (incl. chicks for layers) [head]	6,555,815	6,678,696	7,061,377	8,716,148	9,711,000
Broiler [head]	4,521,528	6,122,650	6,857,436	7,473,648	9,353,900
Other poultry [head]	709,327	687,876	725,600	707,894	712,800
Turkeys [head]	588,522	568,854	615,813	593,645	548,600
Other poultry (excl. turkeys) [head]	120,805	119,022	109,787	114,249	164,200
Other Animals					
Sheep [head]	339,238	325,728	358,415	353,710	393,764
Goats [head]	56,105	55,100	71,768	76,620	92,758
Horses [head]	82,943	92,560	106,280	120,000	130,000
Others [head]	39,612	43,014	47,575	41,388	40,900
Milk yield					
Milk yield - dairy cows [kg milk animal^{-1} year^{-1}]	5,210	5,783	6,100	6,579	7,286
Milk yield - suckling cows [kg milk animal-1 year-1]	3,357	3,500	3,500	3,500	3,500

Table 14: Observed data – Fertilizer

	Observed data				
Category	2000	2005	2010	2015	2020
Mineral Fertilizer					
2-year average nutrient (N) consumption [t N/yr]	120,550	100,250	88,465	120,934	106,955
2-year average Calcium ammonium nitrate (CAN) [t N/yr]	70,547	51,614	38,384	69,977	65,632
2-year average Ammonium solutions (Urea AN) [t N/yr]	216	413	610	806	1,034
2-year average Ammonium sulphate (AS) [t N/yr]	1,597	2,794	3,991	5,188	4,757
2-year average other straight N compounds [t N/yr]	1,356	2,461	3,567	4,672	4,257
2-year average Calcium nitrate (CN) [t N/yr]	25	34	43	51	43
2-year average other straight N compounds [t N/yr]	5,636	3,988	2,340	692	538
2-year average NPK mixtures [t N/yr]	35,649	31,279	26,909	22,539	19,076
2-year average Other [t N/yr]	196	184	172	161	797
2-year average Urea [t N/yr]	5,328	7,483	12,450	16,848	10,821
fraction Urea from total N fertiliser consumption [%]	4.4	7.5	14.1	13.9	10.1
Organic Fertilizer					
Nitrogen left for spreading [kg N year-1]	144,802,923	137,925,421	137,101,519	134,194,995	131,396,045
Urine and dung deposited by grazing animals					
N excretion on pasture, range and paddock [kg N/yr]	13,225,434	10,636,753	11,234,453	11,419,276	11,341,472
Sewage sludge					
Sewage sludge produced [t dm]	392,909	290,110	262,805	234,880	228,009
Sewage sludge agriculturally used [t dm]	43,220	35,541	44,354	46,861	48,357
Sewage sludge agriculturally used [%]	11.0	12.3	16.9	20.0	21.2
N-input from agriculturally used sewage sludge [t N]	1,686	1,386	1,730	1,828	1,886
Compost					
Compost produced [t dm]	293,394	474,990	504,530	543,623	588,263
Compost applied in sector agriculture [%]	21.3	17.1	18.5	19.8	21.0
Compost applied in sector agriculture [t dm]	62,568	81,236	93,140	107,489	123,677
N content [%]	1.4	1.4	1.4	1.4	1.4
N-input from agr used compost [t N]	875.9	1,137.3	1,304.0	1,504.8	1,731.5
Biogas-slurry					
Biogas-slurry from vegetable/plant-inputs [kg N year-1]	1,342,861	2,585,007	3,542,337	4,124,919	3,747,936
Soil lime					
2-year average CaCO3 + MgCaCO3 [t/yr]	95,261	120,230	153,950	186,950	221,651

Table 15: Observed data – Cropping Areas

	Observed data				
Category	2000	2005	2010	2015	2020
Cropping areas					
Cereals total [ha]	828,048	791,510	802,152	766,461	748,455
Wheat [ha]	293,806	288,960	302,852	302,965	277,912
Rye [ha]	52,473	42,847	45,699	39,563	42,735
Barley [ha]	223,762	191,740	168,891	151,769	134,801
Oats [ha]	32,981	30,218	26,576	23,501	20,135
Maize (corn) [ha]	187,802	189,637	201,137	188,728	212,596
Other cereals [ha]	37,224	48,108	56,997	59,934	60,274
Potato [ha]	23,737	22,186	21,973	20,368	24,260
Sugar beet [ha]	42,836	44,690	44,841	45,436	26,287
Fodder beet [ha]	1,036	296	193	134	100
Silo- green maize [ha]	73,960	76,987	81,239	91,989	86,792
Clover-hey [ha]	70,179	79,789	89,555	81,772	79,889
Rape [ha]	51,762	35,251	53,803	37,529	31,827
Sunflower [ha]	22,336	30,179	25,411	19,061	23,828
Soja bean [ha]	15,537	21,429	34,378	56,895	68,424
Horse- /fodderbean [ha]	2,952	3,549	4,344	10,780	5,492
Peas [ha]	41,114	36,037	13,562	7,274	5,616
Vegetables [ha]	8,173	8,042	9,112	9,455	10,259
Oil pumpkin [ha]	10,376	16,271	26,464	31,816	35,438
Cabbage [ha]	906	924	944	801	714
Lattuce [ha]	738	589	480	464	412
Spinach [ha]	302	437	476	554	634
Salad [ha]	679	545	497	386	336
Tomato [ha]	159	184	175	188	200
Green peppers [ha]	185	133	146	156	153
Cucumbers [ha]	575	427	411	402	365
Carrots [ha]	1,264	1,371	1,623	1,632	1,865
Onion [ha]	2,308	2,374	2,905	3,360	3,408
Peas [ha]	1,057	1,057	1,455	1,512	2,171
Cropped area legume production					
Peas (Erbsen) [ha]	41,114	36,037	13,562	7,274	5,616
Soja beans [ha]	15,537	21,429	34,378	56,895	68,424
Horse/field beans [ha]	2,952	3,549	4,344	10,780	5,492
Clover hey, lucerne etc. [ha]	74,266	88,974	106,080	100,364	104,449
Other cropped area					
Other field forage [ha]	4,087	9,185	16,525	18,592	24,559
Wechselwiesen [ha]	56,794	76,501	59,169	57,503	50,440
Cover crops (Winterbegrünungen) [ha]	437,276	475,938	300,969	276,689	261,238

Table 16: Observed data – Production (harvest data)

Category	Observed data 2000	2005	2010	2015	2020
Production (harvest data)					
Cereals total [1,000 t]	4,490	4,880	4,776	4,784	5,595
Wheat [1,000 t]	1,313	1,453	1,518	1,726	1,660
Rye [1,000 t]	183	164	161	171	219
Barley [1,000 t]	855	880	778	840	870
Oats [1,000 t]	118	128	98	96	84
Maize (corn) [1,000 t]	1,852	2,021	1,956	1,638	2,412
Other cereals [1,000 t]	171	234	265	312	350
Potato [1,000 t]	695	763	672	536	886
Sugar beet [1,000 t]	2,634	3,084	3,132	2,853	2,119
Fodder beet [1,000 t]	47	17	11	7	6
Silo- green maize [1,000 t]	3,531	3,600	3,557	3,807	4,277
Clover-hey [1,000 t]	493	705	682	484	607
Rape [1,000 t]	125	104	171	112	100
Sunflower [1,000 t]	55	81	66	38	56
Soja bean [1,000 t]	33	61	95	136	203
Horse- /fodderbean [1,000 t]	7	10	11	25	14
Peas [1,000 t]	97	90	31	19	13
Vegetables [1,000 t]	361	384	457	442	483
Oil pumpkin [1,000 t]	6	8	15	19	23
Cabbage [1,000 t]	51	56	58	43	40
Lattuce [1,000 t]	30	24	15	13	13
Spinach [1,000 t]	7	10	9	11	13
Salad [1,000 t]	35	24	26	17	17
Tomato [1,000 t]	24	35	44	56	58
Green peppers [1,000 t]	9	9	14	15	15
Cucumbers [1,000 t]	43	38	41	44	46
Carrots [1,000 t]	60	79	86	67	116
Onion [1,000 t]	96	103	154	168	155
Peas [1,000 t]	6	5	9	10	10
N from Crop Residues					
N in crop residues returned to soils [t N/yr]	73,363	80,034	76,758	75,489	83,068
N2O emissions from drainage and rewetting and other management of organic soils					
Grassland [ha]	12,954	12,954	12,954	12,954	12,954

Table 17: Model results WEM medium cost scenario – Animal population size and Milk yield

	Model results WEM medium cost scenario				
Category	2025	2030	2035	2040	2050
Bovine animals					
Bovine animals, less than 1 year old, for slaughter [head]	142,774	131,727	131,883	132,039	126,019
Male bovine animals, less than 1 year old, not for slaughter [head]	169,495	159,042	160,476	161,910	156,251
Female bovine animals, less than 1 year old, not for slaughter [head]	261,517	245,389	247,602	249,814	241,083
Male bovine animals, 1 to less than 2 years old [head]	149,064	135,495	131,870	128,246	116,342
Heifers, 1 to less than 2 years old, for slaughter [head]	73,800	68,679	68,832	68,984	65,908
Heifers, 1 to less than 2 years old, not for slaughter [head]	172,081	158,767	158,954	159,142	151,887
Male bovine animals, 2 years old or over [head]	17,796	15,916	15,712	15,507	14,308
Heifers, 2 years old or over, for slaughter [head]	16,354	13,795	13,264	12,733	11,183
Heifers, 2 years old or over, not for slaughter [head]	81,917	72,674	71,053	69,431	63,107
Dairy cows [head]	500,425	469,564	473,797	478,031	461,324
Non dairy cows [head]	176,289	154,167	153,695	153,223	147,384
Pigs					
Piglets, live weight of under 20 kg [head]	602,778	547,176	489,503	431,831	301,489
Young pigs, from 20 kg to less than 50 kg [head]	668,853	607,156	543,161	479,167	334,538
Breeding pigs, gilts not yet covered [head]	20,427	18,684	16,857	15,031	10,885
Breeding pigs, gilts covered for the first time [head]	21,695	19,843	17,903	15,964	11,560
Breeding pigs, sows covered [head]	127,348	116,287	113,848	111,410	107,607
Breeding pigs, sows not covered [head]	40,782	37,240	36,459	35,678	34,460
Breeding boars [head]	3,719	3,396	3,325	3,254	3,143
Fattening pigs, from 50 kg to less than 80 kg [head]	510,940	463,438	410,452	357,466	237,024
Fattening pigs, from 80 kg to less than 110 kg [head]	433,361	393,071	348,130	303,190	201,035
Fattening pigs, live weight 110 kg or over [head]	123,926	112,404	99,553	86,701	57,489
Poultry					
Chicken [head]	18,226,541	15,711,462	14,765,475	13,819,488	11,427,130
Layer (incl. chicks for layers) [head]	9,386,921	8,414,684	8,130,275	7,845,866	7,096,595
Broiler [head]	8,839,620	7,296,779	6,635,201	5,973,623	4,330,534
Other poultry [head]	677,537	571,746	521,992	472,238	436,412
Turkeys [head]	521,460	440,039	401,746	363,454	335,880
Other poultry (excl. turkeys) [head]	156,077	131,707	120,246	108,784	100,531
Other Animals					
Sheep [head]	362,457	268,534	258,588	248,642	205,165
Goats [head]	82,399	51,323	50,885	50,447	47,553
Horses [head]	120,432	91,729	86,985	82,241	63,918
Others [head]	38,919	32,975	32,584	32,193	29,373
Milk yield					
Milk yield - dairy cows [kg milk animal^{-1} year^{-1}]	7,655	8,024	8,393	8,762	9,500
Milk yield - suckling cows [kg milk animal-1 year-1]	3,500	3,500	3,500	3,500	3,500

Table 18: Model results WEM medium cost scenario – Fertilizer

Category	Model results WEM medium cost scenario				
	2025	2030	2035	2040	2050
Mineral Fertilizer					
2-year average nutrient (N) consumption [t N/yr]	109,069	111,184	114,358	117,532	115,429
2-year average Calcium ammonium nitrate (CAN) [t N/yr]	65,479	66,748	68,654	70,559	69,297
2-year average Ammonium solutions (Urea AN) [t N/yr]	977	996	1,024	1,052	1,034
2-year average Ammonium sulphate (AS) [t N/yr]	5,189	5,289	5,440	5,591	5,491
2-year average other straight N compounds [t N/yr]	4,306	4,389	4,514	4,640	4,557
2-year average Calcium nitrate (CN) [t N/yr]	45	46	47	49	48
2-year average other straight N compounds [t N/yr]	605	617	634	652	640
2-year average NPK mixtures [t N/yr]	19,211	19,583	20,142	20,701	20,331
2-year average Other [t N/yr]	582	593	610	627	616
2-year average Urea [t N/yr]	12,677	12,923	13,292	13,661	13,416
fraction Urea from total N fertiliser consumption [%]	11.6	11.8	12.1	12.5	12.2
Organic Fertilizer					
Nitrogen left for spreading [kg N year-1]	121,095,084	110,794,122	108,584,435	106,374,747	97,406,665
Urine and dung deposited by grazing animals					
N excretion on pasture, range and paddock [kg N/yr]	10,526,952	9,712,431	9,723,915	9,735,399	9,291,602
Sewage sludge					
Sewage sludge produced [t dm]	225,000	225,000	225,000	225,000	225,000
Sewage sludge agriculturally used [t dm]	45,000	40,500	27,000	27,000	27,000
Sewage sludge agriculturally used [%]	20.0	18.0	12.0	12.0	12.0
N-input from agriculturally used sewage sludge [t N]	1,778	1,601	1,067	1,067	1,067
Compost					
Compost produced [t dm]	590,000	590,000	590,000	590,000	590,000
Compost applied in sector agriculture [%]	21.0	21.0	21.0	21.0	21.0
Compost applied in sector agriculture [t dm]	123,900	123,900	123,900	123,900	123,900
N content [%]	1.4	1.4	1.4	1.4	1.4
N-input from agr used compost [t N]	1,734.6	1,734.6	1,734.6	1,734.6	1,734.6
Biogas-slurry					
Biogas-slurry from vegetable/plant-inputs [kg N year-1]	3,750,000	3,750,000	3,750,000	3,750,000	3,750,000
Soil lime					
2-year average CaCO3 + MgCaCO3 [t/yr]	216,031	210,411	209,227	208,042	198,726

Table 19: Model results WEM medium cost scenario – Cropping Areas

	Model results WEM medium cost scenario				
Category	2025	2030	2035	2040	2050
Cropping areas					
Cereals total [ha]	730,366	712,277	708,953	705,628	672,422
Wheat [ha]	270,631	263,351	261,776	260,202	247,797
Rye [ha]	41,375	40,014	39,813	39,611	36,954
Barley [ha]	130,985	127,169	126,056	124,943	121,802
Oats [ha]	19,512	18,889	18,812	18,735	17,827
Maize (corn) [ha]	209,534	206,472	207,157	207,842	196,186
Other cereals [ha]	58,328	56,382	55,339	54,296	51,857
Potato [ha]	23,219	22,178	22,036	21,893	21,186
Sugar beet [ha]	25,497	24,707	24,528	24,348	23,229
Fodder beet [ha]	108	104	104	104	101
Silo- green maize [ha]	84,317	81,843	80,910	79,977	75,867
Clover-hey [ha]	77,469	75,049	74,455	73,862	70,315
Rape [ha]	30,843	29,859	29,583	29,307	27,781
Sunflower [ha]	23,376	22,924	23,284	23,644	22,525
Soja bean [ha]	66,659	64,895	65,470	66,045	63,330
Horse- /fodderbean [ha]	5,345	5,198	5,089	4,981	4,983
Peas [ha]	5,356	5,096	4,865	4,633	4,508
Vegetables [ha]	10,222	10,186	10,148	10,109	9,870
Oil pumpkin [ha]	35,122	34,806	34,483	34,160	33,360
Cabbage [ha]	712	709	707	704	687
Lattuce [ha]	411	409	408	406	396
Spinach [ha]	632	630	628	625	610
Salad [ha]	335	334	333	331	323
Tomato [ha]	199	198	198	197	192
Green peppers [ha]	153	152	151	151	147
Cucumbers [ha]	363	362	361	359	351
Carrots [ha]	1,858	1,852	1,845	1,838	1,794
Onion [ha]	3,396	3,384	3,371	3,358	3,279
Peas [ha]	2,163	2,156	2,148	2,140	2,089
Cropped area legume production					
Peas (Erbsen) [ha]	5,356	5,096	4,865	4,633	4,508
Soja beans [ha]	66,659	64,895	65,470	66,045	63,330
Horse/field beans [ha]	5,345	5,198	5,089	4,981	4,983
Clover hey, lucerne etc. [ha]	77,469	75,049	74,455	73,862	70,315
Other cropped area					
Other field forage [ha]	23,874	23,188	23,206	23,225	22,066
Wechselwiesen [ha]	47,772	47,772	47,544	47,316	44,938
Cover crops (Winterbegrünungen) [ha]	251,607	241,975	235,564	229,152	206,467

Table 20: Model results WEM medium cost scenario – Production (harvest data)

	Model results WEM medium cost scenario				
Category	2025	2030	2035	2040	2050
Production (harvest data)					
Cereals total [1,000 t]	5,185	5,194	5,307	5,185	4,740
Wheat [1,000 t]	1,583	1,579	1,610	1,568	1,435
Rye [1,000 t]	201	200	204	199	178
Barley [1,000 t]	805	801	814	791	741
Oats [1,000 t]	79	77	77	75	69
Maize (corn) [1,000 t]	2,208	2,231	2,295	2,257	2,046
Other cereals [1,000 t]	308	306	308	296	271
Potato [1,000 t]	795	778	793	772	718
Sugar beet [1,000 t]	1,930	1,918	1,952	1,899	1,741
Fodder beet [1,000 t]	8	8	8	8	8
Silo- green maize [1,000 t]	4,074	4,019	4,038	3,912	3,565
Clover-hey [1,000 t]	533	516	512	508	484
Rape [1,000 t]	90	90	91	89	81
Sunflower [1,000 t]	70	71	74	73	67
Soja bean [1,000 t]	216	216	223	220	203
Horse- /fodderbean [1,000 t]	13	12	11	11	11
Peas [1,000 t]	13	12	11	10	9
Vegetables [1,000 t]	458	456	454	453	442
Oil pumpkin [1,000 t]	242	242	239	237	235
Cabbage [1,000 t]	37	37	37	37	36
Lattuce [1,000 t]	12	12	12	12	12
Spinach [1,000 t]	12	12	12	12	11
Salad [1,000 t]	17	17	17	17	16
Tomato [1,000 t]	59	59	58	58	57
Green peppers [1,000 t]	15	15	15	15	15
Cucumbers [1,000 t]	47	47	47	46	45
Carrots [1,000 t]	106	106	105	105	102
Onion [1,000 t]	143	142	141	141	138
Peas [1,000 t]	10	10	10	10	9
N from Crop Residues					
N in crop residues returned to soils [t N/yr]	80,984	78,899	78,521	78,144	74,578
N2O emissions from drainage and rewetting and other management of organic soils					
Grassland [ha]	12,954	12,954	12,954	12,954	12,954

Table 21: Model results WAM medium cost scenario – Animal population size and Milk yield

	Model results WAM medium cost scenario				
Category	2025	2030	2035	2040	2050
Bovine animals					
Bovine animals, less than 1 year old, for slaughter [head]	141,223	128,624	127,874	127,124	118,166
Male bovine animals, less than 1 year old, not for slaughter [head]	167,729	155,511	155,837	156,162	147,016
Female bovine animals, less than 1 year old, not for slaughter [head]	258,793	239,941	240,443	240,945	226,834
Male bovine animals, 1 to less than 2 years old [head]	147,254	131,875	127,416	122,956	108,662
Heifers, 1 to less than 2 years old, for slaughter [head]	73,000	67,080	66,775	66,471	61,773
Heifers, 1 to less than 2 years old, not for slaughter [head]	170,212	155,027	154,123	153,218	142,421
Male bovine animals, 2 years old or over [head]	17,575	15,475	15,182	14,889	13,423
Heifers, 2 years old or over, for slaughter [head]	16,164	13,416	12,795	12,174	10,276
Heifers, 2 years old or over, not for slaughter [head]	81,025	70,890	68,818	66,746	58,991
Dairy cows [head]	495,212	459,138	460,099	461,060	434,058
Non dairy cows [head]	174,185	149,959	148,318	146,678	136,277
Pigs					
Piglets, live weight of under 20 kg [head]	597,818	537,257	478,248	419,239	289,133
Young pigs, from 20 kg to less than 50 kg [head]	663,350	596,150	530,672	465,195	320,827
Breeding pigs, gilts not yet covered [head]	20,266	18,360	16,487	14,615	10,470
Breeding pigs, gilts covered for the first time [head]	21,524	19,500	17,511	15,522	11,120
Breeding pigs, sows covered [head]	126,329	114,248	111,597	108,946	103,580
Breeding pigs, sows not covered [head]	40,456	36,587	35,738	34,889	33,171
Breeding boars [head]	3,690	3,337	3,259	3,182	3,025
Fattening pigs, from 50 kg to less than 80 kg [head]	506,720	454,998	400,852	346,705	227,132
Fattening pigs, from 80 kg to less than 110 kg [head]	429,782	385,913	339,988	294,063	192,645
Fattening pigs, live weight 110 kg or over [head]	122,902	110,357	97,224	84,091	55,090
Poultry					
Chicken [head]	18,081,471	15,131,184	14,223,363	13,315,543	10,756,863
Layer (incl. chicks for layers) [head]	9,338,847	8,222,388	7,906,353	7,590,318	6,689,935
Broiler [head]	8,742,624	6,908,796	6,317,011	5,725,225	4,066,928
Other poultry [head]	672,395	551,179	501,910	452,642	408,512
Turkeys [head]	517,502	424,210	386,291	348,372	314,407
Other poultry (excl. turkeys) [head]	154,892	126,969	115,620	104,270	94,104
Other Animals					
Sheep [head]	360,302	259,917	248,426	236,935	190,124
Goats [head]	82,005	49,746	49,092	48,438	44,211
Horses [head]	119,733	88,930	83,526	78,121	58,963
Others [head]	38,696	32,085	31,479	30,874	27,310
Milk yield					
Milk yield - dairy cows [kg milk animal^{-1} year^{-1}]	7,655	8,024	8,393	8,762	9,500
Milk yield - suckling cows [kg milk animal-1 year-1]	3,500	3,500	3,500	3,500	3,500

Table 22: Model results WAM medium cost scenario – Fertilizer

	Model results WAM medium cost scenario				
Category	2025	2030	2035	2040	2050
Mineral Fertilizer					
2-year average nutrient (N) consumption [t N/yr]	110,014	113,072	116,664	120,256	119,229
2-year average Calcium ammonium nitrate (CAN) [t N/yr]	66,046	67,882	70,038	72,194	71,578
2-year average Ammonium solutions (Urea AN) [t N/yr]	985	1,013	1,045	1,077	1,068
2-year average Ammonium sulphate (AS) [t N/yr]	5,233	5,379	5,550	5,721	5,672
2-year average other straight N compounds [t N/yr]	4,343	4,464	4,605	4,747	4,707
2-year average Calcium nitrate (CN) [t N/yr]	46	47	48	50	49
2-year average other straight N compounds [t N/yr]	610	627	647	667	661
2-year average NPK mixtures [t N/yr]	19,377	19,916	20,548	21,181	21,000
2-year average Other [t N/yr]	587	603	622	642	636
2-year average Urea [t N/yr]	12,787	13,142	13,560	13,977	13,858
fraction Urea from total N fertiliser consumption [%]	11.7	12.0	12.4	12.8	12.6
Organic Fertilizer					
Nitrogen left for spreading [kg N year-1]	119,840,399	108,284,754	105,440,663	102,596,571	91,624,521
Urine and dung deposited by grazing animals					
N excretion on pasture, range and paddock [kg N/yr]	10,412,572	9,483,672	9,428,353	9,373,034	8,712,524
Sewage sludge					
Sewage sludge produced [t dm]	225,000	225,000	225,000	225,000	225,000
Sewage sludge agriculturally used [t dm]	45,000	40,500	27,000	27,000	27,000
Sewage sludge agriculturally used [%]	20.0	18.0	12.0	12.0	12.0
N-input from agriculturally used sewage sludge [t N]	1,778	1,601	1,067	1,067	1,067
Compost					
Compost produced [t dm]	590,000	590,000	590,000	590,000	590,000
Compost applied in sector agriculture [%]	26.3	26.3	26.3	26.3	26.3
Compost applied in sector agriculture [t dm]	154,875	154,875	154,875	154,875	154,875
N content [%]	1.4	1.4	1.4	1.4	1.4
N-input from agr used compost [t N]	2,168.3	2,168.3	2,168.3	2,168.3	2,168.3
Biogas-slurry					
Biogas-slurry from vegetable/plant-inputs [kg N year-1]					
Soil lime					
2-year average CaCO3 + MgCaCO3 [t/yr]	215,927	210,204	209,018	207,832	198,419

Table 23: Model results WAM medium cost scenario – Cropping Areas

Category	Model results WAM medium cost scenario 2025	2030	2035	2040	2050
Cropping areas					
Cereals total [ha]	730,120	711,784	708,667	705,549	672,500
Wheat [ha]	270,527	263,142	261,586	260,029	247,659
Rye [ha]	41,345	39,954	39,723	39,491	36,840
Barley [ha]	130,923	127,044	126,024	125,003	121,793
Oats [ha]	19,492	18,848	18,762	18,675	17,762
Maize (corn) [ha]	209,566	206,535	207,401	208,267	196,785
Other cereals [ha]	58,268	56,261	55,172	54,083	51,661
Potato [ha]	23,211	22,162	22,040	21,919	21,170
Sugar beet [ha]	25,496	24,705	24,529	24,353	23,267
Fodder beet [ha]	108	104	104	104	101
Silo- green maize [ha]	84,209	81,627	80,597	79,567	75,227
Clover-hey [ha]	77,405	74,920	74,256	73,592	69,870
Rape [ha]	30,826	29,826	29,568	29,310	27,784
Sunflower [ha]	23,376	22,925	23,280	23,636	22,552
Soja bean [ha]	66,656	64,888	65,446	66,004	63,267
Horse- /fodderbean [ha]	5,339	5,186	5,078	4,971	4,968
Peas [ha]	5,351	5,086	4,860	4,634	4,512
Vegetables [ha]	10,221	10,183	10,144	10,105	9,865
Oil pumpkin [ha]	35,113	34,787	34,485	34,183	33,339
Cabbage [ha]	712	709	706	704	687
Lattuce [ha]	411	409	407	406	396
Spinach [ha]	632	630	627	625	610
Salad [ha]	335	334	332	331	323
Tomato [ha]	199	198	198	197	192
Green peppers [ha]	153	152	151	151	147
Cucumbers [ha]	363	362	361	359	351
Carrots [ha]	1,858	1,851	1,844	1,837	1,793
Onion [ha]	3,395	3,383	3,370	3,357	3,277
Peas [ha]	2,163	2,155	2,147	2,139	2,088
Cropped area legume production					
Peas (Erbsen) [ha]	5,351	5,086	4,860	4,634	4,512
Soja beans [ha]	66,656	64,888	65,446	66,004	63,267
Horse/field beans [ha]	5,339	5,186	5,078	4,971	4,968
Clover hey, lucerne etc. [ha]	77,405	74,920	74,256	73,592	69,870
Other cropped area					
Other field forage [ha]	23,877	23,194	23,191	23,187	21,962
Wechselwiesen [ha]	47,672	47,672	47,412	47,151	44,671
Cover crops (Winterbegrünungen) [ha]	251,536	241,834	235,451	229,068	206,376

Table 24: Model results WAM medium cost scenario – Production (harvest data)

	Model results WAM medium cost scenario				
Category	2025	2030	2035	2040	2050
Production (harvest data)					
Cereals total [1,000 t]	5,184	5,191	5,307	5,187	4,744
Wheat [1,000 t]	1,582	1,578	1,608	1,567	1,434
Rye [1,000 t]	201	199	203	198	177
Barley [1,000 t]	805	800	814	791	741
Oats [1,000 t]	79	77	77	75	68
Maize (corn) [1,000 t]	2,208	2,232	2,297	2,261	2,053
Other cereals [1,000 t]	308	305	307	295	270
Potato [1,000 t]	794	778	793	773	717
Sugar beet [1,000 t]	1,930	1,917	1,952	1,899	1,743
Fodder beet [1,000 t]	8	8	8	8	8
Silo- green maize [1,000 t]	4,068	4,008	4,022	3,892	3,535
Clover-hey [1,000 t]	533	515	511	506	481
Rape [1,000 t]	90	90	91	89	81
Sunflower [1,000 t]	70	71	74	73	67
Soja bean [1,000 t]	216	216	223	220	203
Horse- /fodderbean [1,000 t]	13	12	11	11	11
Peas [1,000 t]	13	12	11	10	9
Vegetables [1,000 t]	458	456	454	452	442
Oil pumpkin [1,000 t]	242	242	239	237	235
Cabbage [1,000 t]	37	37	37	37	36
Lattuce [1,000 t]	12	12	12	12	12
Spinach [1,000 t]	12	12	12	12	11
Salad [1,000 t]	17	17	17	17	16
Tomato [1,000 t]	59	59	58	58	57
Green peppers [1,000 t]	15	15	15	15	15
Cucumbers [1,000 t]	47	47	46	46	45
Carrots [1,000 t]	106	106	105	105	102
Onion [1,000 t]	143	142	141	141	138
Peas [1,000 t]	10	10	10	10	9
N from Crop Residues					
N in crop residues returned to soils [t N/yr]	80,950	78,831	78,459	78,088	74,502
N2O emissions from drainage and rewetting and other management of organic soils					
Grassland [ha]	12,954	12,954	12,954	12,954	12,954