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Land Allocation Module of the METRO Model

User Guide

This guide explains how to activate, implement, and modify the new land allocation module through the METRO model interface. It is complemented by a technical documentation (TAD/TC/CA/WP/RD(2019)4/FINAL) describing the new land transformation methodology that was added to the model.

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In Brief

Using the Land Allocation Module

1. Run aggregation program to create new analysis database
2. Define nesting of land supply to analysis sectors in excel file s_f_r_LandCET.xlsx found in the folder "projects*\database".
3. Define elasticities in same excel file (optional)
4. Run calibration with Land Allocation Module
   a. Activate Land Allocation Module in the Calibration Task, Closure tab by selecting Factor Mobility Closure to "CET"
   b. Select excel file where nesting is defined
   c. Indicate if elasticities for the nesting are "PEM" or "UserDefined"
5. Run simulation with Factor Mobility Closure set to "CET"
   a. Select calibration file with "fm_CET" indicator in its filename ("External Files" tab)
   b. Set Factor Market Closure to "CET" on "Closure" tab.

Introduction

Computable General Equilibrium (CGE) models have a long history of analysis of trade policy impacts. However, over the last couple of decades increased consideration has been given to the trade-off between conventional economic production variables, and impacts on natural endowments, and associated market externalities. These dimensions are represented in CGEs through different variables, and natural factor use is one important of them. This paper presents improvements in the METRO CGE model to more accurately represent the production constraints related to the land factor. It relies on a flexible set-up based on functional forms widely used in the CGE literature, the Constant Elasticity of Transformation (CET) functions. This set-up is implemented here as an optional module to METRO expanding the model with a 4-Tier nesting of CET functions for the land supply, hereby called the "land allocation module" (or "Land CET module"). The present document explains how the module can be activated in the model, parameterized and run with the usual METRO Graphical User Interface (GUI).

The project folder "Ag_supply_19_8_6" contains the necessary excel files to run an example simulation with a land nesting structure similar to OECD Policy Evaluation Model (PEM). It creates an analysis database using database version v92L11 with a fully disaggregated agriculture sector for six regions, and all eight factors of production. The "s_f_r_LandCET.xlsx" excel file in the project folder can be used as a template to set up the land allocation nesting for other simulations. The CET structure and files in this folder are used as an example throughout this user guide.

Before getting started

To use the Land allocation module, the first step is to check that the version of METRO installed contains the module. The module is available if, in the model interface on the "Closure" tab, "Factor Market Closure" has three options: Mobile, Immobile, and CET. METRO model version 3 or later has the necessary files and sets to run the Land allocation module.

The following files should be part of the METRO working copy:

- The "Model" folder should contain a file named "METRO_LandCET.inc", which is the core of the module,
- The "Project*\database" folder should contain an Excel file named "s_f_r_LandCET.xlsx", where s, f, r correspond to the number of sectors, factors and regions, respectively. Note that the sectors listed in this excel file must match those in the user defined analysis database found in the same folder.
- The "Agg" and "GUI" folders should be up to date with the last version of METRO otherwise variables associated with the Land allocation module will not appear in the results viewer.

How to set-up the land allocation module

The land allocation module is composed of four levels of CET functions that can be structured in a flexible way and parameterized automatically (using elasticities from the OECD PEM model) or by custom values that are entered by the user.

Data aggregation

As a first step, to run the module, it is crucial to rerun the data aggregation with the METROAgg GUI. Indeed, even if this is invisible to the user, that module now adds to the METRO input file the elasticities from the OECD PEM model at the right level of regional aggregation. The values of these elasticities are available in the file "METROsam8107_agg.gms" in case of any future update needs. However, these values should not be changed for any other purpose as PEM elasticity updates, as UserDefined CET elasticities can also be entered through the "s_f_r_LandCET.xlsx" Excel file of project's "database" folder. The database aggregation step also reclassifies natural resource factors used in the forest sector to land. This is necessary because the GTAP database does not associate any land as factor inputs into the forest sector (and implicitly considers trees as a natural resource). This reclassification makes it possible to study the competition for land between forest and agricultural use.

CET nesting definition

The "Project*\database" folder contains the file "s_f_r_METRO_LandCET.xlsx". In this excel file, all the data necessary for the CET nesting structure and its parameterization can be entered.

The first spreadsheet of is the "layout" for the data which is needed when loading the information into the METRO model. This spreadsheet should not be changed.

The second spreadsheet "sets_agriland" contains the set of nesting aggregates or nodes, the point at which land is allocated between nodes at a higher level, or between agricultural sectors (Figure 2b) All nodes of the CET nesting should be defined in this spreadsheet.

All three columns have to be filled. Figure 1 provides an illustration of how to set up the "sets_agriland" spreadsheet:

- The "Factor" column should give the domain factor to which the node CET structure belongs. For land, the domain factor will be "fLand".[1]
- "Name" should contain the node name. The nodes correspond to the groupings of the domain factor, for the land allocation module the groupings are the types of land (e.g. pasture, arable)
- "Label" describes the node

Figure 1. Example of definition of the CET nodes in the "sets_agriland" Excel spreadsheet

Names for CET nesting aggregates		
Factor	**Name**	**Label**
fLand	totland	Total agricultural land
fLand	forest	Total forest land
fLand	agland	Total agricultural land
fLand	arabland	Total arable land (incl. pasture)
fLand	pasture	Pasture land
fLand	othcrops	Other crops on arable land
fLand	cere_osd	Cereals and oilseeds
fLand	oth_lnd	Other land (rice, misc)

There are eight factor groupings (nodes) for the nesting of the land factor (fLand).

The third spreadsheet "agriland_ag" is the most important one. It describes the CET nesting structure. The first column is again devoted to the factor domain ("fLand") and the following columns (lnd_ag1, lnd_ag2, lnd_ag3, lnd_ag4) indicate how the domain factor, land, is allocated at each of the four different levels of the CET. Each cell is a node where the supply of the factor can be allocated at the next level. For example in Figure 2a"totland" is a node at level 1, and "totland" can supply land to either "agland" or "forest" in level 2. *Note that only one structure can be defined for all regions, but elasticity values entered in the given structure can be region specific.*

It is possible to have up to four nests with the module. Level 1 is the root level, therefore the node indicated here will contain nesting aggregates that are perfectly immobile. Typically, one can expect to have one single root node (e.g. "totland"), but it is possible to assume coexistence of several roots if justified.

Levels 2, 3 and 4 should contain the additional nodes used for the CET nesting structure. Each node at a given level can be split in one or several nodes at a higher level. Sectors that are branching from the same node at a lower level are considered imperfectly substitutable (or "transformable") within a same CET function with the same transformation elasticity.

[1] Note that it is possible to define nests for other factors (e.g. different imperfectly mobiles labour markets). This module and this document, however, focuses on land.

For example in Figure 2, land used for wheat (awht) and other grains (agro) production are considered imperfectly transformable, within the group of cereals-oilseeds (cer-osd), associated to a CET function at Level 4. Wheat is also substitutable with rice (apdr), but at a lower level, because "cer-osd" is transformable within the group "agland" (CET function Level 3), itself transformable with the group "other land" (oth_lnd) that contains rice (CET function Level 2).

Note that it is possible to have a nesting structure with less than four levels. In these cases, the last node name is used for all higher levels of the nesting in the spreadsheet. For example in Figure 2the nesting for land used in rice (apdr) only has three levels ("totland", "agland", and "oth_land"). The node name of the last level, Level 3, is used again in Level 4. Similarly for the forest sector (afrs). Land used in the forest sector only has two levels ("totland" and "forest"). This means only two levels are used for the forest sector (Level 1 and Levels 2 to 4). For such cases where several levels have the same node name, the elasticity value of the node does not play any role, except for the last level of the CET.[2]

The last column in the 'agriland_ag' sheet contains the list of all sectors for which the factor is available. All sectors that use land must be allocated to a node a Level 4 node. Therefore, it is essential that users ensure all sectors that use land in the model database are listed in column F and included in the nesting structure. As a reference, the example spreadsheet 19_8_6_LandCET.xlsx lists all agriculture sectors that use land.

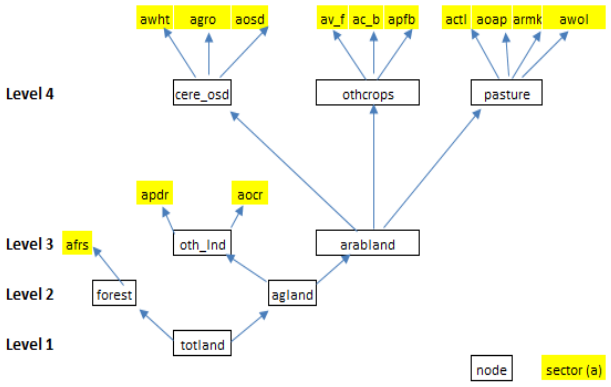
Figure 2 provides an example of how the CET nesting tree can be defined in the Excel spreadsheet for a give representation of the tree nesting. The structure is similar to the nesting structure in the OECD Policy Evaluation Model (PEM).

Figure 2 Excel spreadsheet defining nests and corresponding nesting structure

(a) Excel spreadsheet "agriland_ag"

	A	B	C	D	E	F
1	**Factor market CET nesting structure**					
2		**Level 1**	**Level 2**	**Level 3**	**Level 4**	**Sectors**
3						
4	**f**	**lnd_ag1**	**lnd_ag2**	**lnd_ag3**	**lnd_ag4**	**a**
5	fLand	totland	agland	oth_lnd	oth_lnd	apdr
6	fLand	totland	agland	arabland	cere_osd	awht
7	fLand	totland	agland	arabland	cere_osd	agro
8	fLand	totland	agland	arabland	othcrops	av_f
9	fLand	totland	agland	arabland	cere_osd	aosd
10	fLand	totland	agland	arabland	othcrops	ac_b
11	fLand	totland	agland	arabland	othcrops	apfb
12	fLand	totland	agland	oth_lnd	oth_lnd	aocr
13	fLand	totland	agland	arabland	pasture	actl
14	fLand	totland	agland	arabland	pasture	aoap
15	fLand	totland	agland	arabland	pasture	armk
16	fLand	totland	agland	arabland	pasture	awol
17	fLand	totland	forest	forest	forest	afrs
18						

(b) Corresponding nesting tree structure



[2] This is technically represented in the METRO model by four nested CET functions; Levels 2-4 will only contain one subsector in the CET transformation sector. Therefore the CET function does not play a role.

User defined elasticities

The fourth spreadsheet "agriland_elast" contains the user defined elasticities (optional). These parameters are only used if the elasticity source in the GUI is set to "UserDefined" for the calibration. Otherwise, the default PEM elasticities will be allocated to the different levels of the nesting (as there are only three levels for PEM, the lower level PEM elasticity is allocated to both Levels 1 and 2). In the Excel entry table, each node designates one single CET function, therefore one elasticity is necessary per node, even if the node is used in several levels in a row (remember that for a 1 to 1 mapping of nodes, the elasticity does not play any role, as in the case of the forest nesting in Figure 2). Elasticities are to be entered for each region and can therefore vary from one region to another. Note that all regions in the model database must be included in the "agriland_elast" spreadsheet. Also note that sectors correspond to activities, so entries in this column must 1) start with the prefix "a"; and 2) include all sectors in your analysis database that use land. It is recommended that changes to the structure of the nesting, should also be reflected in the elasticities worksheet even if users intend to use the PEM elasticities. Figure 3 provides an illustration of how the elasticities can be set-up for each node of the CET nesting structure.

Once the Excel spreadsheet is up to date, it can be simply saved and closed. It will be used as an input later when the user runs the calibration via the model interface (GUI).

Figure 3. Example of user defined elasticities entered in the "agrilnd_elast" spreadsheet for the land CET nests parameterization

	A	B	C	D	E	F	G	H
1	**Land CET elasticities (User defined)**							
2								
3	**Domain**	**Nest level**			**Regions**			
4			Europe	USA	Canada	Asia	ROW	
5	fLand	totland	0.05	0.1	0.05	0.05	0.05	
6	fLand	forest	0.05	0.1	0.05	0.05	0.05	
7	fLand	oth_lnd	0.05	0.1	0.05	0.05	0.05	
8	fLand	agland	0.05	0.1	0.05	0.05	0.05	
9	fLand	arabland	0.21	0.15	0.14	0.11	0.21	
10	fLand	pasture	0.22	0.29	0.28	0.15	0.22	
11	fLand	othcrops	0.23	0.55	0.58	0.2	0.23	
12	fLand	cere_osd	0.23	0.55	0.58	0.2	0.23	
13								

Configuration in the METRO model user interface (GUI)

After the steps above have been completed, the model can be run with the land allocation module activated. The land allocation module must be activated in both the calibration and simulation run.

Tip: The land allocation module is activated during the calibration step. The Factor Market Closure setting must be selected at both the calibration AND simulation task, and selection must be the same.

Calibration task

The choice of running METRO with the land allocation module is controlled in the main METRO GUI through the "Calibration" task on the "Closure" tab (Figure 4). Selecting "CET" as the Factor Market Closure activates the land allocation module for the calibration.

The Factor Market Closure drop down menu indicates whether the markets are to be run as:

- "Mobile": in this case, all factors are perfectly mobile in the model, except the natural resource factor which is always immobile. The land allocation module is not activated.
- "Immobile": in this case, all factors are perfectly immobile in the model, including labour. The Land allocation module is not activated.
- "CET": in this case, the land allocation module is activated. Factors that are specified with CET nested functions in the Excel workbook "s_f_r_LandCET.xlsx" will be controlled through the CET nesting structure defined in that file. Other factors are considered perfectly mobile, except natural resources that are always immobile.

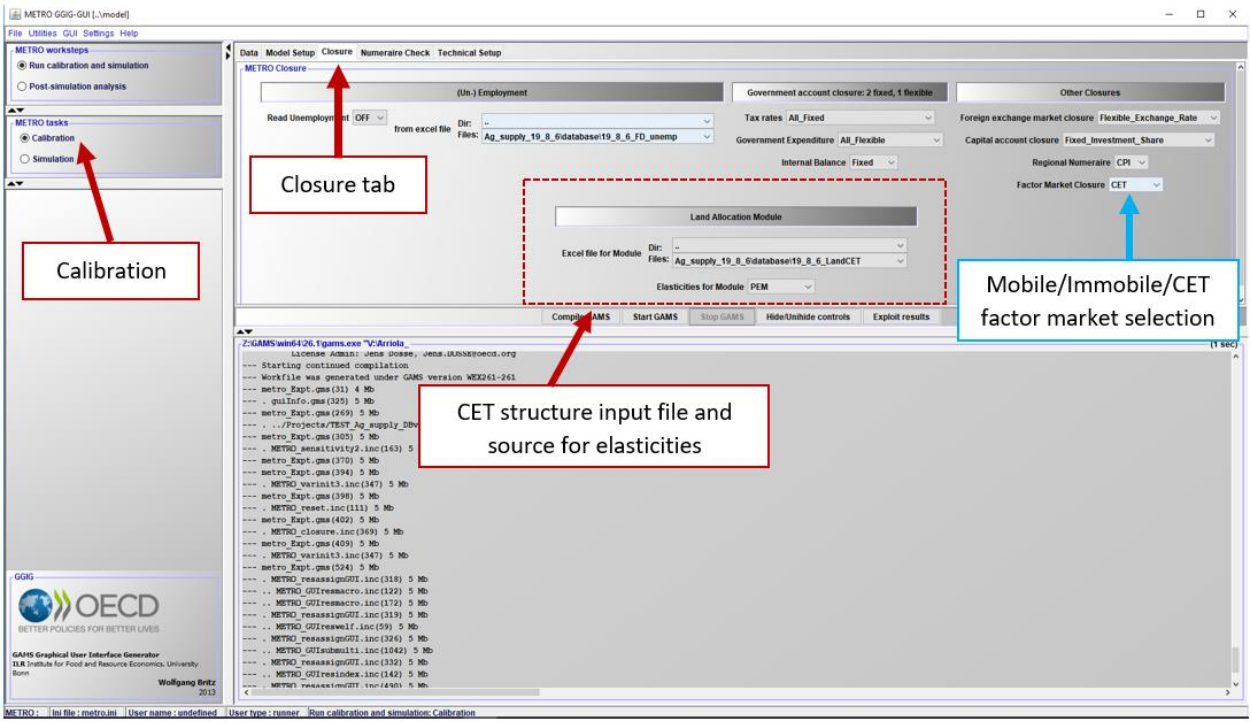
Note that the UNEMPLOYMENT in the factor market is only possible when factors are fully mobile.

To run a calibration with the land allocation module:

- In the calibration task on the "Closure" tab, set the factor market closure to "CET". This activates the land allocation module.
- In the "land Allocation Module" section of the "Closure" tab in the fields for "Excel file for Module", select the directory location and excel file that defines the CET nesting structure (s_f_r_LandCET.xlsx). This excel file must have the same dimensions as the database selected on the "Data" tab. Recall that this excel file also contains user defined elasticities.
- In the field "Elasticities for Module" select the source of the elasticities for the module. In this field, users can select "PEM" (default values stored in the input database created in the aggregation step) or "UserDefined". If the elasticities are "UserDefined", the elasticities used are those from the LandCET Excel file.
- Run the calibration by clicking on the "Start GAMS" button.

The calibration will create two files: the base gdx file in the "Results" folder and the GAMS restart (g00) in the database folder. The selection of the land allocation module as a factor market closure will be reflected in the restart file name by the label "fm_CET" (e.g. s_f_r_v9L11_**fm_CET**_unemp_OFF.g00).

Figure 4. New configuration of the METRO GUI and functions used for the parameterization of the factor CET module



Simulation task

To run an experiment using the METRO model with a CET nesting structure for land, both the calibration and simulation run must have the land allocation module activated. After calibrating the model, the user may then run a scenario in the "simulation task".

To run a scenario with the land allocation module:

- In the "Simulation task" on the "External files" tab, select the calibration file with land allocation module activated. Recall that the calibration will have "fm_CET" in the name (Figure 5).
- Select your simulation control method and file.
- In the "Closure" Tab, set the factor market closure to "CET".
- Users may wish to add a scenario id for the closure (optional)
- Run the calibration by clicking on the "Start GAMS" button[3].

[3] Information for other calibration and simulation settings are explained in the main user guide for the METRO Model interface.

Figure 5. Simulation task, selecting calibration file

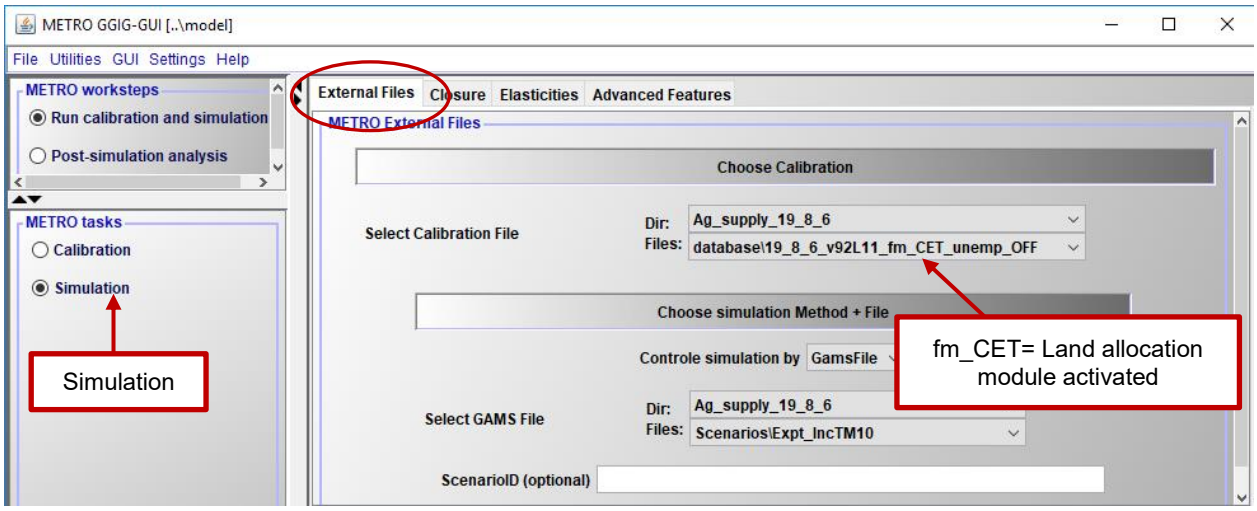
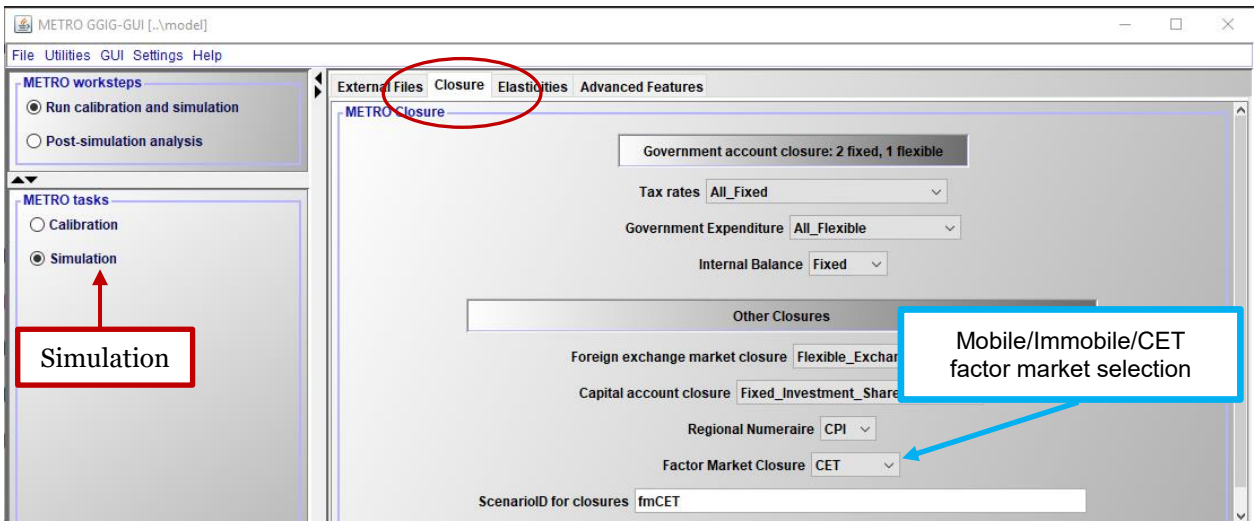


Figure 6. Simulation task, selecting factor market closure



Checking behaviour and results in the output

The new land allocation module introduces some additional variables and parameters that can be checked in the results viewer of the model interface, directly in the GAMS GDX output file or in the GAMS listing file.

New elements introduced for the land allocation module

Below is the list of the elements newly introduced for the module:

- WFD(f,a,r) is the activity specific factor price variable, prescribing substitution and transformation in the factor market. This price is associated to the factor demand FD(f,a,r). The scope of WFD(f,a,r) is global and affects METRO.GMS
- f_closure(f,r) is a parameter indicating the assumption for each factor market mobility:

  - f_closure(f,r) = 0 means the factor are perfectly immobile
  - f_closure(f,r) = 1 means that the factor are perfectly mobile
  - f_closure(f,r) = 2 means the factor are imperfectly mobile and controlled by the CET nesting structure

- The set af contains the list nesting aggregates or nodes. This set is defined by the user in the "sets_agriland" worksheet of the s_f_r_LandCET.xlsx file in the column "Name".
- Sets af1, af2, af3, af4 are the sets containing the nodes at each level of the CET nesting. These sets are all defined as subsets of the af.
- map_af(f,af1,af2,af3,af4,a) is the CET nesting structure set, which defines the set-up of the nodes. This mapping connects the natural factor (land) to the nodes at each level of the CET structure and eventually the sector using the factor as a production input (Figure 7). The mapping is defined in worksheet "agriland_ag".
- map_af1, map_af2, map_af3, map_af4 correspond to the mapping definitions of the CET functions, at each level of the CET nesting tree
- af_sigma(f,af,r) contains the elasticity values
- FS_CET1(f,af1,r), FS _CET2(f,af2,r), FS _CET3(f,af3,r), FS_CET4(f,af4,r) are the aggregated supply of the factors at each level of the CET
- WF_CET1(f,af1,r), WF_CET2(f,af2,r), WF_CET3(f,af3,r), WF_CET4(f,af4,r) are the prices for each of the node aggregated factors

Figure 7. Mapping set "map_af" defining the CET nesting structure in the GDX viewer

map_af(f, af, af, af, af, a): CET nesting aggregate - All mappings

fLand	totland	forest	forest	forest	afrs	Y
		agland	arabland	pasture	actl	Y
					aoap	Y
					armk	Y
					awol	Y
				othcrops	av_f	Y
					ac_b	Y
					apfb	Y
				cere_osd	awht	Y
					agro	Y
					aosd	Y
			oth_Ind	oth_Ind	apdr	Y
					aocr	Y

Note: In the gdx viewer, empty grey cells indicate that values are the same as in the previous cell. For example, all cells in the first column has the value "fLand".

Viewing results in the interface viewer

The variables and parameters of the land allocation module are available in the results viewer of the interface. The new variables are found in the "Factor Market" theme of the results viewer where two new sub-themes are now available: Factor Market – Land Allocation (Supply) and Factor Market - Land Allocation (Prices) (Figure 8). Table 1 shows which sub-theme the parameters specific to the land allocation module are found.

Figure 8. New tables added for the module are found under the Factor Market theme of the results viewer

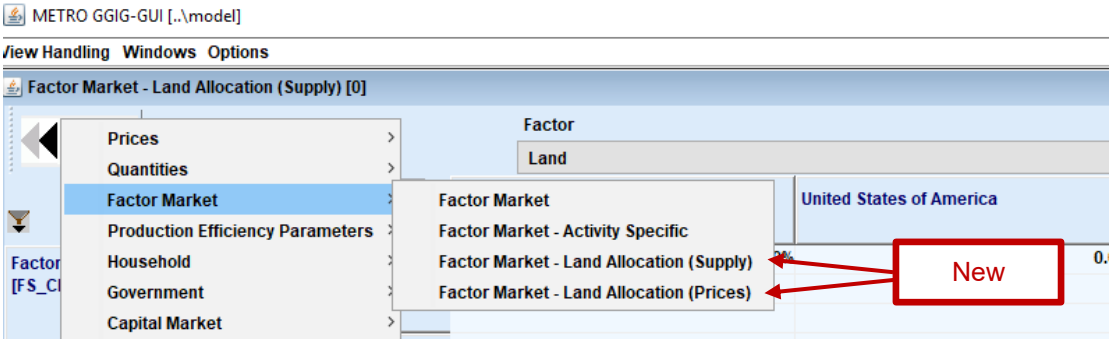


Table 1. Factor market tables available with the land allocation module

Factor market	Factor market
• Factor Market	(FS,WF,UNEMP,YF, YFDIST)
• Factor Market - Activity Specific	(FD, WFD,WFDIST)
• Factor Market – Land Allocation (Supply)	(FS_CET1, FS_CET2, FS_CET3, FS_CET4)
• Factor Market – Land Allocation (Price)	(WF_CET1,WF_CET2,WF_CET3, WF_CET4)

Users should note that not all CET levels are relevant for all land aggregates and vice versa. For example, the land aggregate "total agricultural land" in the PEM setup example, is only relevant at the first level while "pasture land" is a node at Level 4 (Figure 2). As such, when viewing the parameters based on CET levels, it is recommended that users pair the dimensions "land aggregate" and "value" (e.g. FS_CET1, FS_CET2). Moreover, for the moment, the CET nesting structure is only available for the land factor. It is, therefore, recommended that users place dimension "factor" outside of the table area of the view and then filter on land (Figure 9).

Figure 9. Recommended layout for viewing nesting parameters of the land allocation module

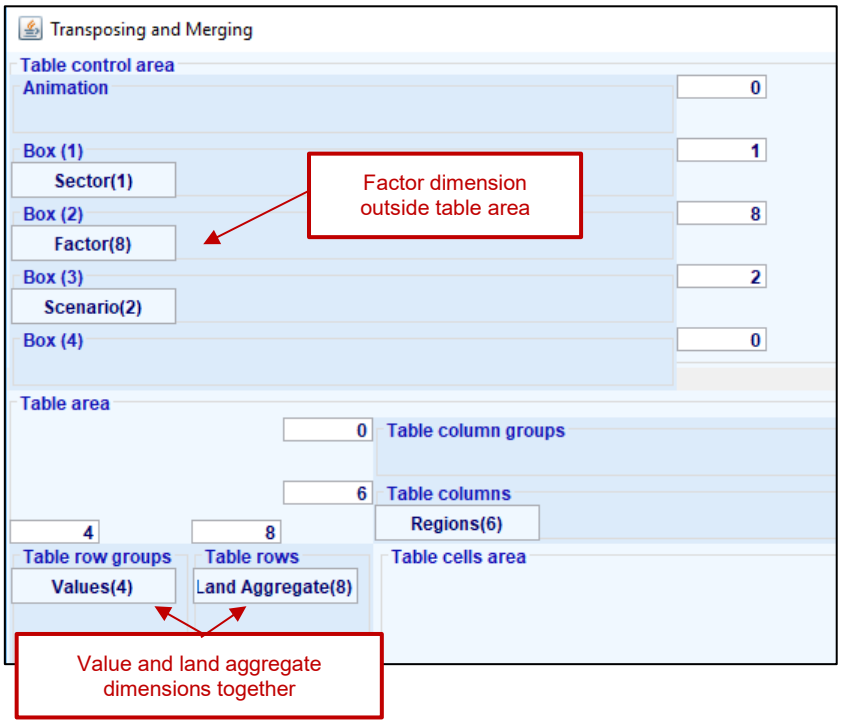
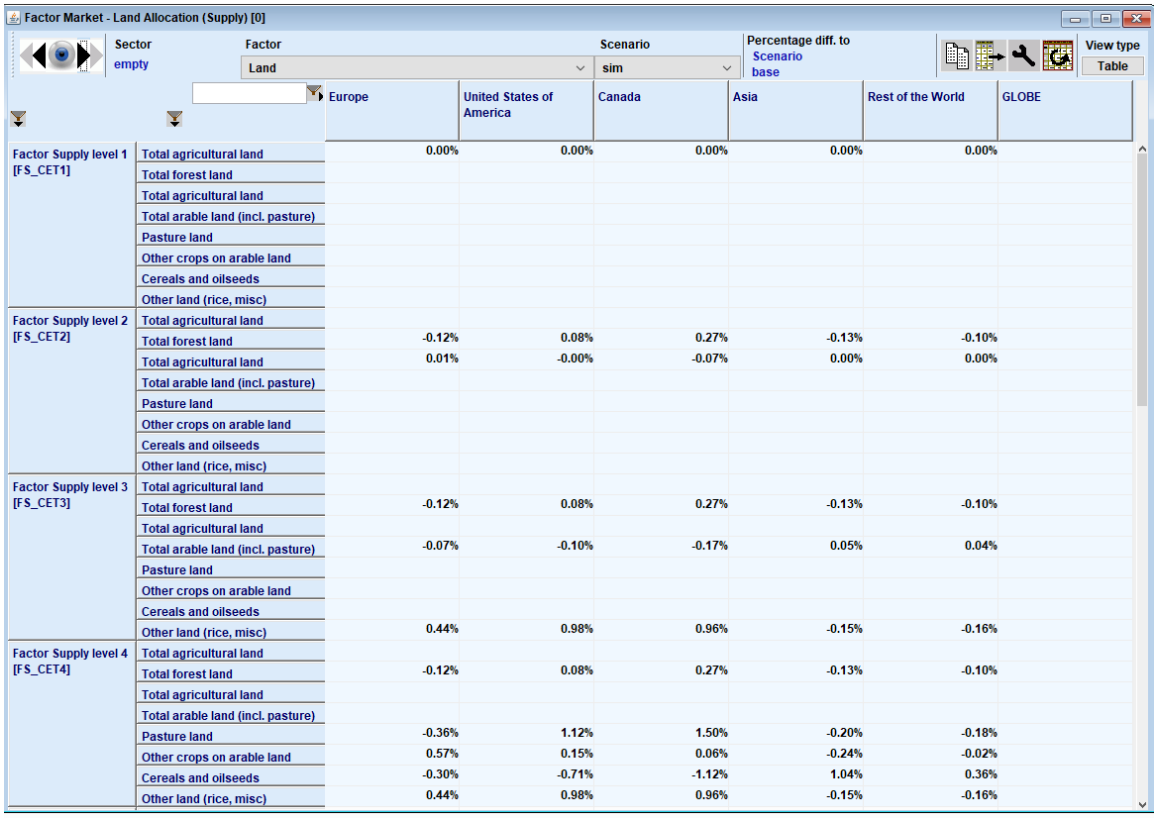


Figure 10. Resulting table view



		Europe	United States of America	Canada	Asia	Rest of the World	GLOBE
Factor Supply level 1 [FS_CET1]	Total agricultural land	0.00%	0.00%	0.00%	0.00%	0.00%	
	Total forest land						
	Total agricultural land						
	Total arable land (incl. pasture)						
	Pasture land						
	Other crops on arable land						
	Cereals and oilseeds						
	Other land (rice, misc)						
Factor Supply level 2 [FS_CET2]	Total agricultural land						
	Total forest land	-0.12%	0.08%	0.27%	-0.13%	-0.10%	
	Total agricultural land	0.01%	-0.00%	-0.07%	0.00%	0.00%	
	Total arable land (incl. pasture)						
	Pasture land						
	Other crops on arable land						
	Cereals and oilseeds						
	Other land (rice, misc)						
Factor Supply level 3 [FS_CET3]	Total agricultural land						
	Total forest land	-0.12%	0.08%	0.27%	-0.13%	-0.10%	
	Total agricultural land						
	Total arable land (incl. pasture)	-0.07%	-0.10%	-0.17%	0.05%	0.04%	
	Pasture land						
	Other crops on arable land						
	Cereals and oilseeds						
	Other land (rice, misc)	0.44%	0.98%	0.96%	-0.15%	-0.16%	
Factor Supply level 4 [FS_CET4]	Total agricultural land						
	Total forest land	-0.12%	0.08%	0.27%	-0.13%	-0.10%	
	Total agricultural land						
	Total arable land (incl. pasture)						
	Pasture land	-0.36%	1.12%	1.50%	-0.20%	-0.18%	
	Other crops on arable land	0.57%	0.15%	0.06%	-0.24%	-0.02%	
	Cereals and oilseeds	-0.30%	-0.71%	-1.12%	1.04%	0.36%	
	Other land (rice, misc)	0.44%	0.98%	0.96%	-0.15%	-0.16%	

Annex A. Aggregating PEM elasticities

From the model interface or GUI, users may choose to use the PEM elasticities for the land allocation module. PEM has land transformation elasticities for 11 regions and rest of world for three levels of nesting. The METRO aggregation program (\Agg\METROsam8107_agg.gms) maps all the METRO regions to a PEM region before performing the aggregation. The elasticities are then aggregated to the new regions of analysis by calculating land rent-weighted averages of the initial PEM elasticities. In an analysis database with regions outside the scope of PEM, the elasticity for ROW is used for countries outside the PEM scope.

Table A.1. The PEM-METRO country mappings

PEM	METRO
ANZ	aus, nzl
CAN	can
CHE	che
CHN	chn, hkg
EU15	aut, bel, dnk, fin, fra, deu, grc, irl, ita, lux, nld, prt, esp, swe, gbr
JPN	jpn
KOR	kor
MEX	mex
NOR	nor
TUR	tur
USA	usa
ROW	*All other regions not previously mapped*

Table A.2. PEM elasticities available for the land allocation module

	Levels 1 and 2	Level 3	Level 4
ANZ	0.05	0.17	0.59
CAN	0.05	0.14	0.58
CHN	0.05	0.18	0.55
EU15	0.05	0.21	0.23
JPN	0.05	0.11	0.2
KOR	0.17	0.09	0.33
MEX	0.1	0.11	0.59
TUR	0.05	0.15	0.35
USA	0.1	0.15	0.55
ROW	0.05	0.21	0.23

Source : PEM 2013. Exception CHN and KOR which use 2019 PEM elasticities.