Economic scenarios outputs based on policy workshops

Deliverable Report

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BESTMAP

Behavioural, Ecological and Socio-economic Tools for Modelling Agricultural Policy

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Summary

This deliverable report elaborates on the development and results of a set of policy scenarios that represent the outcomes of Task 2.4. After clarifying the objective of the deliverable, key features of the DART-BIO model are explained, followed by a definition of two biofuel scenarios in which the EU's Renewable Energy Directive (RED) and in addition global biofuel policies are implemented. Further, two specifications of international climate policies are defined and their implementation explained. In the result section, the impacts of these policies on the EU's agricultural markets and land-use change are illustrated. The results show that with the RED including a ban on palm-oil based biodiesel in place, EU's rapeseed production and therewith also land used to cultivate rapeseed rises, while also imports of other vegetable oils increase. Land-use change outside the EU is limited. Adding biofuel policies in non-EU regions causes global land use-change towards more cropland used for biofuel feedstock (e.g. soybeans, palm fruit) at the expense of pasture land and crops not used for biofuel production. When implementing climate policies, the conversion of pasture land on the global average is reduced. Depending on the specification of climate policies (having a CO_2 or all GHG emission reduction target), land-use change is affected differently. When only considering CO_2 emissions, more biofuels and feedstock are imported into the EU, resulting in less area (-3 percentage points) devoted to rapeseed production compared to a situation with biofuel policies but no climate policy. Adding all GHG emissions to the reduction targets leads to a reduction of 1 percentage point in rapeseed areas in the EU since emission pricing reduces demand for livestock production. The results can serve as input into Agent-Based Modelling in case studies across the EU, changing land-use patterns and opportunity costs of participation in agri-environmental schemes.

1. Introduction

1.1 Objective

This report elaborates on the outcomes of Task 2.4 and provides a short discussion of how the data can be used in Agent-Based Models (ABMs) applied in BESTMAP. The resulting quantitative outputs are available as CSV or GDX files upon request.

1.2 Background

The EU has been one of the leading regions in taking action-oriented steps towards mitigation of Greenhouse Gas (GHG) emissions. The EU-Emissions Trading System (ETS) is a keystone of the EU's action to limit climate change and, until the recent launch of an ETS in China, the EU-ETS was the largest carbon trading market since its inception in 2005[1]. At the same time, additional sectoral policies exist for sectors that are not included in the EU-ETS. As part of its support for climate action internationally, in 2015 the EU pledged under the Paris Agreement (referred to as the Nationally Determined Contribution (NDC)) to reduce its GHG emissions by 40% in 2030 relative to 1990[2].

The reduction of CO_2 emissions is largely achieved through the EU-ETS, although other non-CO_2 GHG emissions, and non-ETS sectors, are subject to complementary policies. One such policy is seen in the transport sector, which is excluded from the EU-ETS. The Renewable Energy Directive (RED), introduced in 2009 and updated (and named as RED 2) in 2018, remains a key policy[3] for transport. RED 2 aims to have 32% of energy in the EU from

[1] https://ec.europa.eu/clima/policies/ets_en

[2] https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/European%20Union%20First/EU_NDC_Submission_December%202020.pdf (Accessed on 2/12/2021)

[3] https://ec.europa.eu/jrc/en/jec/renewable-energy-recast-2030-red-2

renewables, along with a minimum of 14% of the energy consumed in road and rail sectors coming from renewable sources (European Commission 2018). As a consequence of the RED 2 policy, an increase in demand for biofuels for transport is expected, which will impact both the agriculture and energy sectors. The impacts on the agriculture sector arise because of the trade-off between using limited cropland for biofuel production versus using the same land for food or feed production. As such, there might be effects on land use in the EU and also in other parts of the world. The energy sector would be impacted because a shift to biofuels in the transport sector would affect the demand for carbon-intensive fuels that are largely used for transport.

Seemingly, the portfolio of policies that are part of the EU's climate action plan are well-targeted and address the gaps of the preceding policies. Nevertheless, inter-linkages between these policies exist. In task 2.4, we study the synergies between the RED 2 policy, global biofuel quotas and the NDC pledge made by the global community.

2. Methods and Data

2.1 Model characteristics

We use the Computable General Equilibrium (CGE) model DART-BIO for our analysis. The DART model is a global multi-sectoral, multi-regional recursive-dynamic CGE model. It was developed at the Kiel Institute for the World Economy and has been widely applied to analyse international climate policies (e.g. Klepper et al. 2006a), environmental policies (Weitzel et al. 2012), energy policies (e.g. Klepper et al. 2006b), and biofuel policies (e.g. Calzadilla et al. 2016), and global mid-term scenarios (Delzeit et al. 2018). DART-BIO is a version of the DART model which has a detailed representation of the agricultural sector, land use and conventional biofuels. It has been used in interdisciplinary studies to address potential trade-offs between food security and biodiversity (Delzeit et al. 2017, Zabel et al. 2019) and the simulation of global biomass potentials via a hard-link with a crop growth model (Mauser et al. 2015).

The production activities for each sector are defined by using a nested Constant Elasticity of Substitution (CES) function. For non-experts, the CES function can be interpreted to be a mathematical formulation in which different inputs for production can substitute one another depending on a pre-defined elasticity of substitution. In a nested CES function, substitution possibilities are allowed between composite input factors.

Commodity and factor markets are assumed to be perfectly competitive in DART-BIO. The model is recursive dynamic meaning that it solves for an equilibrium in each period.

Table 1: Regional and sectoral specification

Central and South America		Europe	
BRA	Brazil	FSU	Rest of the former Soviet Union
PAC	Paraguay, Argentina, Uruguay, Chile	CEU	Central European Union with Belgium, France, Luxembourg, Netherlands
LAM	Rest of Latin America	DEU	Germany
		MED	Mediterranean with Cyprus, Greece, Italy, Malta, Portugal, Spain
Middle East and Northern Africa		MEE	Eastern European Union with Austria, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Slovakia, Slovenia, Romania, Bulgaria, Croatia
MEA	Middle East and Northern Africa	NWE	North-Western European Union with Denmark, Finland, Ireland, Sweden, United Kingdom
AFR	Sub-Saharan Africa	RNE	Rest of Northern Europe: Switzerland, Norway, Lichtenstein, Iceland
Asia		**Northern America**	
CHN	China, Hong Kong	CAN	Canada
IND	India	USA	United States of America
EAS	Eastern Asia with Japan, South Korea, Taiwan, Singapore		
MAI	Malaysia, Indonesia	**Oceania**	
ROA	Rest of Asia	ANC	Australia, New Zealand, Rest of Oceania
RUS	Russia		

Agriculture-related products (29)		Energy products (15)	
Crops		COL	Coal
PDR	Paddy rice	CRU	Oil
WHT	Wheat	GAS	Gas
MZE	*Maize*	*MGAS*	*Motor gasoline*
GRON	Other cereal grains	*MDIE*	*Motor diesel*
PLM	*Oil Palm fruit*	OIL	Petroleum and coal products
RSD	*Rapeseed*	ELY	Electricity
SOY	*Soybean*	*ETHW**	*Bioethanol from wheat*
OSDN	Other oil seeds	*ETHM**	*Bioethanol from maize*
C_B	Sugar cane and sugar beet	*ETHG**	*Bioethanol from other grains*
AGR	Rest of crops	*ETHS*	*Bioethanol from sugar cane*
		ETHC	*Cellulosic Bioethanol from straw*
Processed agricultural products			
VOLN	Other vegetable oils	Biofuels	
SGR	Sugar	*BETH*	*Bioethanol*
FOD	Rest of food	*BDIE_PLM*	*Biodiese made from palmoill*
FSH	Fish	*BDIE_OTH*	*Biodiesel made from other vegetable oils*
*PLMoil**	*Palm oil*		
*RSDoil**	*Rapeseed oil*	**Non-energy products (3)**	
*SOYoil**	*Soybean oil*	CRPN	Other chemical rubber plastic products
*OSDNoil**	*Oil from other oil seeds*	ETS	Paper, minerals, and metals
*SOYmeal**	*Soybean meal*	OTH	Other goods and services
*OSDNmeal**	*Meal from other oil seeds*		
*PLMmeal**	*Palm meal*	**Forest and forest products (2)**	
*RSDmeal**	*Rapeseed meal*	FRS	Forestry
*DDGSw**	*DDGS from wheat*	FRI	Forest related industry
*DDGSm**	*DDGS from maize*		

*DDGSg**	*DDGS from other cereal grains*
UCO	*Used cooking oil*
STRAW	*Starches, straw*
Meat and dairy products	
OLVS	Outdoor livestock and related animal products (cattle and other grazing animals, raw milk and wool)
ILVS	Indoor livestock (swine, poultry and other animal products from indoor livestock)
PCM	Processed animal products

Note: Additional products compared to the standard GTAP database are in cursive. All goods are produced by an analogous industry, except were indicated by an asterisk (*), which indicates jointly produced goods. Bioethanol and DDGS are jointly produced by the bioethanol industry (3 types of industries), and oilseeds oil and meal are jointly produced by the vegetable oil industry (4 types of industries).

2.2 Data: the Social Accounting Matrix

DART-BIO is based on a database made available by the Global Trade Analysis Project (GTAP) , namely the GTAP-9 database (Aguiar et al., 2016) which in its original format has 140 regions and 57 sectors. The base year of the data is 2011. We merge the add-on database on Agro-Ecological Zones (AEZ) with the GTAP-9 data to disaggregate land, as a factor of production, into different AEZ types.

DART-BIO is primarily used to study the inter-linkages with the bio-economy and therefore it is crucial that the model adequately represents the key sectors of a bio-economy. We make use of a DART-BIO version that includes 21 model regions along with 52 sectors (Delzeit et al. 2021a). To account for complex value chains in the agricultural and biofuel sector, we use a database that has been split into additional sectors: in the case of crops, maize is separated from the aggregated “other grains” sector, oilseeds are split into four types. Accordingly, vegetable oils are split into soybean oil, rapeseed oil, palm oil, and the remaining vegetable oils which are used to produce biodiesel. Biodiesel is also produced from used cooking oil. Bioethanol is produced from maize, other grains, sugar cane/been, and straw. Further, DART-BIO explicitly accounts for the by-products generated during the production process of different vegetable oils and bioethanol. Dried distillers’ grains with solubles (DDGS) are by-products of the production of bioethanol from grains and oilseed meals/cakes are by-products of different vegetable oil industries. Thus, we differentiate between production activities and commodities, which allows us to model joint production in the bioethanol and vegetable oil industry. Table 1 provides a detailed description of the model regions and sectors.

2.3 Inclusion of GHG and CO_2 emissions

CO_2 emissions are available from the main GTAP database. The data for CO_2 emissions covers the consumption of energy goods for use by firms, households and governments (Aguiar et al., 2016). When analysing climate policies, in DART-BIO we implement an emission price for CO_2 where the production of fossil fuel-based energy happens. How the policies are implemented is presented in the following section.

An add-on dataset for the non-CO_2 emissions is available with the GTAP-9 database. The non-CO_2 emissions are provided for methane, nitrous oxide and a group of fluorinated gases (Irfanoglu et al., 2016). Emissions accounted for in the GTAP database come from four drivers: consumption by households, intermediate input use by industries (e.g., application of synthetic fertilizers by agriculture sectors), the endowment of industries (e.g., manure application and management, enteric fermentation) and output by industries (e.g., burning crop residues) (Irfanoglu et al., 2016). Accordingly, for a coherent accounting of the non-CO_2 emissions, in

DART-BIO an emission price for non-CO_2 emissions is included on output production for every sector, on land as a factor input and private consumption. The implementation of GHG prices is done such that there is no double-counting.

As mentioned before, production activities in DART-BIO are modelled using CES production functions. In the base year of 2011, the GHG prices are introduced as an input with an elasticity of substitution equal to zero. This can be interpreted as a coefficient that links production with a fixed quantity of GHGs. Subsequently, with model dynamics in the later years, GHG emissions are calculated by multiplying this coefficient with the production quantities (in each scenario).

3. Scenarios

Our ultimate goal is to model four policy scenarios that are compared to a reference scenario. The policy scenarios represent different policy frameworks in which RED 2, global biofuel policies and the NDC pledges could co-exist. Policy analysis with CGE models is based on comparative statics. This means that the model outputs from each of the policy scenarios are compared to the model outputs in a reference scenario. Since the RED 2 has defined goals for 2030, we compare the model outputs for the year 2030.

In our reference scenario (labelled as REF), the growth rates of real Gross Domestic Product (GDP) and CO_2 emissions are calibrated to match the growth projections from OECD (2019) and IEA (2018) respectively.

In scenario Pol 1, we model the RED 2 target assuming that to fulfil 14% in the transport sector, 7% are fulfilled with biofuels from feed and food feedstocks, 1.7% with used cooking oil (see Table 2). Here we make use of the RED2eq scenarios analysed in Delzeit et al. (2021b). They assume, since it is not clear from the legislation how EU member states will fulfil the overall 14% target of renewables in the transport sector (e.g. if hydro and electric cars will contribute a sufficient share) that member states meet the 14% renewable energy in transport target with the maximum allowable share of biofuels according to the RED II. This means that the share of feed- and food-based biofuels are gradually increased to 7% (having the restriction on palm oil-based biodiesel in place) and the share of UCO-based biodiesel to 1.7% by 2030.

In scenario Pol 2, in addition to the EU biofuel policy, international biofuel quotas are implemented taken from the FAO/OECD Agricultural Outlook (2021) except for MAI. There we assume a share of 10% of biodiesel on total transport diesel in 2030. In both scenarios, no climate policy targets are implemented.

In Pol 3, we add the EU's NDC pledge as well as international NDC pledges on top of the biofuel targets considering CO_2 emissions only. The national reduction targets are implemented by unilateral action through cost-optimal national CO_2 prices. A linear emission reduction pathway is calculated to reduce CO_2 emissions from values in the reference scenario in 2021 to meet the target values in 2030 via an endogenously determined yearly regional CO_2 price.

Lastly, Pol 4 also has each of these policies, albeit now the NDC targets cover all the GHG emissions. For the NDC targets, we make use of calculations by Böhringer et al. (2021). The changes in emissions under Pol3 and Pol4 scenario in 2030 compared to the REF scenario are displayed in Figure A1 in the Annex.

Table 2: Overview of scenarios

	RED 2	RED 2 + global BFQ	NDC_CO_2	NDC_GHG
REF				
Pol 1	X			
Pol 2		X		
Pol 3		X	x	
Pol 4		X		x

4. Results

4.1 Notes on data

CGE models do not use physical units such as produced tons of a good, or hectares of land, but all parameters in the model are in monetary units. For instance, in the base year (2011), the production of wheat is determined by multiplying the price of wheat ($/t) with its physical production (t). The same is done for factor inputs, such as land. Here the land endowment is calculated by multiplying the land rent ($/hectare) with hectares.

Outputs are therefore in monetary units, too. They are displayed using the price of the base year. In this case, if two scenarios are compared, the change in the quantity field is reported. If the price of the target year 2030 is used, the change in production volume is displayed. In this report, we use the changes in quantities (with 2011 prices) and also display changes in prices.

Outputs of the DART-BIO model include producer prices, production, exports, imports (total and bilateral), import and export prices, factor inputs (e.g. land), prices of factor inputs, household consumption, intermediate consumption, GHG emissions, GHG price. These parameters are reported for 52 sectors and 21 regions (abbreviations see Table 1). In a data processing step, average prices, e.g. for EU countries, or global averages are calculated.

The available files contain:

BESTMAP_BT.csv bilateral trade flows in Bill USD

BESTMAP_PQC.csv Change in prices and quantities of the biofuel scenario compared to the REF scenario

BESTMAP_Q.csv Development (2011-2030) of production (quant), Exports (ExpQ), Imports (ImpQ), final consumption (Cons) in Bill. USD

BESTMAP_LUC.csv Change in land use in % under biofuel scenario compared to REF scenario in 2030

4.2 Results

4.2.1 Impact of biofuel policies on agricultural markets and land use

Comparing the biofuel policy scenarios (Pol1 and Pol2) with the REF scenario, in general, the major share of biofuels consumed in the EU is also produced in the EU since imports are primarily intermediate inputs such as vegetable oils and crops (see next section). Meeting demand for bioethanol under the RED 2 scenario (Pol1) and the global biofuel scenario (Pol2) causes an increase in prices by 18 and 31%, and in production by 131 and 289% in the EU, compared to the REF scenario in 2030 (see ∆ P and ∆ Q for Pol1 and Pol2 in Table 3).

Table 3: Production in 2030 in Mio USD, and changes in prices (P) and production (Q) of biofuels in the EU in 2030 compared to REF Scenario in %

	Production REF 2030	∆ P Pol1	∆ P Pol2	∆ P Pol3	∆ P Pol4	∆ Q Pol1	∆ Q Pol2	∆ Q Pol3	∆ Q Pol4
BETH	4.19	30.3	31.3	33.7	34.3	133.9	288.7	303.6	283.7
Biodiesel SUM	5.99					747.5	1,058.9		
BDIE_OTH	4.41	22.9	27.8	27.1	30.3	732.6	1,078.9	983.5	1,064.5
UCOME	1.58	1.5	-3.5	-3.3	-3.1	470.5	1,020.3	1,605.7	1,011.8
BDIE_PLM	0.004	0.2	2.0	0.3	1.5	73	1,070.5	16,059	1,279.9

With both biofuel scenarios, imports from regions outside of the EU increase compared to the REF scenario, as shown in Table 4 below. In the case of bioethanol (BETH), imports originate mainly from Brazil. To meet the EU's target of UCOME consumption, imports from the USA and EAS increase considerably. With higher demand from regions outside of the EU, net imports to the EU under Pol2 are lower compared to the scenario where only the EU biofuel policy is in place (Pol1).

Table 4: EU net imports in million USD in 2030 under different scenarios by trading partner

		REF 2030	Pol 1	Pol 2	Pol 3	Pol 4
BETH	**BRA**	85.3	347.4	91.9	107.2	96.6
BETH	**USA**	48.3	101.3	41.6	59.6	42.6
BDIE	**USA**	84.2	650.5	356.2	318.29	389.7
UCOME	**EAS**	4.62	22.8	47.7	61.5	45.7
UCOME	**USA**	12.7	62.9	49.6	81.5	49.8

The EU typically imports less biodiesel but more vegetable oils to process biodiesel domestically. While the EU as a whole is a net exporter of rapeseed oil under the REF scenario, it becomes a net importer under the biofuel scenarios, although rapeseed oil is predominantly traded within the EU. This is mainly driven by Germany (DEU) which turns into the largest net importer under the Pol1 scenario and starts to import rapeseed oil, mainly from the other European regions Central Europe (CEU) and Middle-Eastern Europe (MEE). In contrast, soybean oil is mostly imported from non-EU regions and all EU regions are net importers of soybean oil under all scenarios.

Even though the EU becomes a net importer of rapeseed oil in the biofuel scenarios, the EU simultaneously expands production of rapeseed oil (by 105 and 213%) to meet high domestic demand and export demand compared to the REF scenario, as shown in Table 5. Global production increases by up to 51%. Soybean oil is mainly imported from Brazil (BRA) and the USA. EU and global soybean production rise less drastically compared to rapeseed oil under the Pol2 scenario; by 27% and 6% respectively in 2030, however, affecting more land area. With a restriction in palm oil-based biodiesel consumption in the EU in place, global palm oil production is not affected by the RED2 policy (Pol1), but with global biofuel policies in place, its global production increases by 24.9% compared to the REF scenario in 2030. The biggest producer, Malaysia/Indonesia raises its production of palm oil by 27.7% under Pol2.

Table 5: Changes in production of selected vegetable oils in selected regions.

		Production in Mio. USD REF in 2030	Δ Q Pol1	Δ Q Pol2	Δ Q Pol3	Δ Q Pol4
Rapeseed oil	**EU**	6011.0	105	213.3	192.7	204.5
	global	27058.9	27	51.1	47.3	47.3
Soybean oil	**BRA**	7077.7	6	24.2	24.1	23.5
	USA	8963.7	3	3.6	3.7	3.7
	EU	3135.9	21	27	25.3	28
	global	66594.1	4	6.3	6.9	5.9
Palm oil	**MAI**	28177.4	0	27.7	24.4	15.6.
	global	40710.9	0	24.9	22.5	13.2

Concerning crops, the EU's net imports increase and net exports decline with higher demand for biofuels. Production of crops used for biofuel production (wheat, maize, rapeseed, sugar beet) increases at the cost of production of other crops. Rapeseed production, for example, rises by 49.1% under the Pol2 Scenario (see Table 6). The bioethanol market in the EU is small compared to the biodiesel market, meaning that the impacts of crops used for bioethanol production are smaller compared to those used for biodiesel production. The biofuel policies have only a small effect on processed meat and food production and prices. This is because the two sectors are very large in value terms. However, we can observe the expected signs of the effects under biofuel policies: with lower costs for animal feed (meals as co-products of vegetable oil production), the price for meat decreases while its production increases. The opposite effect is seen for processed food (FOD): the price for processed food increases and production decreases, caused by crop demand induced by the biofuel policies.

Table 6: Change in crop production and prices in the EU in 2030 compared to REF Scenario in %

	Production REF 2030	Δ P Pol1	Δ P Pol2	Δ P Pol3	Δ P Pol4	Δ Q Pol1	Δ Q Pol2	Δ Q Pol3	Δ Q Pol4
Wheat	6804.0	3.0	5.5	5.2	8.8	-0.2	0.7	-3.0	-1.3
Maize	2320.8	3.4	5.9	5.1	8.6	8.9	7.2	6.5	7.3
other grains	2506.9	3.4	5.8	4.9	10.0	-2.9	-3.0	-4.1	-2.4
rapeseed	1813.7	3.6	6.0	6.0	10.6	45.2	49.1	43.1	47.1
soybeans	157.8	4.3	6.6	5.3	8.9	-0.8	5.6	3.3	5.5
other oilseeds	2144.5	3.0	5.2	6.6	8.3	5.0	8.9	3.4	7.2
sugar beet	739.2	18.3	24.9	25.3	30.4	12.4	17.5	17.9	16.9
rest of agriculture	27588.6	2.7	5.5	2.2	3.8	-2.8	-1.8	-0.9	-2.1
processed meat	74819.2	-0.1	-0.4	-0.8	4.2	0.1	-0.1	-0.2	-1.7
processed other food	130643.5	0.6	0.3	0.0	1.1	-0.3	-0.6	-0.7	-1.6

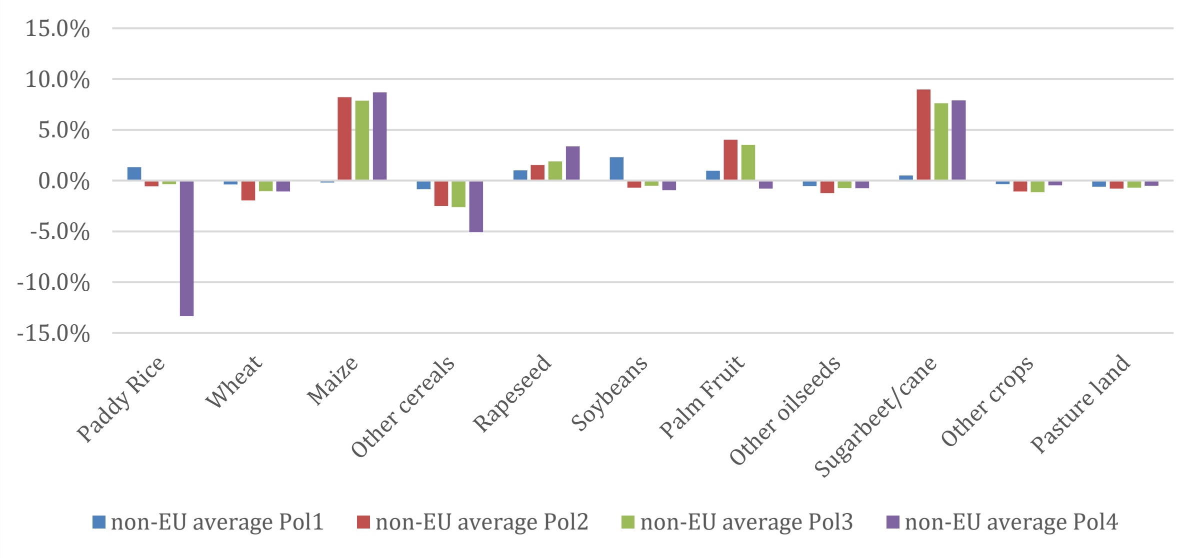
These changes in EU's crop production and changes in trade are also mirrored in a land-use change in the EU and non-EU countries. Taking the Pol1 scenario as an example (see Figure 1), more land in the EU is allocated to rapeseed production in Pol 1 (+45%, mainly at the costs of "other grains" and "rest of crops" (-3%). Disaggregated results show that the increase in rapeseed production is particularly high in CEU (Central EU), a region that strongly increase exports to other EU member states (see Table 6).

Table 6: Change in land use by crop and EU region under all policies compared to REF scenario 2030 in %

		wheat	maize	other grains	rape-seed	soy-beans	other oilseeds	sugar cane / beet	rest of agri-culture	pasture-land
CEU	**Pol1**	-3.4	10.8	-6.6	66.9	6.9	10.2	13.2	-4.6	0.2
	Pol2	-1.0	9.8	-7.3	63.5	12.4	7.0	13.3	-4.7	-1.2
	Pol3	-6.3	10.6	-9.4	50.3	7.0	2.2	15.3	-1.7	-1.3
	Pol4	-7.7	7.1	-4.9	67.5	8.9	4.5	14.3	-2.6	-0.9
DEU	**Pol1**	-0.9	5.3	-0.5	43.8			9.5	-3.3	-0.6
	Pol2	-1.2	4.1	-1.5	41.5			10.2	-2.7	-1.2
	Pol3	0.9	4.0	-1.8	43.9			10.5	-3.4	-1.0
	Pol4	1.2	3.7	1.6	23.0			8.0	-2.0	-1.2
MED	**Pol1**	-3.4	11.2	-5.7	27.7		13.4	2.0	-1.2	0.1
	Pol2	-0.2	7.4	-7.1	31.3		14.8	4.8	-1.1	-1.0
	Pol3	-7.6	6.0	-6.0	12.8		5.0	5.1	0.1	-0.7
	Pol4	8.1	9.4	-6.1	37.6		16.1	5.7	-1.9	0.4
MEE	**Pol1**	4.8	-5.8	4.1	-28.0	-2.0	-1.2	-5.5	7.3	-0.3
	Pol2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Pol3	1.5	-3.3	-1.2	-0.6	0.7	0.8	-0.1	1.6	-1.7
	Pol4	2.3	-2.6	-1.1	-1.8	-0.3	1.1	-0.1	1.2	-1.4
NWE	**Pol1**	8.2	-6.1	2.4	50.5		1.5	2.0	-5.8	-0.4
	Pol2	4.6	-8.2	0.7	46.8		0.1	8.0	-3.9	-1.5
	Pol3	5.6	-7.6	0.3	44.2		2.1	6.7	-4.0	-1.3
	Pol4	7.5	-5.1	4.1	51.0		2.2	7.7	-6.3	-0.2
EU av	**Pol1**	-2.2	7.5	-2.7	45.2	2.4	5.3	7.0	-3.9	-0.1
	Pol2	-1.1	4.3	-3.9	43.5	3.4	6.0	8.0	-3.2	-1.3
	Pol3	-2.7	4.7	-4.1	40.3	2.1	3.1	8.4	-2.5	-1.1
	Pol4	-1.5	5.8	-3.7	42.1	4.1	4.7	7.8	-3.4	-0.4

In non-EU countries, having the RED2 policy in place, the strongest percentage change in land use compared to the REF scenario occurs for land used for soybean production (+2.3%). Adding global biofuel quotas, the areas used for sugar cane production increase by 9%, maize area by 8%, and palm fruit area by 4% (see Figure 1). Pasture land is reduced by 0.8% on average in non-EU countries.

Figure 1: Change in land use by crop in non-EU regions under different policy scenarios compared to REF Scenario in 2030 in %



4.2.2 Impact of international climate policy on agricultural markets and land use in the EU

When adding climate policies to the global biofuel policies, we see in general more imports of biofuels into the EU, which is driven by lower mitigation costs in several non-EU countries (Table 4) and reduced production of rapeseed oil in the EU (Table 5) and therefore also rapeseed production (Table 6).

In addition to these general trends, we also see differences between the two sets of climate policies. When implementing NDCs based on CO_2 emissions in addition to global biofuel quotas, the EU's production of rapeseed is reduced by 6 percentage points compared to having no climate policies but instead biofuel policies (comparing Pol2 and Pol3). This difference reaches only 2 percentage points when all GHG emissions are included (Pol4). Here, more biodiesel is imported from e.g. the USA.

Interestingly, when considering all GHG emissions, the expansion of palm fruit plantations as well as areas cultivated with paddy rice are reduced (see Figure 1, Pol4). In the case of paddy rice, with the NDC targets including all GHG emissions, methane emissions during the production process are priced, leading to a reduction of paddy rice production and therefore its cultivation area in non-EU regions. In addition, crops used to produce animal feed (e.g. soybeans, other grains) are produced in smaller volumes and therefore demand less land, since the emissions caused during animal production (mainly methane) are priced.

Regarding the land-use change in the EU, when adding climate policies to biofuel policies, less cropland is converted to pasture land (see Table 6, EU av). While pasture land is reduced by 1.3% with global biofuel policies (Pol2), it is only reduced by 0.4% when having GHG emission-based NDCs. Further, the main biofuel feedstock in the EU, rapeseed, is used in the livestock industry as fodder. Pricing GHG emissions makes livestock production more expensive, causing demand, and also production, to drop. A reduction in livestock production (1.7% less "processed meat" production in the EU, see Table 6) results in less demand for fodder, e.g. rapeseed and soybean (cake).

5. Conclusions and future research

In the EU, increasing demand for biofuels is to a large extent supplied by rapeseed-based biodiesel. Countries within the EU, and in the eastern part of the EU in particular, are major global rapeseed producers, and as such benefit from the RED 2.

Land-use change caused by the RED 2 predominantly takes place within the EU. With the ban on palm-oil based biodiesel in place, outside of the EU areas used to produce soybeans show the strongest increase. The pressure on sensitive areas through soy production in South America increases, and would even remain high if biofuel consumption produced from food and feed crops in the EU stays significantly under 7%. Nevertheless, biofuel policies are not the major driver of soybean production.

When adding global biofuel quotas, crop production and land-use changes at the global and EU level. With higher demand and higher global prices, the EU imports fewer biofuels and vegetable oils, resulting in more crop production at the cost of pastureland. The practical realization of global biofuel quotas in 2030 is uncertain. According to the OECD/FAO Agricultural outlook, the region in DART-BIO Malaysia/Indonesia will have a consumption share of 26% of biodiesel on total diesel in transport in 2030. This implies an increase of biodiesel consumption of 1693% compared to 2011, which given that the countries are focused on exports because global prices are higher compared to the prices paid domestically, fulfilling the consumption share of 26% would be very difficult In addition, even a share of 10% which we assumed results in an increase in palm fruit area of 25%.

In the model, the land use is restricted to the currently managed areas. Hence, no GHG emissions from land use-change of crops or pasture into unmanaged areas are considered. This will be a task for future research. We have started to model spatially explicit potential expansion areas of cropland (Schneider et al. 2022, Zabel et al. 2021), but have not linked related emissions yet.

The results show that crop prices and therefore opportunity costs for farmers when participating in agri-environmental schemes differ depending on the policy scenario. This is relevant given that EU farmers are strongly connected to the global market. The results on land-use change within cropland and also changes in pasture land differ across policy scenarios. While they are presented in an aggregated way for the sake of readability, they are available for 18 Agro-Ecological Zones and 6 EU regions for 10 crop categories.

The results can be included in the agent-based model (ABM) developed in BESTMAP where the decision to adopt agri-environmental schemes depends on opportunity costs. Currently, the opportunity costs of participating in agri-environmental schemes are assumed to be the same across scenarios in the ABM. The outputs of the CGE analysis show changes in land use under the biofuel and climate policy scenario: depending on the policy scenario, prices of e.g. rapeseed under biofuel policies rise, causing farmers to use more land for rapeseed production. Other scenarios show changes in pasture land. As these changes in land use are directly linked to changes in opportunity costs of agri-environmental schemes, the CGE output can be used to analyse how farmers' decision making on participation in agri-environmental schemes is affected by changes in biofuel and climate policy.

Future research might also include an improvement of the (land) decision-making process in CGE models. But since they are run at a highly aggregated level, information on e.g. the participation in agri-environmental schemes of farmers in different locations might be passed on to agricultural sector models with a higher sectoral and spatial resolution. Since agricultural sector models miss the intersectoral feedback effects of e.g. climate policy, CGE models have a clear role in bridging the gap to aggregated and cross-sectoral impacts. Based on this deliverable and task 4.1, further potential in these model linking exercises will be elaborated in the course of task 5.4.

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Appendix

Figure A2: Change in Emissions under NDC pledges considering CO_2 and all GHG emissions in 2030 compared to REF in per cent