Documentation

FABLE Calculator

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Acknowledgements

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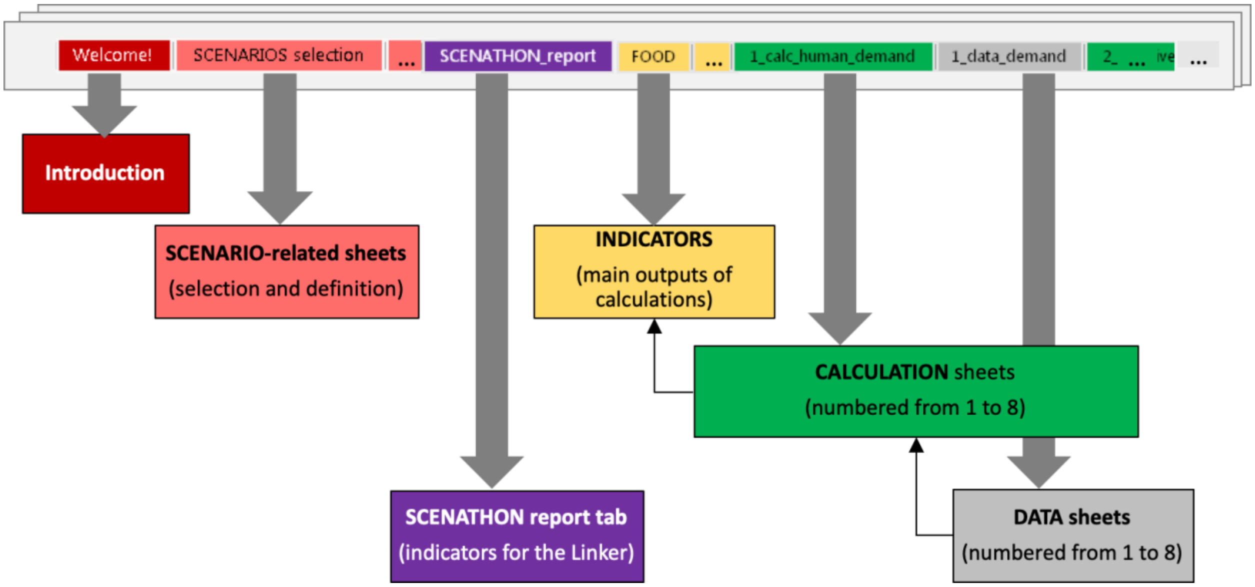
1 Introduction

1.1 What is the FABLE Calculator?

The FABLE Calculator is an Excel accounting tool used to study the potential evolution of food and land-use systems over the period 2000-2050. The impact of different policies as well as changes in the drivers of these systems can be tested through the combination of a large number of scenarios. The FABLE Calculator focuses on agriculture as the main driver of land-use change. It includes 76 agricultural raw and processed products from the crop and livestock sectors (Appendix 1) and relies extensively on the FAOSTAT database for input data. In each 5-year time step over 2000-2050, the level of agricultural activities, land use, food consumption, trade, and greenhouse gas (GHG) emissions is computed according to selected scenarios. The current version of the FABLE Calculator is a light Excel file (<6 MB) which contains country or regional historical data in the grey "DATA" sheets, the formulas for the calculation in the green "CALCULATION" sheets, the scenarios definition and selection in the light red "SCENARIOS" sheets, and the visualization of the main results in the yellow "INDICATORS" sheets (Figure 1). Users can replace data from global databases with national or sub-national data. This is not an optimization tool and prices are only used ex-post to compute production and trade value (i.e. they do not influence the results and results do not influence commodity prices, contrary to economic models).

Figure 1: Overview of the FABLE Calculator Excel workbook



1.2 Why did we develop the FABLE Calculator?

We developed the FABLE Calculator because we are convinced models can help frame better policies. First, models describe and explain in a simplified framework how things work. By integrating various sources of existing information, they highlight information gaps and inconsistencies as well as the different parts of a system that are connected. Second, models explore the potential impact of policies that are not in place, or changes that cannot be currently observed. Specifically, scenarios make it possible to test for the consequences of a wide range of "if" assumptions and their most important dependencies.

The FABLE Calculator can identify major imbalances in, and threats to, national food and land-use systems without complex optimization algorithms. It can be opened on almost any computer since Excel is one of the most widely used programs in the world and newer versions are backwards-compatible with older Excel files. Because all of the data is visible and the structure of the functions is clear, the Calculator contains no hidden "black-box" that can obfuscate its weaknesses. Users can quickly select alternative combinations of scenarios and see the impacts on the main indicators. This is an advantage when interacting with stakeholders, as assumptions can be changed easily and transparently. In certain contexts, there may be some value in starting with a simple tool and progressively including more complexity to address clear shortcomings identified by stakeholders, rather than presenting a very complex tool whose value may not be well understood. However, results should be always challenged knowing the limitations of the tool, and some questions simply cannot be answered by the FABLE Calculator because it lacks the necessary complexity (cf. section 4.4 Discussion of the results in FABLE, 2019).

1.3 Who are the targeted users?

The Food, Agriculture, Biodiversity, Land-Use, and Energy (FABLE) Consortium is a collaborative initiative, operating as part of the Food and Land-Use Coalition, working to understand how countries can transition towards sustainable land-use and food systems. The Consortium is a global network of researchers organized by country teams who are building the tools and analyses for integrated food and land-use planning at the national and global level (Schmidt-Traub, Obersteiner, & Mosnier, 2019). Before joining the Consortium, few country teams had developed a model that covered both food and land systems. Therefore, the FABLE Calculator was developed with the objective of providing a model to each country team as quickly as possible to allow them to make first projections of their food and land-use systems up to 2050. Seventeen country models (Argentina, Australia, Brazil, Canada, China, Colombia, Ethiopia, Finland, Indonesia, India, Mexico, Malaysia, Russia, Rwanda, Sweden, the UK, and the USA) and seven rest-of-the world (RoW) regional models were produced to generate sustainable pathways. The FABLE Consortium played a key role in identifying problems and mistakes in the Calculator and in suggesting improvements.

The FABLE calculator has been used to play the first FABLE Scenathon, a process where the same standardized indicators derived from the modeled pathways of all country teams and rest of the world regions were submitted to an online platform (also called Linker tool) which allowed the comparison of the pathways, the aggregation at the global level, and the computation of trade imbalance for each product and year. Several iterations have been used to balance trade and to try to collaboratively align national pathways with the global FABLE targets. The results and methodology of this first Scenathon are described in the FABLE Report 2019 (FABLE, 2019).

More generally, the FABLE Calculator can be used by anyone who is interested in integrated analyses of food and land-use systems. It is especially suitable for people with no or limited previous experience in modelling.

2 Scenarios

Worksheet(s) in the FABLE Calculator:
⇒ *Scenarios Selection*
⇒ *Scenarios Definition*

We have established a list of parameters that can be changed through the selection of different scenarios. Each parameter and corresponding alternative scenarios are grouped by tables. By default, there are 10 parameters which can be modified through scenarios, each of which has between 2 to 14 possible alternative values. There are, therefore, thousands of possible combinations that lead to different pathways (Table 1). The user can select pre-defined scenarios or add new scenarios. To select a scenario, the user simply needs to enter "x" next to the scenario that they want to test (Table 2). There can be only one scenario selected per table. The parameters and selected scenarios are automatically updated by the SUMIFS and VLOOKUP Excel functions, respectively.

Table 1: Example of a pathway definition in the FABLE Calculator: a combination of selected scenarios for different parameters

Scenario on GDP	Scenario on Population	Scenario on food diet	Scenario on land availability	Scenario on the share of food waste	Scenario on the share of imports	Scenario on the level of exports	Scenario on livestock productivity	Scenario on Crop productivity	Scenario on Afforestation/ Reforestation	Scenario on Fixed Trade
SSP3	SSP3	SSP1	NoDefor2030	Current	I3	E1	HighGrowth	HighGrowth	BonnChallenge	Yes

Table 2: Example of scenario selection

TABLE: Pop_Scen				
S.2	**Alternative population projections**			
SELECTION	**POP_SCEN**	**DESCRIPTION**	**Population variation 2000-2050**	**USED in**
	SSP1	"***Sustainability***" - Low to medium fertility, low mortality, medium migration, high education. Fast urbanization.	1.32	
	SSP2	"***Middle of the Road***" - Medium fertility, medium mortality, medium migration, medium education. Extension of current trends in urbanization.	1.43	
x	SSP3	"***Fragmentation***"- High fertility, high mortality, low migration, low education. High rural population growth.	1.60	
	SSP4	"***Inequality***" - High fertility, high mortality, medium migration, very low education. Fast urbanization.	1.33	calc_hum_demand;
	SSP5	"***Conventional Development***" - Low fertility, low mortality, high migration, high education. Fast urbanization.	1.30	
	UN_medium	Medium growth	1.53	
	UN_high	High growth	1.71	
	UN_low	Low growth	1.36	
	UN_constantfertility	Constant fertility	1.63	
	UN_instantreplacement	Instant replacement	1.52	
	UN_momentum		1.46	
	UN_zeromigration	Zero migration	1.52	
	UN_constantmortality	Constant mortality	1.47	
	UN_nochange	No change in fertility, mortality, replacement, and migration	1.57	
	countryteam		0.00	

A key concept for implementing the scenarios are shifters, which are created to introduce a time variation for any parameter based on historical value or trajectory.

2.1 Population

Population growth is a key parameter as it is used to compute the evolution of the targeted demand together with the diet assumption. Nine population projections are taken from the United Nations DESA population division prospects: low, medium, high, constant fertility, instant replacement, momentum, zero migration, constant mortality and no change (UNDESA, 2017). Five population projections are taken from the SSP database developed at IIASA: SSP1 to SSP5 (KC & Lutz, 2017). Historical data for 2000, 2005, 2010, and 2015 are taken from UN-DESA (UNDESA, 2017). Shifters are computed as the ratio between the projected population in each time step and the population reported in 2015 in each database. The corresponding relative changes (shifters) to the selected population scenario are applied to the 2015 historical population level from the UN-DESA. It is important to note that the historical population value for 2015 is inconsistent across the UN and SSP databases.

2.2 GDP

GDP is only used in case the selected diet scenario is an SSP scenario. In this case, dietary evolution depends on the evolution of GDP per capita and the income elasticity of each food group. There are 3 alternative GDP projections taken from the IIASA-SSP database: SSP1 to SSP3 (Riahi et al., 2017).

2.3 Diets

The diet scenario determines the targeted average daily kilocalorie consumption per capita (kcal/cap/day) for each food group and each time step. Scenarios include IIASA-GLOBIOM SSP scenarios where future consumption levels depend on GDP per capita and income elasticities from USDA. Three other scenarios were defined in the Calculator by default: *No change*, *Healthy diet,* and *Fat diet*. *No change* corresponds to the 2010 consumption profile taken from the FAO. Healthy diet corresponds to an average of the range indicated by the EAT-Lancet report for each food group (Willett et al., 2019). We have defined the *Fat Diet* as a high share of meat products, oil, and sugar in the total food intake (Table 3). We compute the difference between the kilocalorie consumption per food group in the selected diet and the consumption level observed in 2010. This difference is then progressively reduced over time starting in 2015 in order to match the selected diet in 2050. Several implementation rates of the target can be chosen (Appendix 2). Corresponding shifters are computed for each time step. The shifters are the same for all the products within a food group (Appendix 1).

Table 3: Definition of the healthy diet and fat diet scenarios in average kilocalorie per capita per day

	Healthy diet	Fat diet
cereals	808	750
fish	40	10
fruits & vegetables	204	130
poultry meat & pork	77	250
milk	153	300
oilseeds & vegetable oils	414	560
other	327	30
eggs	19	45
pulses	284	15

beef, mutton & goat meat	15	250
roots and tubers	39	90
sugar	120	400
TOTAL	2500	2830

2.4 Food waste

Food waste corresponds to the waste at the household level (i.e. excluding post-harvest losses which are included as a separate parameter in the FABLE Calculator). Food waste is represented as a share of total food consumption. For instance, if the targeted food consumption is 2500 kcal/cap/day, the total market supply needs to correspond to an average consumption level of 2750 kcal/cap/day if food waste at the household level represents 10% of consumption. A default share of 10% is applied to all food groups. Three scenarios are available: a constant share of food waste over time, increased food waste over time (up to 20% in 2050) and reduced food waste over time (down to 5% in 2050).

2.5 Trade

Imports are computed based on total consumption including food and non-food human consumption, food waste, and feed consumption. The parameter which allows the computation of future imports is the share of the total consumption which is satisfied by imports. Exports are computed differently: targeted exports are purely exogenous and expressed in 1000 tons. The final exports can be reduced if there is not enough land (cf. Feasible production, trade and consumption). The default assumption is that the share of the total consumption which is imported, and the level of exports, remain constant at the 2010 level, as reported by the FAO in the Commodity Balances (FAOSTAT, 2019). The "Exports" and "Imports" scenarios make it possible to change this assumption but only for the products which are selected in the export and import scenarios tables (Tables *product_impscen* and *product_exports*; Appendix 4). Users can specify by how much the 2010 exports or the 2010 share of consumption which is imported will vary by 2050 for each selected product using a shifter (2010=1) and the implementation rate of the target (Appendix 2). By-default, three scenarios are defined for the imports (I1, I2, and I3) and 3 scenarios are defined for the exports (E1, E2, E3) with no change, reduced, and increased trade assumptions.

One scenario makes it possible to fix trade to certain values, (i.e. overwriting the previous imports and exports scenarios and impeding trade adjustment due to the land constraint (*Fix Trade* scenario). This scenario is used during the Scenathon for the global trade harmonisation stage after the global trade imbalance that is produced once the results of all country and regional

Calculators have been computed and national and regional net trade have been adjusted accordingly.

2.6 Productivity

Because of the large number of products, the design of the scenarios on productivity relies on very simplistic assumptions: the starting point is always the historical productivity growth over 2000-2010 which is computed based on FAOSTAT Production data (FAOSTAT, 2019). The default assumption in the *High* productivity growth scenario is that the historical growth rate will be multiplied by -1 if it was negative, by 2 if it was below 1%, and by 0.7 if it was above 1%. For the *Low* productivity growth scenario, the historical growth rate is multiplied by -0.5 if the historical growth rate was negative, by 0.5 if it was lower than 1%, and by 0.1 if it was higher than 1%. Two additional alternative scenarios are available: *NoChange* which fixes the crop productivity to the 2010 level, and *BAUGrowth* which uses the same crop productivity growth as observed during 2000-2010. We have added a condition so that productivity cannot drop below 50% of the reported yield in 2010. In the future, we plan to add maximum productivity values to avoid unrealistic productivity projections. This is the priority for improving the tool.

2.7 Land availability

This scenario makes it possible to restrict agricultural expansion even when there is still some land available. There are three default scenarios: *No expansion,* which places a restriction on the expansion of agricultural land beyond 2010 agricultural land area; *NoDefor2030,* which forbids agricultural expansion on forest land after 2030; and *Free expansion,* which allows for agricultural expansion of natural land up to the limit of the natural land area which is under protection.

2.8 Afforestation/reforestation

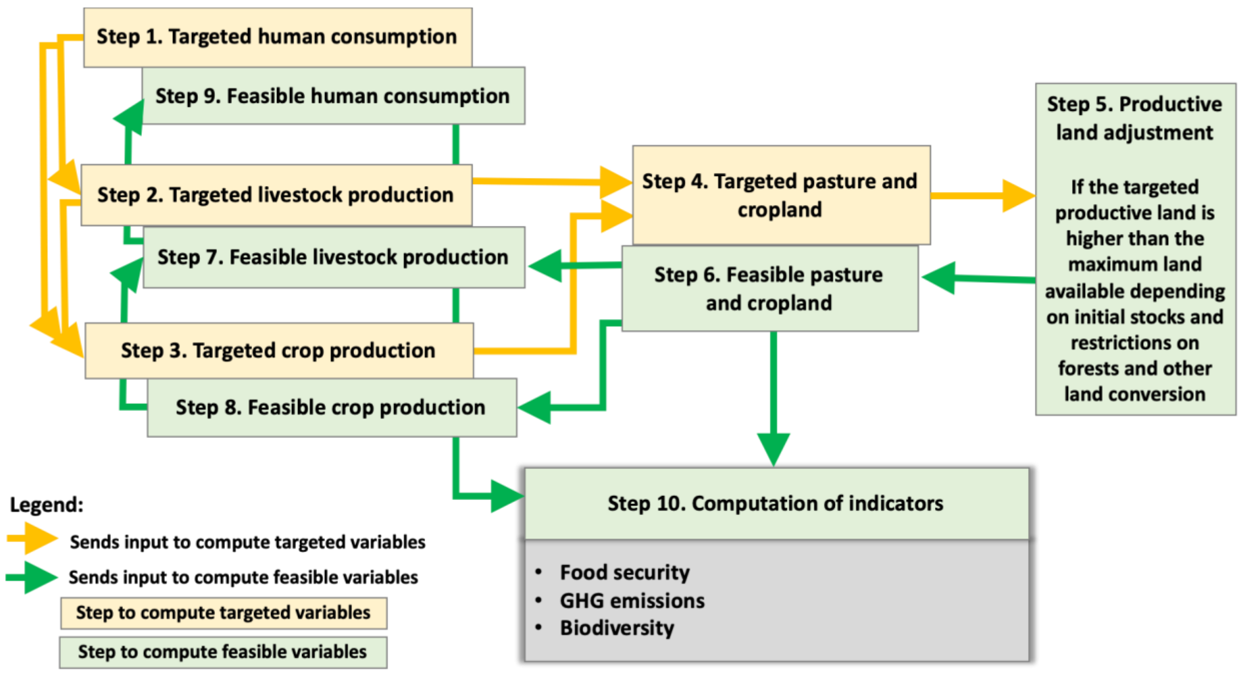
Afforestation (or reforestation) is exogenously driven in the FABLE Calculator. Afforestation (or reforestation) is represented as a separate land cover class and this scenario fixes the total targeted afforested area by 2050 and the share of the total afforested area which is planned on each land cover type (i.e. cropland, pasture and other natural land) then selects the implementation rate to distribute the afforestation target over the period. There are two alternative scenarios: *No afforestation* and *BonnChallenge,* where the target should correspond to the commitments which have been made under the Bonn Challenge.

Additional scenarios are available in certain optional features of the Calculator (cf. Appendix 5).

3 Calculation steps

The principle of the FABLE Calculator is to define several steps of calculation where, with the exception of the first step, all the other steps are dependent on one or several variable(s) that are computed in the previous steps (Figure 2). The numbering of the calculation worksheets in the FABLE Calculator reflects the sequence of the calculation steps. In each calculation worksheet, there is one or several Tables defined in previous steps which can be used in the formulas of the Tables defined in next steps.

Figure 2: Sequence of the calculation steps in the FABLE Calculator



3.1 Human demand

Worksheet(s) in the FABLE Calculator:

⇒ 1_calc_human_demand

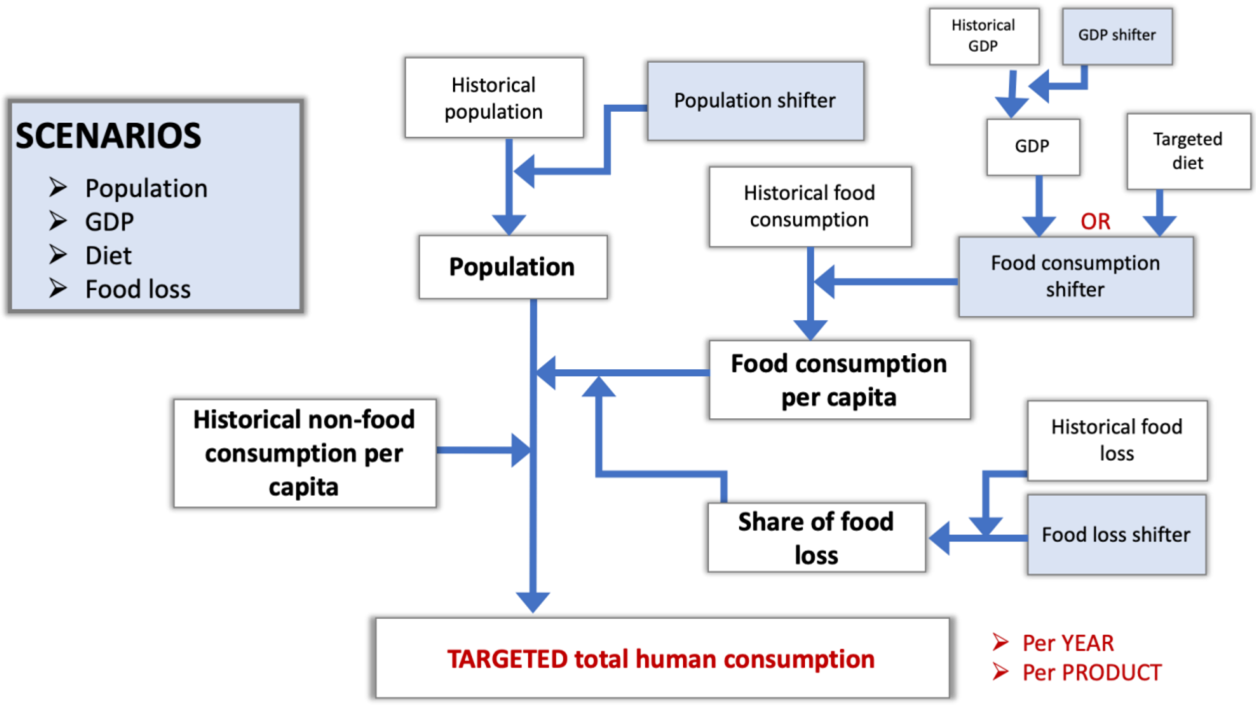
⇒ 1_data_demand

The computation of the annual demand for food and non-food human consumption is the first step of the FABLE Calculator. This means that all computed changes in the food and land-use systems modelled in the FABLE Calculator are caused by human demand (i.e. the underlying assumption is that human demand is the key driver of change in food and land-use systems).

Human demand has two components: food and non-food consumption (Figure 3). Most of the agricultural products in the FABLE Calculator are food products but can also be used for other purposes (e.g. bioenergy, chemicals, etc.) and some agricultural products are not fit for human consumption (e.g. rubber, jute, etc.). Food and non-food demand per product per capita for the historical years is computed based on the commodity balance of the FAOSTAT. In the current version of the FABLE Calculator, non-food demand per capita is fixed at the 2010 level. In the future, we may include alternative scenarios on the evolution of non-food demand by 2050 to better reflect certain policies (e.g. bioenergy policies).

The evolution of food consumption per capita depends on which scenario is selected. It is computed as the historical food demand in 2010 (without food waste) times the shifter corresponding to the selected scenario (cf. Diets). The final demand per capita per year per product is computed as the sum of non-food consumption per capita plus food consumption per capita augmented by the share of consumption which is wasted (cf. Food waste). Finally, the total demand is computed by multiplying average demand per capita by total population (cf. Population). Historical consumption levels are directly taken from the FAOSTAT for 2000, 2005, and 2010 and future demand is computed for each 5-year time step over 2015-2050 for each of the 76 raw and agricultural products (cf. Appendix 1).

Figure 3: Computation of the targeted human demand



3.2 Livestock

Worksheet(s) in the FABLE Calculator:

⇒ 2_calc_livestock

⇒ 2_data_livestock

The computation of the production from the livestock sector is the second step in the FABLE Calculator. The livestock sector supplies animal food products (cf. Appendix 1) and consumes other agricultural products for animal feed. This explains why we need to compute the production of the livestock sector before the production of the crop sector. The objective of this calculation step is to compute the evolution of the livestock herd which then determines the feed demand and the pasture area which are used in the calculation steps that follow.

3.2.1 Herd

The demand for livestock products which has been defined in Step 1 (cf. Human demand) is the starting point of the calculation (Figure 4). Next, imports are computed as the share of total consumption which is imported times the consumption for each product and time step. Exported quantity is taken from the selected scenario (cf. Trade). Consumption minus imports plus exports increased by the share of the production which is lost gives the production which is required domestically by animal product and time step. Production loss is product specific. It is computed based on FAO's Commodity balance (FAOSTAT, 2019) and is kept constant at 2010 levels over 2010-2050. We differentiate between *dairy* cattle and *other* cattle, *dairy* sheep and goats and *other* sheep and goats, *laying hens*, *chicken broilers*, and *poultry mixed*, and there is only one production system for pigs. Livestock production systems, input, output, and emission factors are taken from Herrero et al. (2013).

One difficulty in modelling the livestock sector is the fact that some animal products, such as milk, can be produced by different animals and across different production systems. In order to compute the number of animals which are required to reach the projected domestic production level, we multiply total domestic production by animal product by the contribution of each animal type and production system in the total production by animal product in 2000 as reported by Herrero et al. (2013). This parameter is constant but should be made dependent on scenarios in the future to allow for testing of structural changes in the livestock sector. Finally, the production per animal type and production system is divided by the average productivity per Tropical Livestock Unit (TLU) to compute the herd in 1000 TLUs for each animal type, production system, and time-step. Animal productivity depends on the level in the year 2000 as reported by Herrero et al. (2013) and the productivity shifter in the selected animal productivity scenario (cf. Productivity).

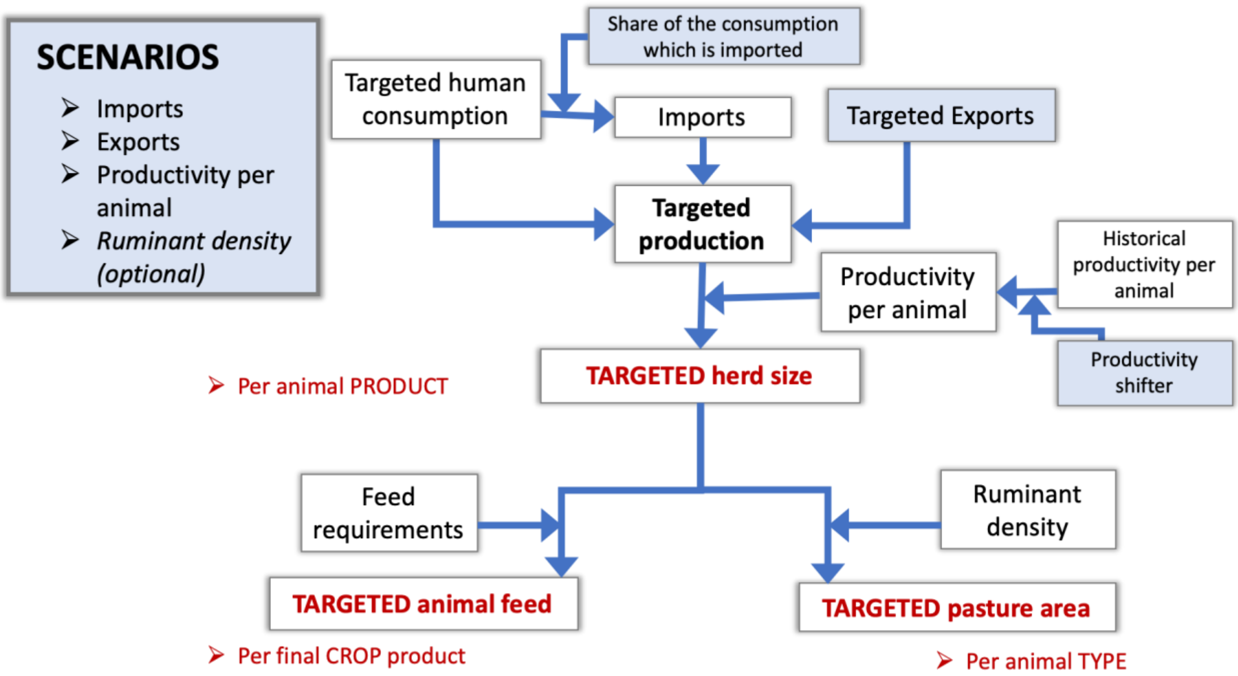
3.2.2 Feed

The herd number by animal type and production system which is computed during the previous computing step is the starting point for the calculation of feed demand (cf. Herd). We use the feed requirements per TLU computed by Herrero et al. (2013) for corn, wheat, sorghum, rice, barley, other cereals, and soybean, for each animal type and production system. The current assumption is that these feed requirements are proportionally adjusted with changes in animal productivity (cf. Productivity). In reality, several factors could explain a lower increase in animal feed than in animal productivity so this assumption might lead to overestimation of the increase in animal feed demand over time when productivity gains are high.

3.2.3 Pasture

The total herd number for ruminants (cattle, sheep and goats) is the starting point for the calculation of the pasture area (cf. Herd). We then divide the number of ruminants by the average ruminant density per hectare to obtain the targeted pasture area. By default, historical ruminant density is computed using the FAOSTAT ruminant numbers divided by the grassland area for 2000, 2005, and 2010 and kept constant at 2010 levels over 2015-2050. However, an optional update package for implementing alternative scenarios about the evolution of the ruminant density is available (cf. Ruminant density).

Figure 4: Computation of the targeted livestock herd, feed demand, and pasture area



3.3 Crops

Worksheet(s) in the FABLE Calculator:

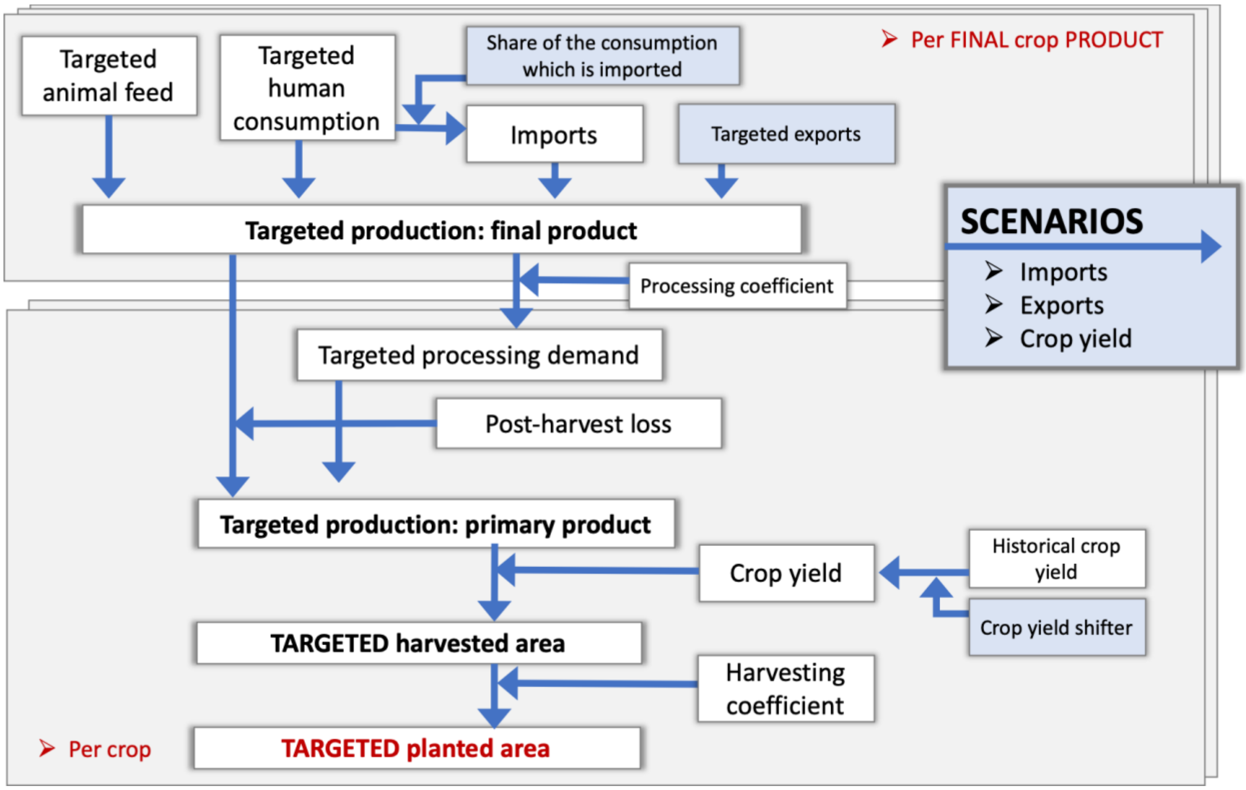
⇒ 3_calc_crops
⇒ 3_data_crops

For crops, the starting points are human and feed demand which have been computed during the previous steps (cf. Human demand and Feed). Then we compute imports by multiplying the sum of human demand and feed demand with the share of the consumption which is imported according to the selected import scenario, and exported quantity is taken from the selected export scenario (cf. Trade). According to the FAO, post-harvest losses include "waste during the year at all stages between the level at which production is recorded and the household" (i.e. storage and transportation). We compute the share of losses for each commodity in each country as the historical losses quantity over production plus imports plus stock withdrawals, based on historical data from the FAO Commodity balance. We keep the share constant at 2010 levels for the rest of the period 2015-2050. This parameter could typically be subject to alternative scenarios in the future. Stock variation is only included for historical years using FAO statistics and assumed null for the rest of the period. Targeted production is computed as targeted human consumption, plus targeted feed consumption, plus targeted exports, minus imports, plus losses, minus stock variation.

An additional demand for crops comes from processing. This is related to the human and feed demand of processed commodities such as vegetable oils or refined sugar. Targeted production or processed commodities is computed as described in the previous paragraph but an additional computation step is required to compute the quantity of raw product (crop) which is needed to produce the targeted production of the final product. We compute the processing coefficient as the reported production level of a processed product divided by the reported processed quantity of the raw product which is used as input in 2010 according to FAO Commodity balance (e.g. the production of sunflower oil divided by the sunflower quantity which is reported as processed). Targeted production is the sum of the targeted production of a crop which is used as the final product and the targeted production of a crop which is used for processing. In fact, several products can result from the processing of the same input (e.g. after extracting the oil from oilseeds, oilseed cakes which are left over can be used for animal feed). In order to convert the targeted production into harvested areas, we need to select the targeted input production for the production of a single final processed product to avoid double-counting.

Harvested area is computed as the total targeted production of a crop divided by the average annual yield in ton per hectare. This productivity is taken from FAOSTAT for 2000, 2005, and 2010 and depends on the productivity scenario which is selected for the period 2015-2050 (cf. Productivity). In some countries, several harvests are possible during the year resulting in lower cropland area than the total harvested area per year. We compute the average harvesting coefficient as the sum of all harvested area per crop divided by the total cropland area using historical FAO data. If the total harvested area is lower than cropland area, the harvesting coefficient is set to 1. The planted area is obtained by dividing the harvested area by the harvesting coefficient.

Figure 5: Computation of the targeted crop production, harvested area, and planted area



3.4 Land

Worksheet(s) in the FABLE Calculator:

⇒ 4_calc_land

⇒ 4_data_land

We represent 6 land cover types in the FABLE Calculator: pasture, cropland, urban area, forest, new forest, other natural land. Computed changes in area of pasture, cropland, urban and new forest induce changes in area of forest and other natural land as the total land area cannot expand. For each land cover type, we first compute the initial area at the beginning of the period using 2000 historical data as the base year and the feasible computed area at the end of the previous period for the other time steps.

The difference between the targeted pasture area for each time step which is computed in the previous steps (cf. Pasture) and the initial pasture area at the beginning of the time step corresponds to the targeted pasture area change (expansion or reduction) (Figure 6). The targeted pasture change is compared with the maximum pasture expansion which depends on the selected land scenario (cf. Land availability) e.g. in the *No Expansion* scenario, there is no pasture expansion possible after 2015. In case the targeted expansion is higher than the maximum expansion, the maximum value is used to compute the feasible pasture area. The same is done for cropland. The targeted cropland area is computed as the sum of computed harvested area by crop in previous steps (cf. Crops) plus the area for "other crops" which results from the difference of cropland area in 2000 and the sum of harvested area by crop in the FAO database. The discrepancy between reported cropland and the sum of harvested area can be explained by missing crops in the FAO database but also because arable land includes "temporary meadows for mowing or pasture, land under market and kitchen gardens and land temporarily fallow (less than five years)" (FAO), which are not yet explicitly taken into account in the FABLE Calculator. The area under "other crops" is set constant at 2000 levels for the whole period of simulation. Targeted urban area is computed based on historical expansion rates computed based on ESA-CCI land cover maps from 2000 and 2005 but capped at 3.5% of total land area maximum. Depending on the Afforestation scenario which is selected (cf. Afforestation), there might be some land which is taken out of pasture, cropland and/or other natural land to be converted into new forest. In this case, the afforested area is removed from the initial land area before the land expansion/reduction is computed.

Targeted deforestation is computed as the share of the total expansion which occurs at the expense of forests and the total targeted expansion which is computed by adding cropland, pasture, and urban area expansion. The share of the expansion which occurs on forest is based on FAO data over 2000-2005 but can also be changed through land scenario (cf. Land availability) e.g. in the *No deforestation* scenario, the share is set to zero. This targeted deforestation is compared with the maximum deforestation which is computed as the initial forest area at the beginning of the period minus the forest within protected areas. The computed deforestation cannot be higher than the maximum deforestation.

The initial other natural land category in 2000 is computed as the difference between the total land area of the country/region minus pasture, cropland and urban areas. It can thus include quite heterogeneous land types and degree of wilderness. The maximum other natural land which can be converted to productive land use is computed as the initial other natural land at the beginning of the period, minus the area within protected areas and minus the area which is targeted for afforestation. The targeted other natural land change is the sum of the targeted productive land use expansion minus the computed deforestation which already accommodates for some of the targeted expansion, and the targeted reduction of productive land area. The computed other natural land change cannot be higher than the maximum available other natural land area. In the of case a targeted expansion which could not be met through available forest and other natural land area, productive land use should be adjusted.

Excess land expansion is computed as the difference between targeted and feasible expansion (Figure 7). The adjustment is allocated between pasture and cropland area proportionally to their role in total expansion of agricultural land. The adjustment factor for pasture and cropland is computed as the maximum feasible pasture area over the targeted pasture area and the maximum feasible cropland area over the targeted cropland area. Urban and afforested area are excluded from the adjustment.

Figure 6: Computation of targeted expansion of agricultural land and urban area with a focus on pasture and feasible deforestation and other natural land change

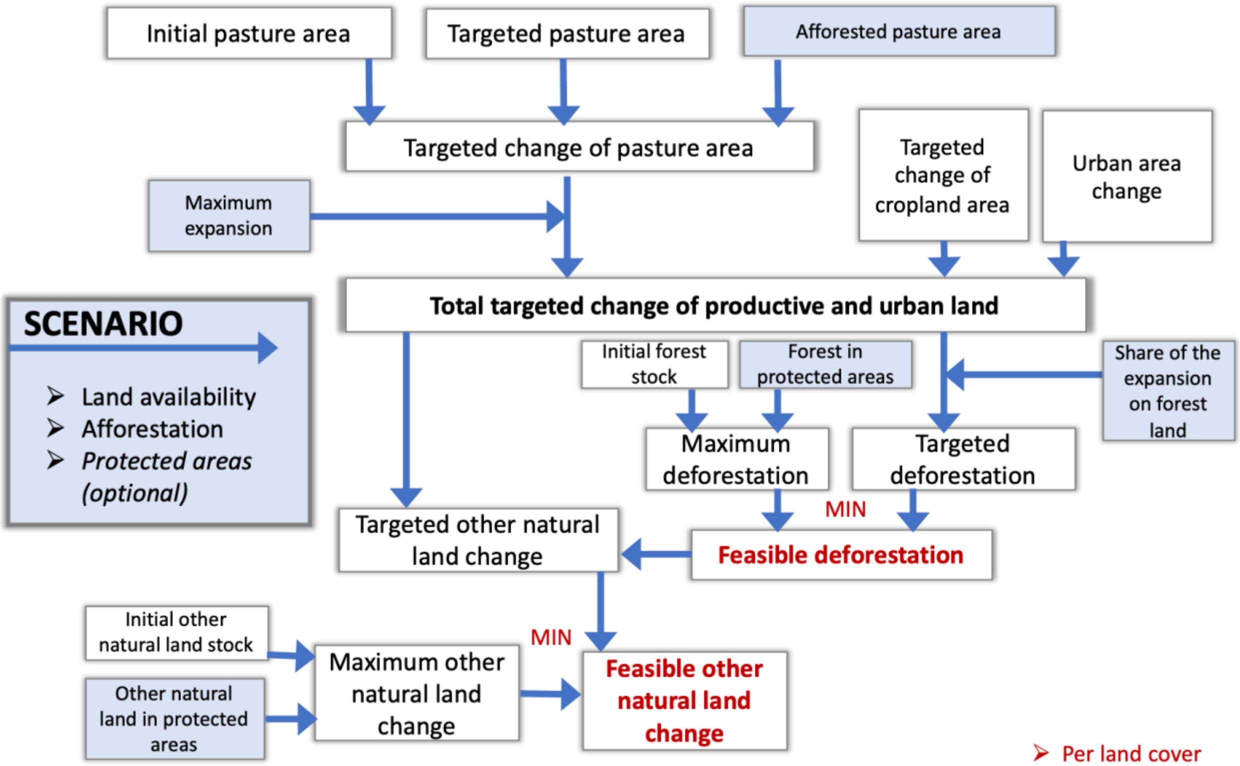
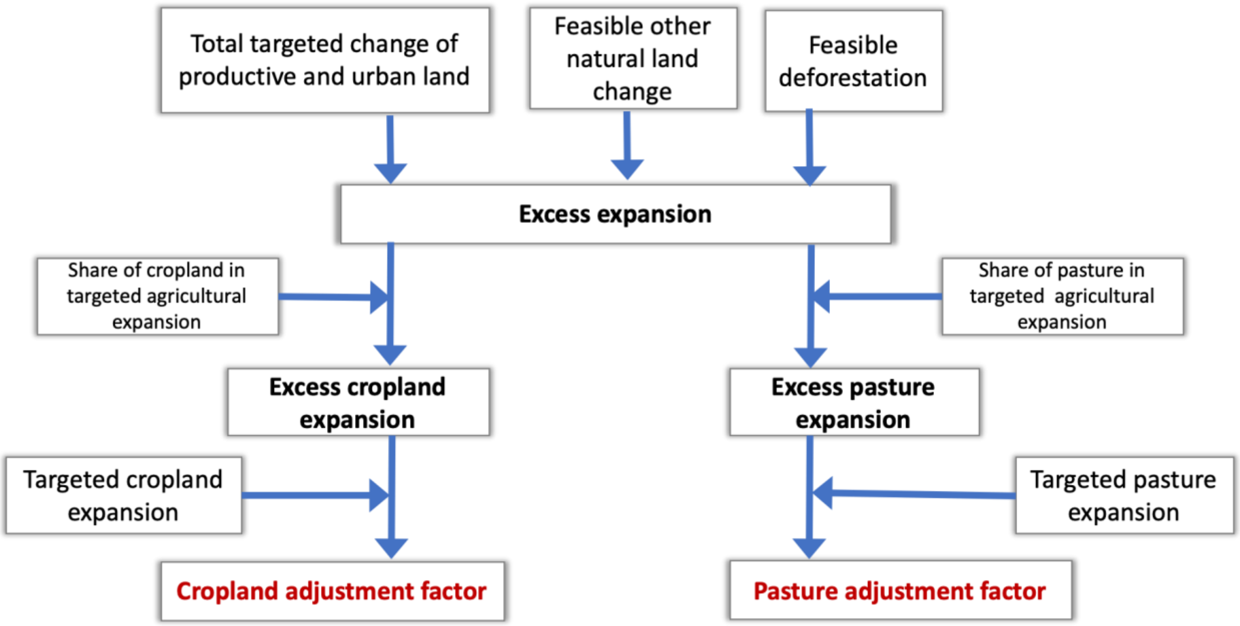


Figure 7: Computation of the excess expansion and resulting cropland and pasture adjustment factors



3.5 Feasible production, trade, and consumption

Worksheet(s) in the FABLE Calculator:

⇒ 5_feas_livestock

⇒ 6_feas_crops

Any discrepancy between targeted and feasible pasture area and/or cropland area needs to be channeled back through the causality chain up to the consumption level (cf. Figure 2). Livestock is the first sector that should be adjusted. The targeted pasture area (cf. Pasture) is first multiplied with the pasture adjustment ratio. This affects the ruminant herd number (cf. Herd) which is recomputed as the feasible pasture area times the ruminant density. The feed demand for all crops and processed products from crops (cf. Feed) is first multiplied by the cropland adjustment ratio. Then, the new feed demand based on feasible ruminant herd number is computed using feed requirements. The feasible feed demand is the minimum value between the new feed demand based on adjusted herd and the adjusted feed demand based on cropland adjustment ratio. The feasible herd is finally computed as the feasible feed divided by the feed requirement. Exports and final human consumption of livestock products are proportionally reduced to the reduction of the feasible herd compared to the targeted herd.

For crops, targeted harvested area for all the crops (cf. Crops) is multiplied by the cropland adjustment factor (i.e. harvested area by crop is reduced proportionally to the total cropland reduction). Feasible production is computed as the feasible harvested area by crop times the productivity per hectare. Feasible feed is taken from the previous step and imports are fixed. Feasible final human demand, feasible exports, and feasible processed demand are adjusted to compensate for the remaining crop production reduction so that market balance is ensured.

Note: if the scenario Fixed trade is selected, exports are not adjusted proportionally to the production reduction resulting from the land constraint: the reduction is distributed between feed demand and final human consumption only.

4 Results indicators

In a final step, the Calculator computes key indicators using as an input the feasible variables computed during the last steps. These include daily kilocalorie consumption per capita; greenhouse gas emissions from land-use change and agriculture; and the share of total land area used for biodiversity conservation. Other available indicators include water footprint and species loss. This list of computed indicators will be expanded in the future.

4.1 Food

Worksheet(s) in the FABLE Calculator:

⇒ FOOD

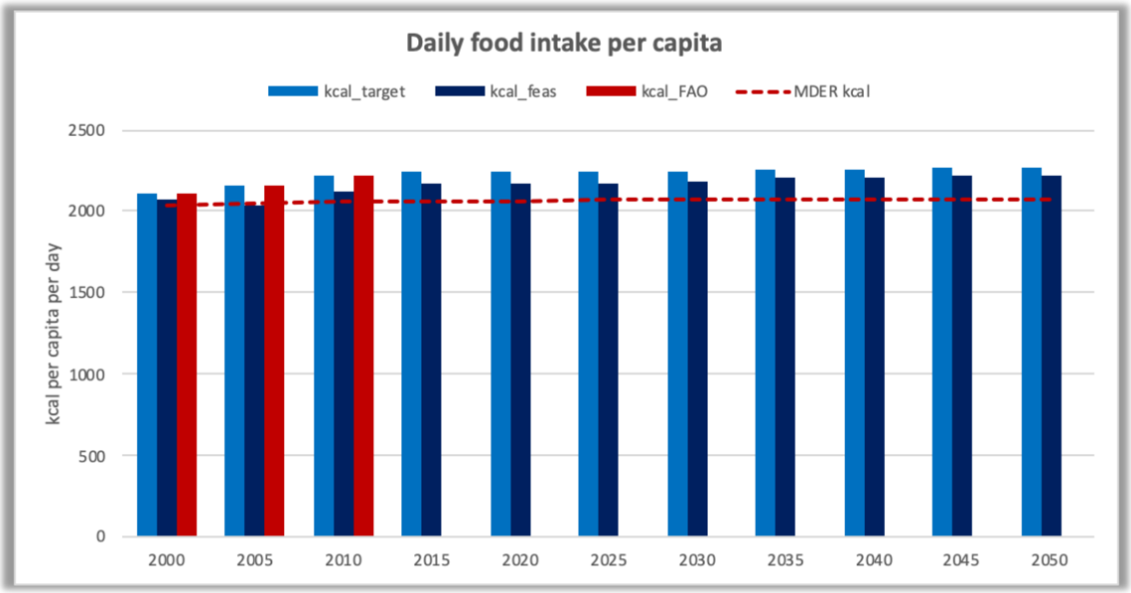
⇒ 7_feas_consohum

⇒ 1_data_demand

The main food indicator is the average calorie consumption per capita per day (kcal/cap/day). We also compute proteins and fats consumption in grams per capita per day. We start from the feasible total consumption for each product (cf. Feasible consumption), we multiply it by the share of the total consumption which is for food, we subtract food waste at the household level, we divide by the population number to get the average per capita consumption and by the number of days per year to get the average daily consumption (cf. Human demand). Finally, we multiply the average daily consumption per capita by the calorie content of each product. Kilocalories, protein, and fat content per product per country is taken from the FAO Food Balance Sheets (FBS) for the year 2000.

In the FABLE Calculator, the main results related to food are presented in the FOOD worksheet. In the first figure (Figure 8), we display the evolution of the total kcal/cap/day both for the targeted and the feasible levels. A difference between the targeted and the feasible food consumption can be due to two reasons: there is not enough land available or production is not represented for some of the products included in the demand (cf. Appendix 1) because there is no data on production in the FABLE Calculator. In this case, a lower feasible consumption than the targeted consumption should be observed for the historical period. If the gap between the targeted and the feasible consumption increases over time, the missing products on the production side are expected to represent a larger share of total consumption and/or the targeted production cannot be met because of land constraints (cf. Land scenarios and Land calculation).

Figure 8: Daily food intake per capita

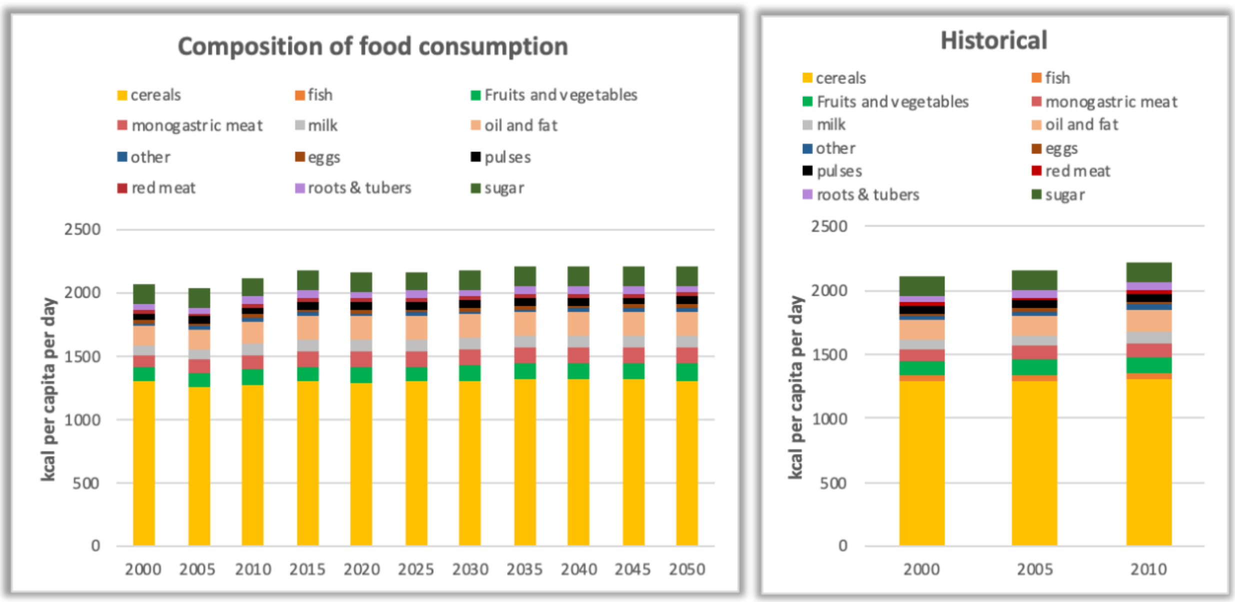


We compare our results with the historical consumption level according to FAO and the Minimum Daily Energy Requirement (MDER). The historical consumption level can be lower than the reported kcal/cap/day from the FAO database because it does not include animal fat and alcohol which are not represented in the FABLE Calculator. The targeted consumption should be equal to the FAO consumption for the historical years.

The daily MDER is computed following FAO guidelines (Cafiero, 2014) using data on the structure of the population by age, class, and sex and the dietary recommendations by age, class, and sex for a certain level of activity. The average MDER at the national level is the sum of the minimum daily energy requirements by population group multiplied by the population number in each group ("age-bracket") divided by the total population number. Because the population number can also depend on a separate growth scenario determined by the user, the number of people in each age-bracket is scaled accordingly. Scaling of populations in age-brackets is simple and linear, meaning that there is no effect on the population age structure across age-brackets (i.e. selecting different population growth scenarios in the default Calculator changes only the number of individuals represented in each age-bracket, not the structure across age-brackets). The dietary requirements are taken from the Institute of Medicine of Washington (DC) for three different activity levels, low, medium, high (Institute of Medecine, 2002), and the population structure is taken from the UN medium estimate scenario (UN-DESA Population Division, 2017). The user is free to select the level of preferred activity as part of the scenario selection. An average feasible consumption level below, or just at, the MDER level could be worrying as it would mean that each individual in a given country would have just enough food to cover the minimum requirements of the whole population if the available food were perfectly shared across the population.

The second figure of the FOOD worksheet presents the average daily kilocalorie consumption per capita per food group (Figure 9). The correspondence between product and food groups is presented in Appendix 1. The results are presented for the feasible consumption only. The comparison between the computed feasible consumption by food group and the historical data from the FAO can help identify where a large gap between the computed and the historical consumption could come from and facilitate the debugging of the Calculator.

Figure 9: Daily food intake per capita per food group



4.2 Production and trade

Worksheet(s) in the FABLE Calculator:

⇒ PRODUCTION

⇒ TRADE

⇒ 5_feas_livestock

⇒ 6_feascrops

The main indicator related to production is the total production value of the agricultural sector in local currency and US dollars in 2000. Prices are not generated by the FABLE Calculator. Historical producer prices from FAOSTAT are currently used to compute future production value. With constant prices over time, variation of the total production value over time is only caused by changes in the production quantities and changes in the share of products of different prices in the total production (composition effect). Targeted, feasible, and historical production values are displayed on the figure.

The main indicator related to trade is the net trade balance of the agricultural sector. It is computed as the sum of all exported quantities times historical export prices minus the sum of all imported quantities times historical import prices. It generally does not match national statistics on the value of the agricultural trade balance; it includes more processed products with usually higher unit price. This indicator is very coarse, but it still gives an idea of the evolution of the trade balance over time (i.e. if the agricultural trade balance deteriorates or improves). An agricultural trade deficit is not necessarily negative, but it can lead to a broader discussion about how the deficit is compensated by other the trade surplus in other sectors, increased debt, or increased foreign investment in a given country.

4.3 Land

Worksheet(s) in the FABLE Calculator:

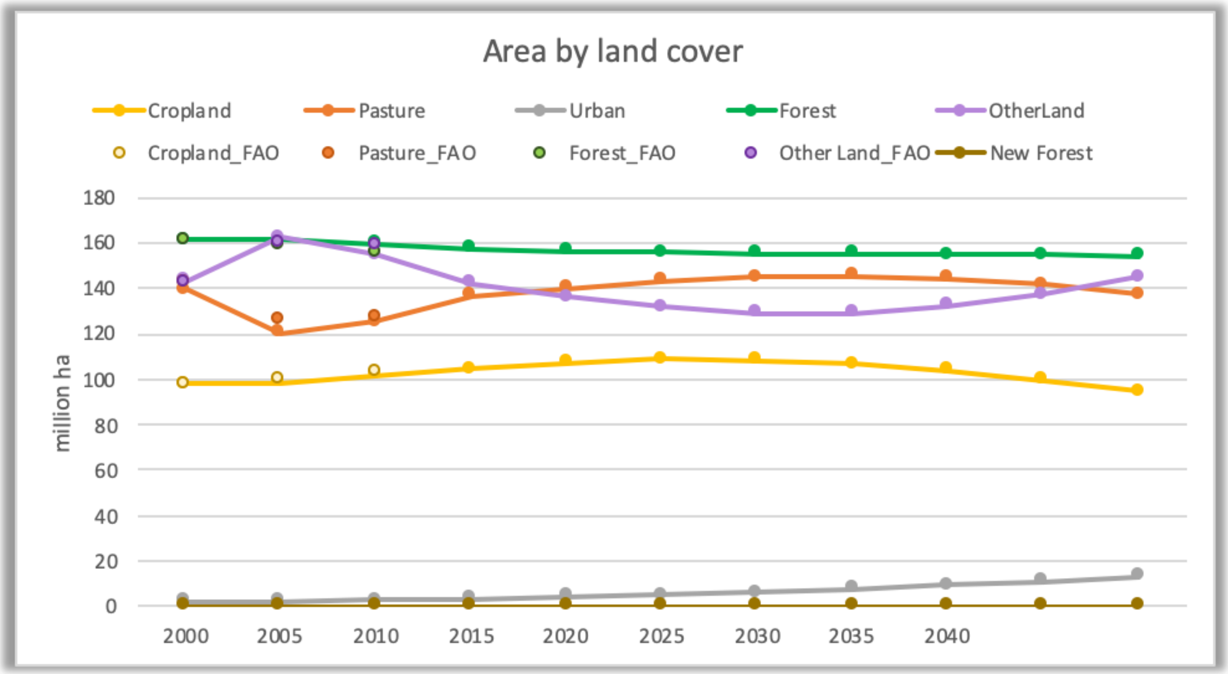
⇒ LAND

⇒ 4_calc_land

Our main indicator related to land is the evolution of the area of each land cover type (Figure 10). It shows the feasible area in each land cover class (cf. Land) and the historical data. FAOSTAT is used as the default reference. The objective is to mimic the historical evolution of land as closely as possible. Discrepancies highlight some potential problems in the FABLE Calculator. Such problems are for instance related to the evolution of the different demand components. Currently, the FABLE Calculator only includes a limited set of products in the animal feed requirements (i.e. the feed demand for some products is not represented, leading to an underestimation of the total demand for these products). For human demand and trade, estimates should be very close to the FAO values as historical data has been used to initialize key parameters (cf. Human demand, Trade). Another known problem is related to the non-food demand and, in particular, the biofuels demand. In fact, during the processing of oilseeds or corn to produce biodiesel or bioethanol, some by-products are produced. These could be used in animal feed, potentially substituting other crops and feedstock. This only leads to significant bias on historical land-use estimates in countries where ambitious biofuel targets were put in place during the period 2000-2010.

Two other figures are displayed in the LAND worksheet: land use change by 5 year-time step and the historical, targeted, and feasible harvested area and the historical, targeted, and feasible production quantity by crop.

Figure 10: Area by land cover



4.4 GHG

Worksheet(s) in the FABLE Calculator:

⇒ *GHG*

⇒ *8_calc_emissions*

⇒ *8_data_emissions*

4.4.1 GHG from Crops

There are three sources of emissions related to crop cultivation in the FABLE Calculator: methane emissions from rice cultivation, nitrogen emissions from synthetic fertilizers, and emissions related to energy use in crop fields. Emission factors are computed based on, or taken directly from, FAOSTAT for the year 2010. For rice cultivation, the emission factor is country specific and is expressed in tCO2e/ha harvested rice. Total emissions are computed as the total harvested rice area (cf. Crops and Feasible production) times the emission factor per hectare. For emissions from fertilizer use, without detailed data on fertilizer use per crop, we compute the emission factor as total emissions from fertilizer use divided by total harvested area (i.e. the same emission factor per hectare for all the crops). Finally, the emission factor for energy use for crops is also not specific by crop because of the lack of more detailed information on the energy use by crop in the FAOSTAT database. We have three emission factors for energy: one for methane emissions, one for nitrogen emissions, and one for carbon emissions, but all are expressed in tCO2e per ha harvested area.

4.4.2 GHG from Livestock

There are two sources of emissions related to livestock production in the FABLE Calculator: methane emissions from ruminant enteric fermentation and methane and nitrogen emissions from manure. Emission factors per TLU per animal and production system come from the Herrero et al. (2014) database which has been calibrated on FAOSTAT for the year 2000. Total emissions are computed by multiplying the emission factor by TLU with the total herd in 1000 TLU per animal type and production system (cf. Herd and Feasible production).

4.4.3 GHG from Land

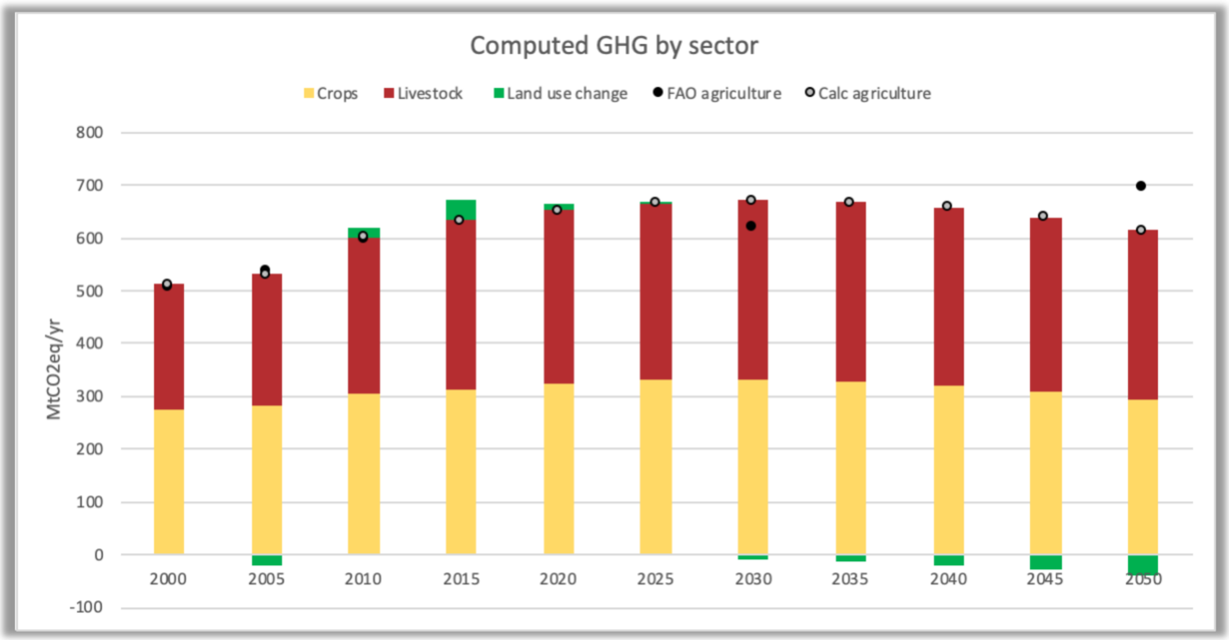
There are two sources of carbon sequestration and three sources of emissions from land use and land-use change in the FABLE Calculator: carbon sequestration in afforested land and in abandoned agricultural land, emissions due to the expansion of cropland, pasture and urban areas into forests and other natural land. There is also an optional feature for computing emissions from peatland drainage (cf. Appendix 5).

Emissions from land-use change are computed based on the land-use change matrix of each time-step as the number of hectares of forest and other natural land which have been converted to cropland, to pasture, and to urban areas, multiplied by the emission factor which depends on the land-cover class which is converted and the land cover class which expands. Land-use change emission factors are computed as the difference between the carbon stock per hectare in the initial land cover and the carbon stock per hectare of the land cover class at the end of the period. In the FABLE Calculator, emissions from land-use change include conversion of forests and other natural land to cropland, pasture, and urban area. The FAOSTAT database only provides carbon stock of forest land. Carbon stock in other natural land is assumed to be 30% of the forest carbon stock, carbon stock in pastureland 10% of forest carbon stock, and cropland 5%. Carbon stock in urban areas is assumed to be null. These are very rough assumptions and each user is strongly encouraged to replace these assumptions by statistics on average carbon stock by land-cover class based on domestic biomass measurements.

Carbon sequestration in afforested land is computed as the cumulative afforested land since 2000 and the sequestration rate is computed as the initial forest carbon stock divided by 50. This is also a rough assumption which implies linear growth of biomass and a 50 year period to reconstitute forest biomass. Carbon sequestration in abandoned agricultural land is assumed to be passive (i.e. without human action), which is why we assume a slower rate of carbon sequestration than on afforested land as we compute the annual sequestration rate by dividing the forest carbon stock by 80 instead of 50 for afforested land. Sequestration through passive regeneration is computed as the cumulative abandoned cropland and pasture times the sequestration rate.

In the GHG worksheet of the Calculator, GHG emissions are expressed in MtCO2e per year per 5-year time-step (Figure 11). GHG emissions are grouped into 3 categories: emissions from crops, emissions from livestock, and net emissions from land-use change. Total emissions from the year 2000 cannot be directly compared with the other time-steps as it does not include emissions from land-use change. Historical emissions from agriculture (crops and livestock) and projected emissions from agriculture according to FAOSTAT are also displayed for comparison. Historical emissions from land-use change according to FAOSTAT are not displayed as they are not directly comparable with emissions from land-use change computed in the Calculator.

Figure 11: GHG emissions from agriculture and land use change



4.5 Biodiversity

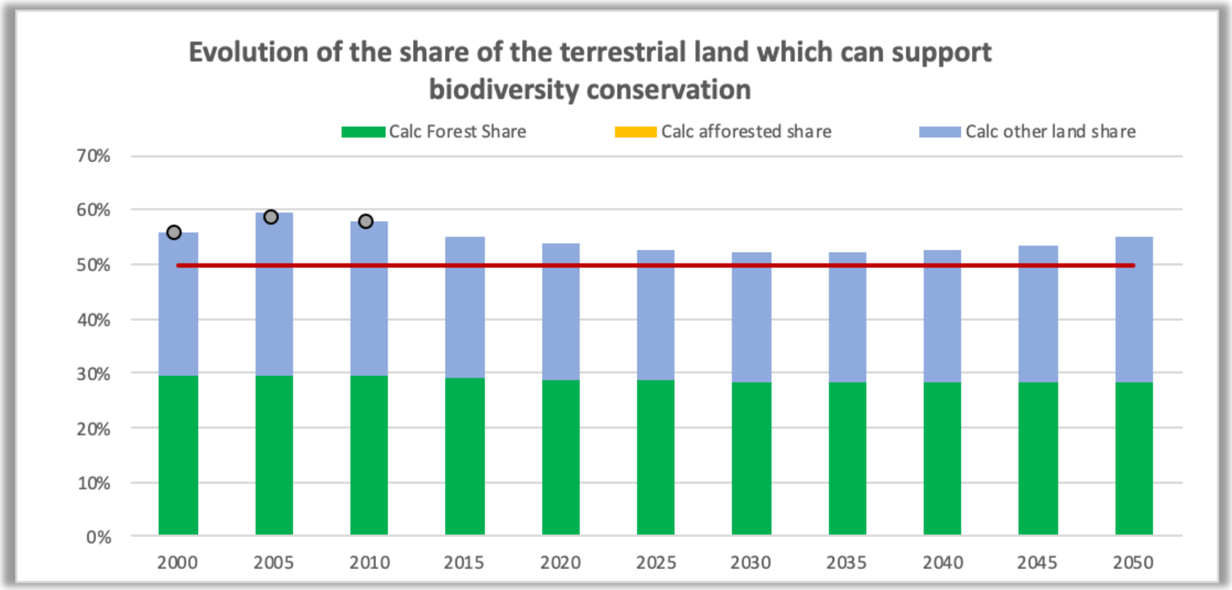
Worksheet(s) in the FABLE Calculator:

⇒ *BIODIVERSITY*

⇒ *4_calc_land*

The main indicator related to biodiversity is the share of the total land which could support biodiversity conservation (Figure 12). This indicator is the proportion of total land which is covered by forest, non-agricultural, and non-urban land areas to the country or region's total land area. It includes new forest as well as land converted from other uses. By default, the target is set at 50% share of total land area (cf. FABLE targets).

Figure 12: Share of total land which could support biodiversity conservation



5 Conclusion

The FABLE Calculator is a recent tool which has been developed over the past two years (2018-2019). It has been used to produce pathways at a country level and for the rest of the world regions, as described in the recently published in the FABLE 2019 Report (FABLE, 2019). Thanks to the scrutiny of the FABLE country teams and the FABLE Secretariat, and through several iterations of the Scenathon, many bugs and mistakes were discovered and removed. However, we are conscious that mistakes may remain and that there is room for further improvement. All users are welcome to report problems and suggestions for improvements to the forum dedicated to the FABLE Calculator or by email to info.fable@unsdsn.org. You can also visit the FABLE page on the FOLU website for more information on the FABLE Consortium, as well as the FABLE Calculator training website where you can find more training materials and the latest updates of the Calculator.

The version of the FABLE Calculator which has been made freely and publicly available has been developed for “Rest of Asia”, one of the rest of the world FABLE regions. Specific country calculators have already been produced for: Argentina, Australia, Brazil, Cameroon, Canada, China, Colombia, Ethiopia, Finland, India, Indonesia, Malaysia, Mexico, New Zealand, Russia, Rwanda, South Africa, Sweden, the UK, and the USA. If you would like to adapt the tool to your country, or another jurisdiction, you only need to replace the input and scenario data which is listed in Appendix 4 and in the worksheet called “Index Tables” in the FABLE Calculator. However, we acknowledge that this documentation does not provide sufficient guidance on scenario construction or how the calculator could be adapted to individual country/user contexts. There is also limited explanation on key formulas and their construction. A more technical documentation with “hands-on” exercises is under development in addition to a more user-friendly version of the FABLE Calculator. We welcome any feedback and/or collaborations to help us to move in this direction.

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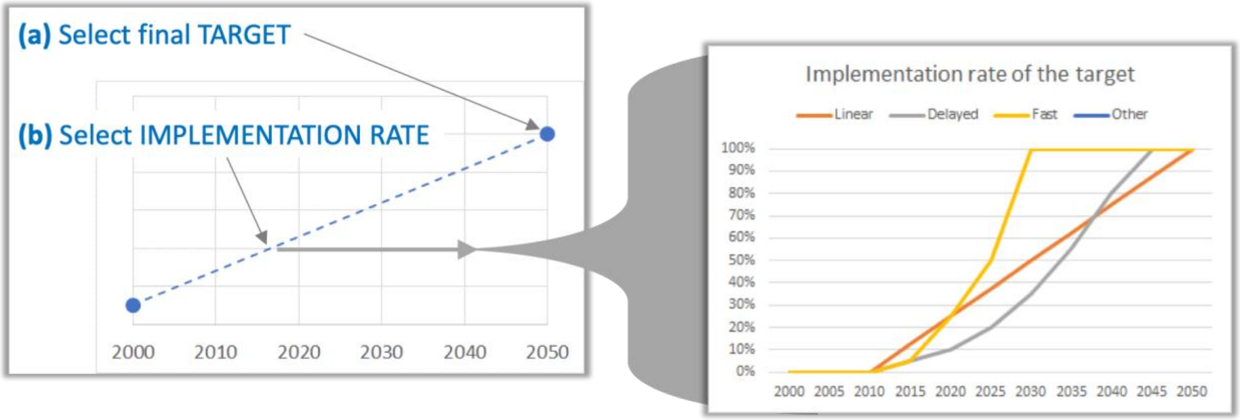
Appendix 1: List of products and product mappings

Broad group	Food group	Products	Production computed	Demand computed
crop	OTHER	abaca	YES	YES
crop	FRUVEG	apple	YES	YES
crop	FRUVEG	banana	YES	YES
crop	CEREALS	barley	YES	YES
crop	PULSES	beans	YES	YES
crop	ROOTS	cassava	YES	YES
crop	CEREALS	cereal_other	YES	YES
crop	FRUVEG	citrus_other	YES	YES
crop	OTHER	clove	YES	YES
crop	OTHER	cocoa	YES	YES
crop	FRUVEG	coconut	YES	YES
crop	OTHER	coffee	YES	YES
crop	CEREALS	corn	YES	YES
crop	OSDVOL	cotton	YES	YES
crop	FRUVEG	date	YES*	YES
crop	FRUVEG	fruit_other	YES	YES
crop	FRUVEG	grape	YES	YES
crop	FRUVEG	grapefruit	YES	YES
crop	PULSES	groundnut	YES	YES
crop	OTHER	jute	YES	YES
crop	FRUVEG	lemon	YES	YES
crop	CEREALS	millet	YES	YES
crop	OTHER	nuts	YES	YES
crop	CEREALS	oats	YES	YES
crop	OSDVOL	oilpalmfruit	YES	YES
crop	OSDVOL	oilseed_other	YES	YES
crop	OSDVOL	olive	YES	YES
crop	FRUVEG	onion	YES*	YES
crop	FRUVEG	orange	YES	YES
crop	PULSES	peas	YES	YES
crop	OTHER	pepper	YES	YES
crop	OTHER	piment	YES	YES
crop	FRUVEG	pinapple	YES	YES
crop	FRUVEG	plantain	YES	YES
crop	ROOTS	potato	YES	YES
crop	PULSES	pulses_other	YES	YES
crop	OSDVOL	rapeseed	YES	YES
crop	CEREALS	rice	YES	YES
crop	OTHER	rubber	YES	YES
crop	CEREALS	rye	YES	YES
crop	OSDVOL	sesame	YES	YES
crop	OTHER	sisal	YES	YES
crop	CEREALS	sorghum	YES	YES
crop	PULSES	soyabean	YES	YES
crop	OTHER	spices_other	YES*	YES
crop	SUGAR	sugarbeet	YES	YES
crop	SUGAR	sugarcane	YES	YES
crop	OSDVOL	sunflower	YES	YES
crop	ROOTS	sweet_potato	YES	YES
crop	OTHER	tea	YES	YES
crop	OTHER	tobacco	YES	YES
crop	FRUVEG	tomato	YES	YES
crop	ROOTS	tuber_other	YES	YES
crop	FRUVEG	vegetable_other	YES	YES
crop	CEREALS	wheat	YES	YES
crop	ROOTS	yams	YES	YES

Broad group	Food group	Products	Production computed	Demand computed
livestock	MGMEAT	chicken	YES	YES
livestock	PTEGGS	eggs	YES	YES
livestock	MGMEAT	meat_other	NO	YES
livestock	MILK	milk	YES	YES
livestock	RMMEAT	mutton_goat	YES	YES
livestock	MGMEAT	pork	YES	YES
livetsock	RMMEAT	beef	YES	YES
fish	FISH	fish	NO	YES
other	SUGAR	honey	NO	YES
processed crop	OSDVOL	soyoil	YES	YES
processed crop	OSDVOL	cocooil	YES	YES
processed crop	OTHER	cottcake	YES	NO
processed crop	OTHER	cottlint	YES	YES
processed crop	OSDVOL	cottoil	YES	YES
processed crop	OTHER	groundnutcake	YES	NO
processed crop	OSDVOL	groundnutoil	YES	YES
processed crop	OSDVOL	oliveoil	YES	YES
processed crop	OSDVOL	other_oil	YES	YES
processed crop	other	other_olscake	YES	NO
processed crop	OSDVOL	palm_oil	YES	YES
processed crop	other	palmkernelcake	YES	NO
processed crop	OSDVOL	palmkerneloil	YES	YES
processed crop	other	rapecake	YES	NO
processed crop	OSDVOL	rapeoil	YES	YES
processed crop	OSDVOL	sesamoil	YES	YES
processed crop	OTHER	soycake	YES	YES
processed crop	SUGAR	sugarraw	YES	YES
processed crop	OTHER	sunflcake	YES	NO
processed crop	OSDVOL	sunfloil	YES	YES

Appendix 2: Implementation rate of the scenarios

The implementation rate parameter is used to translate targeted values for 2050, as targeted values for each time step between 2015 and 2050. The implementation coefficient is the share of the difference between the current situation and the 2050 target that is assumed to be achieved in each time-step.



Year	Linear	Delayed	Fast
2000	0%	0%	0%
2005	0%	0%	0%
2010	0%	0%	0%
2015	13%	5%	5%
2020	25%	10%	25%
2025	38%	20%	50%
2030	50%	35%	100%
2035	63%	55%	100%
2040	75%	80%	100%
2045	88%	100%	100%
2050	100%	100%	100%

Appendix 3: Guidelines to use the FABLE Calculator

Conventions of the FABLE Calculator

Figure A3.1. Naming convention of the tables in the FABLE Calculator

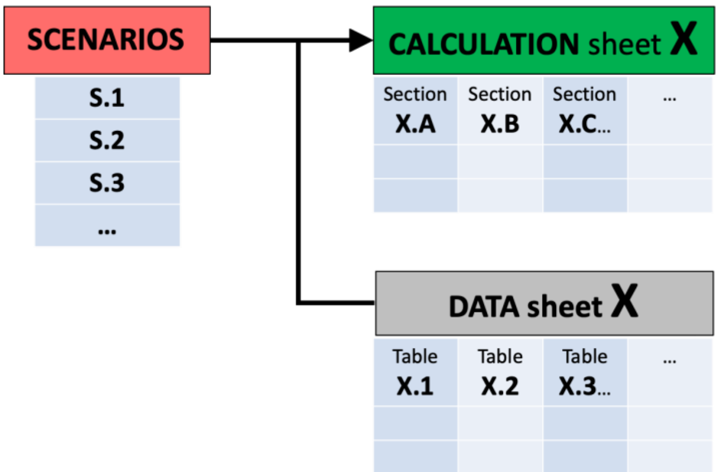
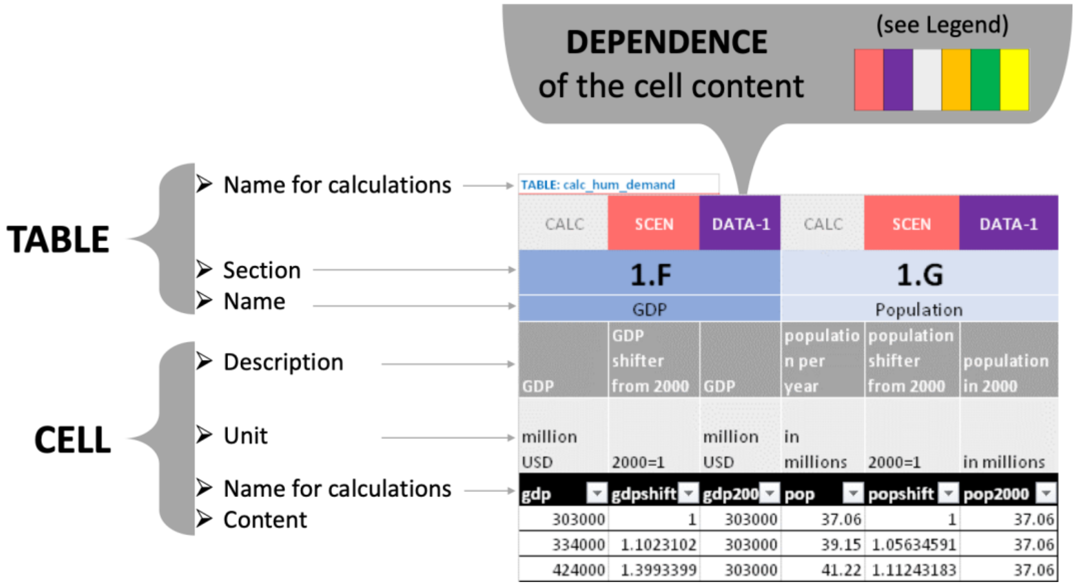


Figure A3.2. Legend for table columns

SCEN	The cell content depends on the selection of a SCENARIO.
DATA-n	The cell content is taken from a table in a DATA sheet (**n** indicates the number of the data sheet).
CALC	The cell content is calculated based on cells in the SAME sheet.
CHECK	The cell serves as data verification.
OUTPUT-n	The cell content represents an output result obtained within a table in a CALCULATION sheet (**n** indicates the number of calculation sheet).
DIRECT	The cell content is filled directly (and not linked to anything).

Figure A3.3. Information displayed in each table



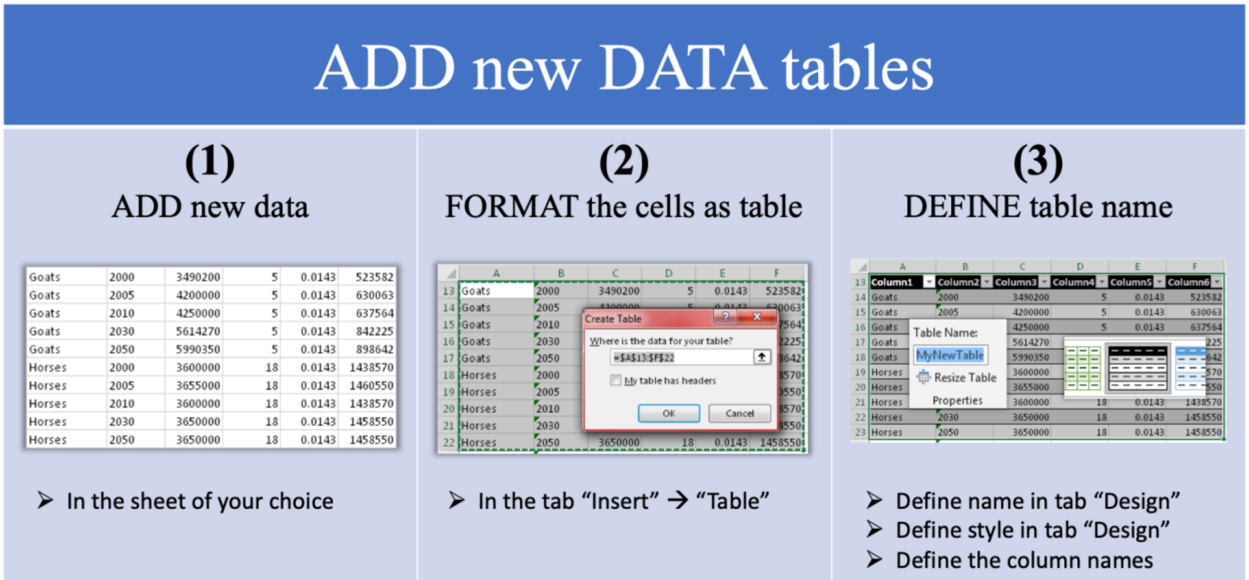
Most used Excel features and formulas

Each table is formatted as a table i.e. when you create a new table you have to select the table and click on "Format as a table" (cf. Figure A3.4). This is a nice feature in Excel which:

- gives a name to a table which can be directly used in calculations,
- recognizes automatically all columns' names which can be used in calculations as an attribute of the table name,
- the calculation entered in the first row is automatically copied to all the lines of the table in the same column.

There are several advantages of using this feature. It allows some kind of programming language in the formulas and it is easier to understand the formula when table names are self-explanatory. There is some tradeoff here between the length of a table name and the name being self-explanatory as a long table name will also increase the length of a formula and a long formula is harder to understand.

Figure A3.4. Format as table



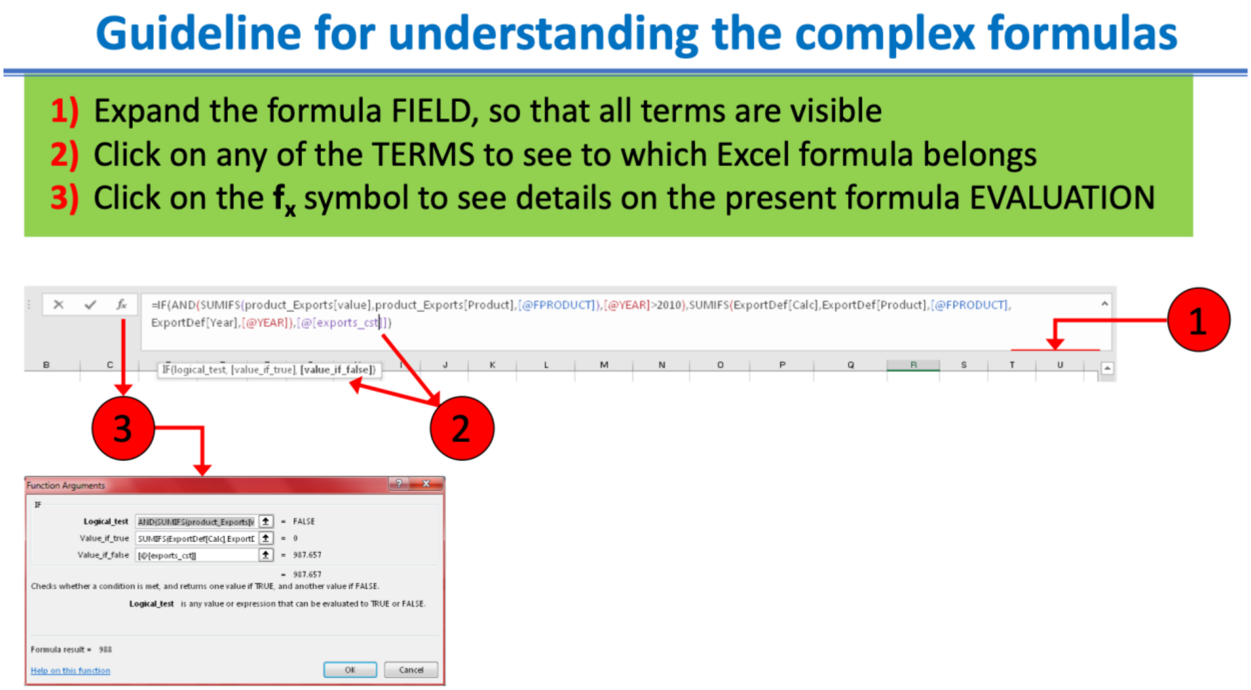
For instance, if you click on the cell AA28 in the worksheet 1_calc_hum_demand you see that the value of this cell is equal to the column "Pop_shift"of the table called "gdp_pop_hist" when the year is lower or equal than 2015, and to the column "pop_shift_2000" from the table GdpPopTarget when the year is higher than 2015 :
=IF([@year]<=2015,SUMIF(gdp_pop_hist[YEAR],[@year],gdp_pop_hist[POP_shift]),SUMIFS(GdpPopTarget[POP_shift_2000],GdpPopTarget[SCEN],[@[POP_scen]],GdpPopTarget[YEAR],[@year]))

You can easily find the table called gdp_pop_hist if you do an advanced search in the whole workbook looking for gdp_pop_hist in values. You will be directed to the cell where the name gdp_pop_hist appears which is at the top of the worksheet where the table is introduced, and above the table. Or you can go to the worksheet Index Tables and look for the table name in the first column. If you click on it, you will be also directed to the table.

The most used formulas in the FABLE Calculator are:

- **IF** - e.g. in the table called calc_hum_demand, in the column popshift (calc_hum_demand[popshift]).
- **IFERROR** - e.g. in calc_crops[PlantArea]
- **AND** - e.g. in calc_livestocknb[FinalExports]
- **SUMIF** - e.g. in calc_hum_demand[popshift])
- **SUMIFS** - e.g. in calc_hum_demand[popshift])
- **VLOOKUP** - e.g. in calc_crops[Crop_scen]
- **OFFSET** - e.g. in calc_land_cor[Initpasture]

We encourage users who are not yet familiar with these formulas to look at the help within Excel and explanations in several forums and online Excel tutorials.



Documentation of the changes

It is good practice to document your changes in the Change Log worksheet: it is useful for the user itself because we tend to forget quickly, especially if we carry several projects at the same time, and when different people work on the same tool. We recommend that the FABLE Calculator is saved under different version names after a change or a series of changes are implemented.

Appendix 4: List of tables in the FABLE Calculator

By alphabetical order

Table name	Table number	Table Description
AfforScenDef	**S.10.b**	***Scenario*** - Afforested target by land cover by year
AfforTarget	**S.10.a**	***Scenario*** - Total afforested/reforested area target and by land cover by 2050
Calc_cropemis	**8.C**	***Result indicator*** - Emissions from crop cultivation
Calc_crops	**3.A to 3.C**	***Computation step*** - Targeted exports, production, processing,harvested and planted area by crop and by year
Calc_dmer_activitylevel	**1.F to 1.H**	***Result indicator*** - Total minimum calorie consumption per age class
Calc_FeasConsoHum	**7.A**	***Result indicator*** - Food consumption indicators by product and by year
Calc_FeasCrops	**6.A to 6.B**	***Computation step*** - Recomputation of crop production, exports, human demand, processing, based on feasible cropland area
Calc_FeasFeed	**5.B**	***Computation step*** - Recomputation of feed demand based on feasible cropland area and feasible herd
Calc_FeasProdLivestock	**5.C**	***Computation step*** - Recomputation of livestock production, exports and human consumption based on feasible herd
Calc_FeasRuminants	**5.A**	***Computation step*** - Recomputation of the ruminant livestock herd based on feasible pasture
Calc_feed	**2.E to 2.F**	***Computation step*** - Targeted feed consumption for animals
Calc_hum_demand	**1.A to 1.G**	***Computation step*** - Targeted human consumption

Calc_land_cor	**4.A to 4.I**	***Computation step*** - Initial area by land cover type at the beginning of the period, targeted and feasible area at the end of the period and area change by land cover type by period
Calc_landemis	**8.D**	***Result indicator*** - Emissions from land use change
Calc_livestocknb	**2.A to 2.C**	***Computation step*** - Targeted livestock production and herd
Calc_min_daily_kcal	**1.I**	***Result indicator*** - Minimum average calorie consumption per capita per day
Calc_monogemis	**8.B**	***Result indicator*** - Emissions from monogastric livestock
Calc_pasture	**2.G to 2.I**	***Computation step*** - Targeted livestock production and herd
Calc_rumemis	**8.A**	***Result indicator*** - Emissions from ruminant livestock
CalcHistLand	**4.6**	***Data*** -Historical land use change by land cover type
Chk_animproducts	**2.J**	***Check*** *- Compares computed demand, trade and production of animal products with historical data*
Chk_herd	**2.D**	***Check*** - Compares computed animal numbers with historical animal numbers
ChkCrops	**3.D to 3.E**	***Check*** - Compares estimated crop human demand, trade, feed demand, processing demand, production and harvested area with historical data from FAOSTAT
CropPdtyDef	**S.8.b**	***Scenario*** - Crop historical productivity shifter by crop and by year compared to 2000
CropPdtyTarget	**S.8.a**	***Scenario*** - Change in the crop historical annual productivity rate in 2050 compared to 2000-2010 for different crop productivity scenarios
Data_live	**2.1 to 2.3**	***Data*** - Weighted average of input-output data for livestock production systems for 2000 from Herrero et al. (2014)

Def_dmer	**S.13**	***Scenario*** - Minimum calorie requirement per capita per day by age, sex and activity level
DietImplRates	**S.3.b**	***Scenario*** - Implementation rates of targeted diets
DietScenDef	**S.3.d**	***Scenario***- Definition of shifters by food group to match targeted diets
DietTarget	**S.3.c**	***Scenario***- Definition of daily kilocalorie consumption per capita per food group by 2050
ESALandArea	**4.1**	***Data*** - Area by land cover class according to the ESA-CCI land cover map for 2000, 2005, 2010 and 2015
ExportDef	**S.6.c**	***Scenario*** - Exports quantity target for each time-step and for selected products
EXPScenTarget	**S.6.b**	***Scenario*** - Exports quantity target for 2050 for selected products
FAOAnimalMap	**2.7**	***Mapping*** - Correspondence between the FAOSTAT animal categories and the animal categories used in the FABLE Calculator
FAOAvgCropEF	**8.4**	***Data*** - Historical emission factors for synthetic fertilizer use and energy use in tCO2e per ha of cropland based on FAOSTAT
FAOCropEmis	**8.3**	***Data*** - Historical emission factors from crop residues, biomass burning and rice cultivation per crop from FAOSTAT
FAOCropPdty	**3.4**	***Data*** - Historical crop productivity growth based on FAOSTAT
FAOCropProd	**3.2**	***Data*** - Crop production, harvested area and yield for 2000, 2005 and 2010 from FAOSTAT
FAOheads	**2.6**	***Data*** - Historical number of heads per animal type in 2000, 2005 and 2010 from FAOSTAT
FAOLandArea	**4.3**	***Data*** - Historical data on area by land cover class in 2000, 2005 and 2010 from FAOSTAT

FAOLandCarbon	**8.5**	***Data*** - Historical average carbon stock in forests in 2000, 2005 and 2010 from FAOSTAT
FAOLiveEmis	**8.2**	***Data*** - Historical emissions from manure and enteric fermentation by animal type in 2000, 2005 and 2010
FAOLivePdty	**2.11**	***Data***- Historical livestock productivity in 2000, 2005 and 2010
FAOPrices	**1.5**	***Data*** - Historical producer prices in USD and local currency, export price and import price in USD by product in 2000, 2005 and 2010 from FAOSTAT
FAOTotalEmis	**8.1**	***Data*** - Historical total methane and nitrogen emissions in CO2e by source 2000, 2005 and 2010 and projections for 2030 and 2050 from FAOSTAT
FeedCropMap	**2.8**	***Mapping*** - Correspondence between the feed categories in Herrero et al. (2014) and in the FABLE Calculator
FinalTradeAdj	**S.12**	***Scenario***- Fixed imports and exports by product, by year
FLScenTarget	**S.4.a**	***Scenario*** - Alternative share of household final consumption which is wasted in 2050
Food_indic	**1.4**	***Data*** - Historical food security indicators: product calories, protein and fat content, and average annual food consumption per capita
FoodLossTarget	**S.4.b**	***Scenario*** - Alternative share of household final consumption which is wasted per year
FprodCount	**3.3**	***Mapping*** - Selection of the final product which is driving the land use - for each raw product, only one final product can be chosen to avoid double-counting
Gdp_pop_hist	**1.1**	***Data*** - Historical GDP and population by year between 2000 and 2016 from World Development Indicators for GDP and UN-DESA for population
GdpPopTarget	**S1 and S2**	***Scenario*** - Projections of GDP and population between 2015 and 2050 from the SSP database and UN-DESA

HansenForArea	**4.4**	***Data*** - Historical forest area and deforestation in 2000, 2005, 2010 and 2015 from Global Forest Watch
Herdcount	**2.9**	***Mapping*** - Choice of the main product by animal type and production system used to compute the animal number and avoid double-counting
ImplCoefOptions		***Scenario*** - Alternative rates of Implementation of the 2050 scenario by year
ImportDef	**S.5.c**	***Scenario*** - Share of the total consumption which is imported in each time-step for selected products
IMPScenTarget	**S.5.b**	***Scenario*** - Share of the total consumption which is imported in 2050 for selected products
Income_elas	**S.3**	***Scenario*** - Alternative consumption income elasticities by product group
LandCarbon	**8.6**	***Data*** - Estimation of the average carbon stock in each land cover class based on historical carbon stock in forests
LandScenTarget	**S.9**	***Scenario*** - Maximum area of cropland and grassland by year
LiveItemMap	**2.4**	***Mapping*** - Correspondence between items in Herrero et al. (2014) database and FABLE Calculator livestock items
LivePdtyDef	**S.7.b**	***Scenario*** - Livestock historical productivity shifter in 2050 compared to 2000
LivePdtyTarget	**S.7.a**	***Scenario*** - Change in the livestock historical annual productivity rate in 2050 compared to 2000-2010 for different livestock productivity scenarios
Map_fproduct_crop	**3.1**	***Mapping*** - Correspondence between final products and crop used as input and processing coefficient
Map_group	**1.3**	***Mapping*** - Correspondence between products and food groups
MapAnimal	**2.1**	***Mapping*** - Correspondence between livestock production systems, animal types and ruminants and description of livestock production systems

MapESALCAgg	**4.2**	***Mapping*** - Correspondence between the ESA-CCI land cover classes and the land cover classes used in the FABLE Calculator
MapFAOLCAgg	**4.5**	***Mapping*** - Correspondence between the FAOSTAT land cover classes and the land cover classes used in the FABLE Calculator
Prod_balance	**1.2**	***Data*** - Historical commodity balances - former supply and use account - in 2000, 2005, and 2010 from FAOSTAT
Product_Exports	**S.6.a**	***Scenario*** - List of products which are included in the export scenarios (the exported quantity remains constant across all export scenarios for the other commodities)
Product_impscen	**S.5.a**	***Scenario*** - List of products which are included in the import scenarios (the share of the demand which is imported remains constant across all import scenarios for the other commodities)
ProtectedAreas	**4.7**	***Data***- Forest area and other natural land area within protected areas in 2000 (land cover map GLC 2000 combined with WDPA)

Appendix 5: Optional features

Land cover map

Worksheet(s) in the FABLE Calculator:

⇒ LAND

⇒ 4_calc_land

⇒ 4_data_land

Release date: 8th October 2018

This package provides guidance on how to include new data on land cover in the Calculator and use this information instead of the by-default FAO land cover data. However, depending on the format of your data, you might need to do slight changes to the proposed formulas (e.g. if the data on land cover is not split between protected and not protected areas). It contains 23 changes.

Peatland

Worksheet(s) in the FABLE Calculator:

⇒ LAND

⇒ 4_calc_land

⇒ 4_data_land

Release: 20th February 2019

This package allows tracking peatland drainage because of conversion to agricultural land and associated emissions.

Ruminant density

Worksheet(s) in the FABLE Calculator:

⇒ Scenarios definition

⇒ Scenarios selection

⇒ 2_calc_livestock

⇒ 2_data_livestock

⇒ 5_feas_livestock

Release date: 19th November 2018

This package introduces the possibility to vary the ruminant density per hectare of pasture i.e. introduces a new leverage of productivity increase related to cattle and sheep and goats. It contains 24 changes.

Species loss indicator

Worksheet(s) in the FABLE Calculator:

⇒ BIODIVERSITY

⇒ calc_biodiversity

⇒ data_biodiversity

Release date: 19th November 2018

This package provides guidance on how to include the species loss indicator in the FABLE Calculator. It contains 24 changes.

Water footprint

Worksheet(s) in the FABLE Calculator:

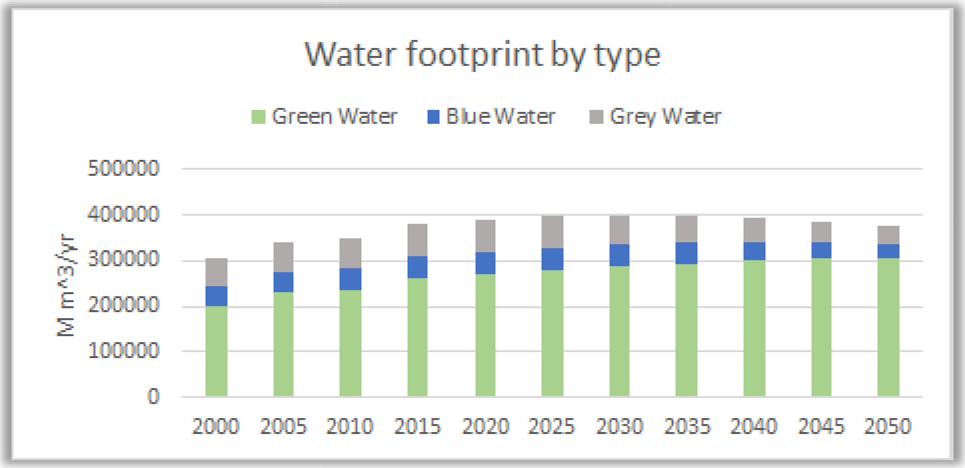
⇒ WATER

⇒ 9_calc_water

⇒ 9_data_water

Our indicator for water usage (SDG6) is water footprint[1]. Water footprint (WF) is the volume of water used to produce crops and livestock. In the Calculator, water footprint can be considered volume of water drawn from an annual budget, which is left up to the user to determine. The Calculator does not constrain the total volume of water used. WF is subdivided into three fractions: soil ("green") water, surface ("blue") water, and polluted ("grey") water.

Figure A5.1: Water footprint by fraction



1 See Hoekstra *et al.* (2011) for further details.

Comparison with GLOBIOM

Release date: 23rd May 2019

This package allows users to compare GLOBIOM results with Calculator’s results either in GAMS or in Excel. It contains 9 changes, grouped in 2 categories: (A) changes to the Calculator to allow the extraction of the main results to GAMS and (B) changes to the Calculator to allow the comparison of GLOBIOM results with the Calculator’s results in the Calculator.