**MUSE-SGI Non-Technical Overview**

**Agriculture Sector Module**

Context

The agriculture sector is only responsible for less than 10 % of the total final energy for direct use in the operation of machinery, equipment and site operation [1]. However, if the indirect energy use, required for agrochemical production, input manufacturing, food processing, marketing and transport is included, this figure would increase up to 30%. Furthermore, the agriculture sector (including deforestation for agriculture expansion) is roughly responsible of 22% of worldwide emissions [2]. Apart from CO2 emissions, attributed to direct use of fossil fuels and change in land use (e.g. deforestation), NO2 emissions released from the use of agrochemicals and CH4 emissions due to ruminant livestock, manures and slurries, represent the biggest source of GHG emissions in the sector.

In order to achieve decarbonisation goals, it is important to cut sector emissions as the food and the biomass demand growth will increase sector’s energy consumption and carbon emissions. As novel technologies and changes in carbon taxes can easily impact sector’s land use allocation and energy consumption [3], novel models are required to gain insight into present and future sectorial energy, economic and environmental interactions.

Problem Statement

Within the MUSE modelling environment, the agriculture module (AgSM) has to determine the demand in terms of agrochemicals and land use to meet food crops and biomass demand as well as quantify the sector fuel demand for every region in the world, period and timeslice of the simulation. Furthermore, the model has to determine the impact of the sector on global warming quantifying emissions due to direct energy uses and to the changes in the land use from the existing one to alternative destinations. In doing so, the model AgSM needs to realistically represent the stakeholders’ decision making process for investing into new processes in agriculture and must apply a technology rich and bottom-up approach in order to assess impact on energy use and GHG emissions as well as the effects of technology innovation.

Module Approach

The AgSM is a simulation model with the aim to produce a time series of fuel demand to meet the projected energy service demand. The model responds to a series of macroeconomic parameters such as GDP, population growth and household income, as well as carbon and fuel prices. The AgSM is a bottom-up model with sufficient techno-economic data to spatially and timely simulate the energy demand over a period of time using MUSE regional disaggregation.

The AgSM is based on a two-step simulation approach. First, the energy service demand is dynamically calculated using selected macrodrivers. Secondly, to model investment decisions and operating strategies, a merit order approach based on Net Present Value (NPV) is used to define technology market share and fuel mix.To represent the future state of the sector, the model selects technologies based on capital and operational costs, technology efficiency and environmental impact. In addition to the fuel demand, the AgSM also produces techno-economic (CAPEX, OPEX) and environmental performance (GHG emissions), energy crop and residue supply production, and land use allocation and its associated emissions, per region, simulated period and timeslice.

Relationship with MUSE Modules

The AgSM dynamically exchanges a set of variables with the Market Clearing Algorithm (MCA) in MUSE by sending information regarding fuel demand and emissions per region, time period and timeslice. Then the MCA will come back with a set of fuel and carbon prices. Additionally, the module uploads exogenous parameters for the energy service demand projections, for the techno-economic and environmental characterisation of technologies per region as well the land uses. Fig. 1 illustrates a generic iteration in a generic time period and timeslice. The detailed description of the data exchange protocol between AgSM and MUSE can be seen in Table 1.

forward fuel demand,

forward emissions

AgSM

MCA

**Exogenous Inputs:**

policy framework,

cost by technology,

efficiencies by technology,

emissions by technology,

existing stock by technology and retirement profile,

forward macrodrivers,

land use

**Specific Outputs:**

aggregate capacity by technology

aggregate CAPEX,

aggregate OPEX,

activity by technology,

emissions by technology,

energy crops and residues supply (biofuels),

use of agrochemicals and corresponding emissions,

land use allocation and corresponding emissions

forward fuel prices,

forward carbon price

**Figure 1: Exchanged variables with the MUSE modules**

**Table 1: Exchange data flow for the AgSM.**

|  |  |
| --- | --- |
| AgSM Key Inputs | AgSM Key Outputs |
| MUSE core dynamic variables | **MUSE core dynamic variables** |
| * Forward fuel price for each time period with region and timeslice disaggregation $\left(\frac{MUSD\_{2010}}{PJ}\right)$
* Forward carbon price $\left(\frac{MUSD\_{2010}}{Gt\_{CO2}}\right)$
 | * Fuel demand each time period, region and timeslice $\left(\frac{PJ}{year}\right)$
* Forward emissions for each time period, region and timeslice $\left(\frac{Gt\_{CO2}}{year}\right)$
 |
| AgSM-specific input parameters | **AgSM-specific outputs** |
| * Macroeconomic drivers projections
* Techno-economic and environmental characterisation (conversion efficiency, unit investment and operating costs) of each agriculture technology by type in each time period and region
* Land use availability and yields characterisation by type in each time period and region
* Existing stock for the model base year per region by technology type, including their retirement profile
* Policy framework and fiscal regimes
 | * Investment and retirement in capacity terms by time period, technology type and region
* Aggregate CAPEX and OPEX by time period, timeslice and region
* Agriculture technologies details (e.g. activity, energy consumption and emissions) by time slice, technology type and region
* Energy crops and other residues outputs (biofuels) by time period, timeslice and region
* Use of agrochemicals and land use change to estimate carbon emissions by time period, timeslice and region
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# References

1. Environment and Natural Resources Working Paper No. 4, FAO, 2000.

FAO. Energy-smart food for people and climate. Issue paper. Food and Agriculture Organization of the UN. 2011.

1. Wise, M. et al., Implications of limiting CO2 concentrations for land use and energy, Science, 2009.