The SUSFANS toolbox for assessing EU Sustainable food and nutrition security

Deliverable No. 9.5

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SUSFANS DELIVERABLES

The SUSFANS toolbox for assessing EU sustainable food and nutrition security provides a multidisciplinary instrument for analysing and monitoring SFNS in the EU, providing a set of mutually consistent indicators and signals for (un)sustainable food (in)secure situations.

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TABLE OF CONTENT

DELIVERABLE SHORT SUMMARY FOR USE IN MEDIA

This deliverable describes the conceptualization of the SUSFANS modelling toolbox. This is an advanced framework connecting 4 models that stand out in terms of their capacity to model:

- EU fish-agriculture markets, policies and environmental impact (CAPRI),
- EU and global environmental-economic systems (GLOBIOM)
- Economy-wide effects including endogenous income changes (MAGNET) to individual food intake data
- The diet optimization with consistent food groups for Czech Republic, Denmark, France and Italy built on these micro data (SHARP).

We explore the differences in diet patterns across socioeconomic groups by grouping the individual data into a more manageable 12 groups based on age (working versus retired), sex and three levels of education. Apart from capturing differences in diets, these groups are also relevant for understanding insight into the effects of diet interventions for inequalities in welfare. That is important for governments that aim to address inclusion in policy design ("leaving no-one behind").

When operationalizing the toolbox we balance various objectives:

- We develop the methodology with the purpose of quantifying food and nutrition-related metrics for the EU alongside the more common assessments of the economic and environmental performance of the food system.
- The toolbox also allows a forward-looking or hypothetical perspective on the average sustainability indicators of agriculture and food products (e.g. from the analysis of carbon emissions or land use during product life cycles); these can in principle be applied in search for optimal diets by the SHARP model. Expected changes in sustainability of food products, for example under scenarios of gradual or radical food system transformation, can thus be incorporated when searching for the most optimal direction to steer future diets.
- The population groups allow us in a rough way to assess income and food expenditure changes alongside each other. This provides a first glimpse of possible distributional consequences of future diets.

The SUSFANS toolbox linking models from different disciplines in thus provides an operational method to assess different options from government or industry to steer European diets and food systems in a healthier and more sustainable direction.

TEASER FOR SOCIAL MEDIA

The SUSFANS toolbox links models from different disciplines providing an operational method to assess different options from government or industry to steer European diets in a healthier and more sustainable direction.

The SUSFANS toolbox designed to help steer European diets and food systems in a healthier and more sustainable direction.

ABSTRACT

This deliverable describes the (i) conceptualization of the SUSFANS toolbox, (ii) a subnational population stratification capturing socioeconomic diversity from a diet and policy perspective and (iii) the operationalization of the macro-micro links in the SUSFANS toolbox.

The SUSFANS toolbox operationalizes the (input and output) linkages between global macro level economy-wide and agricultural sector models on the one hand, and individual level data on food intake in the EU. The model linking allows an up- and downscaling of information, providing consistent outcomes across the four dimensions of the SUSFANS metrics (balanced and sufficient diets, competitiveness of EU agro-food business, reduction of environmental impacts and equitable outcomes and conditions). Jointly these metrics signal if diets are more or less food secure and/or sustainable in a mutually consistent manner in the short, medium and long term, showing indicators that measure the food availability, access and utilization dimensions of FNS and indicators for the environmental, economic and health dimensions of sustainability of FNS in the EU.

A middle ground between individual intake data and national level concerns is found by stratifying the population in 12 groups based on age (working versus retirement groups, gender and three levels of education. The latter serves as a proxy for socio-economic status lacking more detailed information on income levels or sources. This stratification is relevant not only to capture differences in diet patterns but also to address concerns regarding the distributional consequences of diet interventions.

The choices made in the operationalization of the toolbox serve four main purposes: (i) quantifying future SUSFANS health and nutrition metrics; (ii) deriving sustainability indicators for SHARP that capture changes in the food system; (iii) imposing micro-based SHARP diets in macro models; (iv) provide a rough assessment of distributional implications of food system changes.

The SUSFANS toolbox enhances existing work in four major ways: (i) use of food intake data as opposed to food availability data for European countries; (ii) accounting for sub-national distributions in food intake across 12 population groups; (iii) relying on country-specific as opposed to generic food composition tables to assess nutritional content; and (iv) linking to models that stand out in terms of capacity to model EU agriculture and its policies (CAPRI), livestock systems (GLOBIOM) and economy-wide effects including endogenous income changes (MAGNET).

INTRODUCTION

SUSFANS focuses on assessing European diets from a sustainability and nutritional point of view using a set of metrics covering environment, competitiveness (economic viability), nutrition and to a limited extent equity (Zurek et al. 2017). The ambition of SUSFANS stretches beyond describing the current state of play by providing foresight on how changes in macro drivers in combination with actions of policy-makers and other incentive-makers affect European diets. The three macro models in the SUSFANS modelling toolbox (CAPRI, GLOBIOM and MAGNET) are regularly used for foresight exercises, most commonly focussed on the environmental and economic assessments. The key challenge addressed in this deliverable is bridging the gap between the macro and production-focussed representation of consumer demand in these three models and the micro detail allowing a nutritional assessment based on individual intake data and thus accounting for the diversity in what people actually eat and need.[1]

Several recent papers use a modelling approach to address connections between environment, nutrition security and health. Tilman and Clark (2014) assess the environmental and health dimensions of the income-driven global dietary transition towards processed foods and meats. Combining food life cycle analysis (LCA) data with historical data on drivers of dietary change and the association of diets and health, they project the environmental and health impacts of the growing and richer global population. They then compare these projections with the disease burden and environmental impacts of three alternative (observed) diets finding scope for increases in both health and environmental impact of food production. Springmann et al. (2016) use an agricultural sector model to assess the impact of climate change on average national per capita food availability. Combining changes in red meat, fruit and vegetables, and total calorie availability with a health modelling framework they then derive changes in major non-communicable disease burden from climate change. The net impact of reductions in red meat (positive), fruit and vegetables (negative) and reduced calorie availability (negative or positive, depending on the region) is found to be negative: climate change is expected to cause an additional half a million deaths by 2050. In contrast to the fixed impacts in the LCA-based analysis of Tilman and Clark (2014), their approach allows change in the agricultural production and thus environmental impact in response to climate and demand changes. This line of

[1] We thank the participants of the SUSFANS stakeholder core group meeting, 5-6 June 2018 in Badhoevedorp, Netherlands, for useful reflections and input on the consumer perspective in the modeling of food systems change.

reasoning is further explored in a study using the same modelling framework to assess the mitigation and health potential of selectively taxing emissions from food, exploiting the fact that meat and dairy have higher emissions while being less preferred from a health-perspective than fruit and vegetables (Springmann, Mason-D'Croz, Robinson, Wiebe, et al. 2016). Myers et al. (2017), reviewing a broad range of interconnected pathways through which climate change may affect future global food security, point to a critical limitation in these studies: the use of national availability data to assess nutrition impacts. Lacking better global data studies resort to using FAO estimates of food availability deduced from data on production and trade. These data do not capture actual intake of food, nor the distribution of intake across income and demographic groups. Furthermore, the nutritional content is computed on a limited set of incomplete and outdated regional food composition tables.

This deliverable describes the developments of the SUSFANS model toolbox in terms of linking three macro models to micro level food intake data for four European countries. These links are conceptually similar to the approach in the two papers of Springmann et al. (2016) by linking macro level simulations of the agro-food systems to diet changes, while enhancing existing work in four major ways: (i) use of food intake data as opposed to food availability data for European countries; (ii) accounting for sub-national distributions in food intake across 12 population groups; (iii) relying on country-specific as opposed to generic food composition tables to assess nutritional content in food intake; and (iv) linking to models that stand out in terms of capacity to model EU agriculture and its policies (CAPRI), livestock systems (GLOBIOM) and economy-wide effects including endogenous income changes (MAGNET). The connections between the macro models and micro data allow us to project changes in the SUSFANS metrics for "balanced and sufficient diets", thus permitting an assessment of future synergies and trade-offs between environment, profitability, nutrition and equity as envisaged in the design and progressive conceptualisation of the project (Rutten et al. 2018, Zurek et al. 2017).

The development of the toolbox connects different strands of SUFANS work. At the modelling side it establishes a connection between the newly developed SHARP model (WP7) and the macro models enhanced in earlier WP9 work packages (described in D9.2, D9.3 and D9.4). The design of the toolbox is furthermore critical to the operationalization of the health and nutrition metrics defined in the course of WP1 work. In the absence of the toolbox these metrics cannot be computed beyond the food intake survey years (varying between 2003 and 2008, depending on the country). In response to parallel work on diet scenarios in D10.3, additional links beyond the immediate needs for the metrics or connection to SHARP area added attempting to gauge sub-national distributional implications of food system changes. Looking ahead the toolbox contributes to the ongoing scenario work in WP10 and case study assessments in WP5 and policy analyses and discussions in WP11 by providing the means to assess food system changes from the health and nutrition side alongside the competitiveness, environment and equity metrics from the macro models. The toolbox also allows the imposition of results from the SHARP model developed in WP7 in the macro models (bottom-up link through the formulation of scenarios for demand or consumption) while feeding the sustainability implications (i.e. changes in the environmental performance of the food system and related LCA indicators) back into the diet modeling in SHARP. This enhances the scope of SHARP to determine optimal diets from a sustainability point of view, accounting for future changes in environmental indicators in the food system due to business as usual developments (as defined by the SUSFANS contextual scenarios) or due to the imposition of SHARP diets on top of these developments.

The deliverable is divided in three main parts. First, in section 2, we extend the conceptual model of the SUSFANS toolbox (Rutten et al. 2016). We establish the required relations and steps in the connection between the various models and thus conceptualise the quantification in SUSFANS metrics of the food system. Section 3 develops a stratification of the population building on earlier findings regarding the socioeconomic diversity of diets, limited longitudinal evidence on changes in diets and policy objectives or concerns regarding distributional implications of food system changes. In section 4 we describe in detail the operationalization of the SUSFANS toolbox. We conclude by outlining the limitations of the current toolbox and identify promising directions for future research.

CONCEPTUAL FRAMEWORK FOR LINKING MACRO AND MICRO DIET ASSESSMENTS

Figure 1 outlines the conceptual framework used to develop a modelling toolbox to assess diets at macro and micro level. The left hand side summarizes what part of the supply chain is covered by each model highlighting the complementary strengths of each in light of assessing European diets, with a more detailed description of coverage of diets from the production side (availability) or consumption side (intake at national or individual level).
The right hand side summarizes external inputs that affect the assessments of the models: the drivers for the macro models (as defined in D10.1) and LCA sustainability data at FoodEx level for SHARP. The macro drivers play a pivotal role in projecting towards 2050 from the observed data. The light green boxes indicate the toolbox parts affected by these drivers. The critical observation here is that there is no direct connection between SHARP and the long run macro drivers.

The top part indicates which models can contribute to each of the four quadrants in the SUSFANS spider diagram (defined in D1.5). The three macro models can all feed (part of the) metrics on environment, profitability and equity. The challenge here is to get a clear approach to handling multiple suppliers of the same metric. The nutrition metrics as defined in WP1 can only be computed from the FoodEx data. The absence of a direct connection between drivers and SHARP, however, implies that no projections of the nutrition quadrant can be made unless a link between the macro models and SHARP database is established. The series of boxes at the bottom of Figure 1 suggest two alternative approaches to establish a macro-micro connection on diets.

The route through the light green boxes follows the same approach as already implemented for the GENuS nutrition module in MAGNET (described in D9.2). It maps the MAGNET food commodities (covering both primary and processed foods) to FoodEx commodities. This mapping is then used to translate changes in demand from MAGNET (from 2011 to 2050 expressed in percentage change) to changes in the FoodEx intake thus creating a 2050 version FoodEx intake database. One key challenge is that such an update of individual intake data may result in an national level change which is inconsistent with the MAGNET results if the demographic composition changes from 2011 to 2050 and diets differ by demographic group. Since this approach can rely on the already developed approach for the GENuS data it can be realized relatively quickly to populate the nutrition quadrant in the spider diagram by scenario.

This first route, however, does not allow transmission of sustainability indicators linked to primary production. Such a connection can be established if the FoodEx items are translated into (model specific) primary equivalents. Such an approach is already used in connecting the FoodEx data with LCA data to determine the sustainability indicators by food item as needed by the SHARP model (D7.2). In setting up the SHARP database a choice was made for external LCA data to get as much detail as possible for the processed commodities not covered by CAPRI nor GLOBIOM. Although enriching the SHARP database, it does not provide an obvious connection to changes in sustainability indicators from the macro models. Challenges in developing this route lay with computing the primary equivalents through recipes for processed foods (building on D7.2 work).

Comparing these numbers at national level with the production side would yield for the four case study countries an interesting view on how the availability (production side) and intake (consumption side) data relate to each other.
The second step would be to associate sustainability indicators with the availability of each primary product which would allow passing changes in sustainability indicators to the SHARP database. Here there is similar challenge as with the population changes. The diet in terms of primary products from the macro models will change in each model run and then needs to be translated in a change in more detailed FoodEx items in a consistent way. This will require an allocation mechanism of primary commodities over FoodEx items since processed foods use multiple primary foods (in fixed ratios defined by the recipes). A second challenge would be to combine the changes in the sustainability indicators with the LCA based calculated indicators, or one could opt for keeping them in separate sets and run the SHARP model with both sets of sustainability indicators.

Note that Figure 1 outlines separate links from each macro model to the FoodEx database. This would thus result in three alternative representations of future diets at FoodEx level since each macro model has a different response to the (harmonized) macro drivers which are not easily consolidated[2]. This set of alternative FoodEx databases can be interpreted as variation or sensitivity of calculated future diets to different modeling assumptions.

[2] Understanding different model responses to harmonized drivers is rather challenging given the complexity of the models involved. All three macro models are part of the Agricultural Model Intercomparison and Improvement Project aiming for such an understanding, see http://www.agmip.org/ for more details.

Figure 1: Conceptual framework for linking macro and micro diet assessments

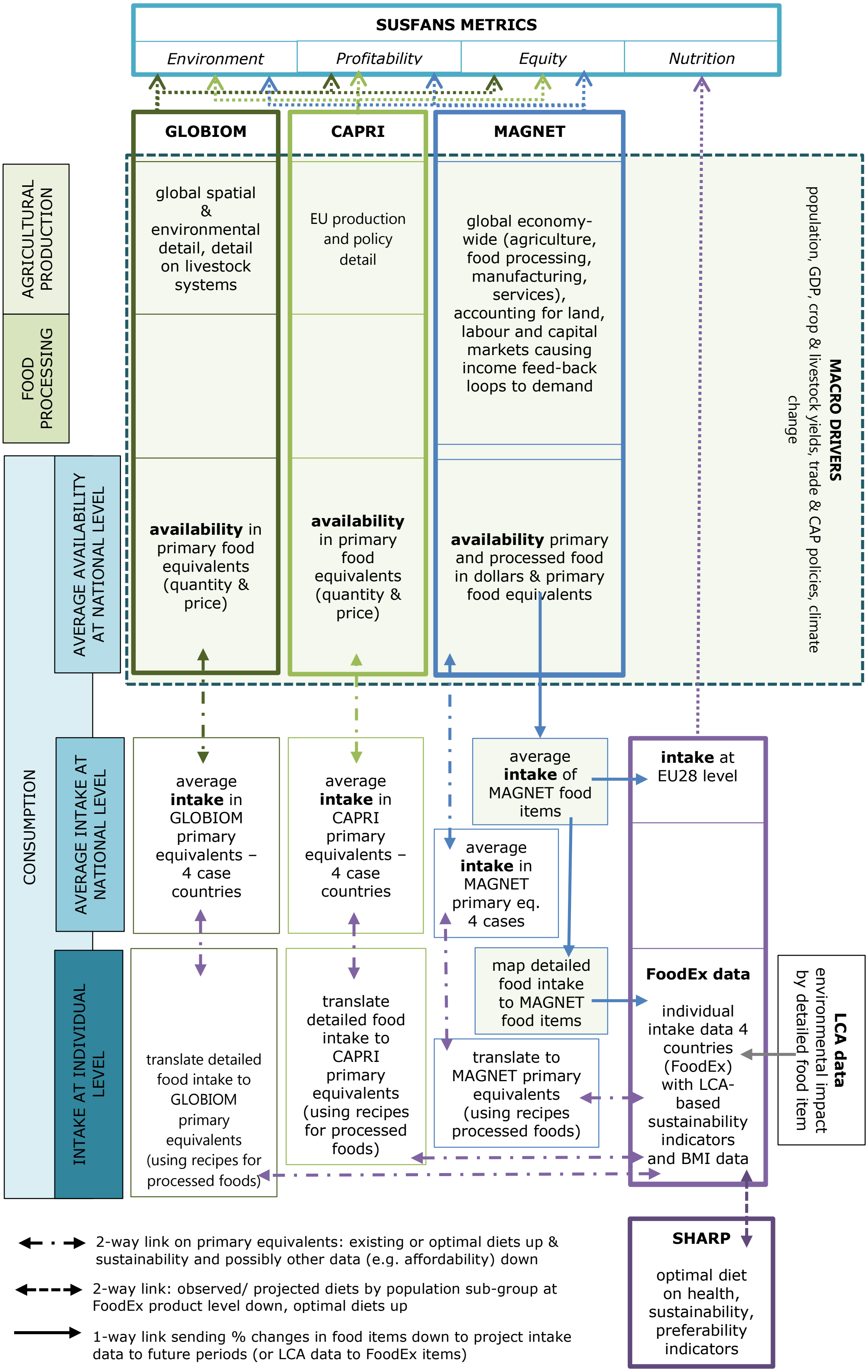


Figure 2: Capturing changing diets and food systems with the model toolbox in the SUSFANS policy and foresight exercises

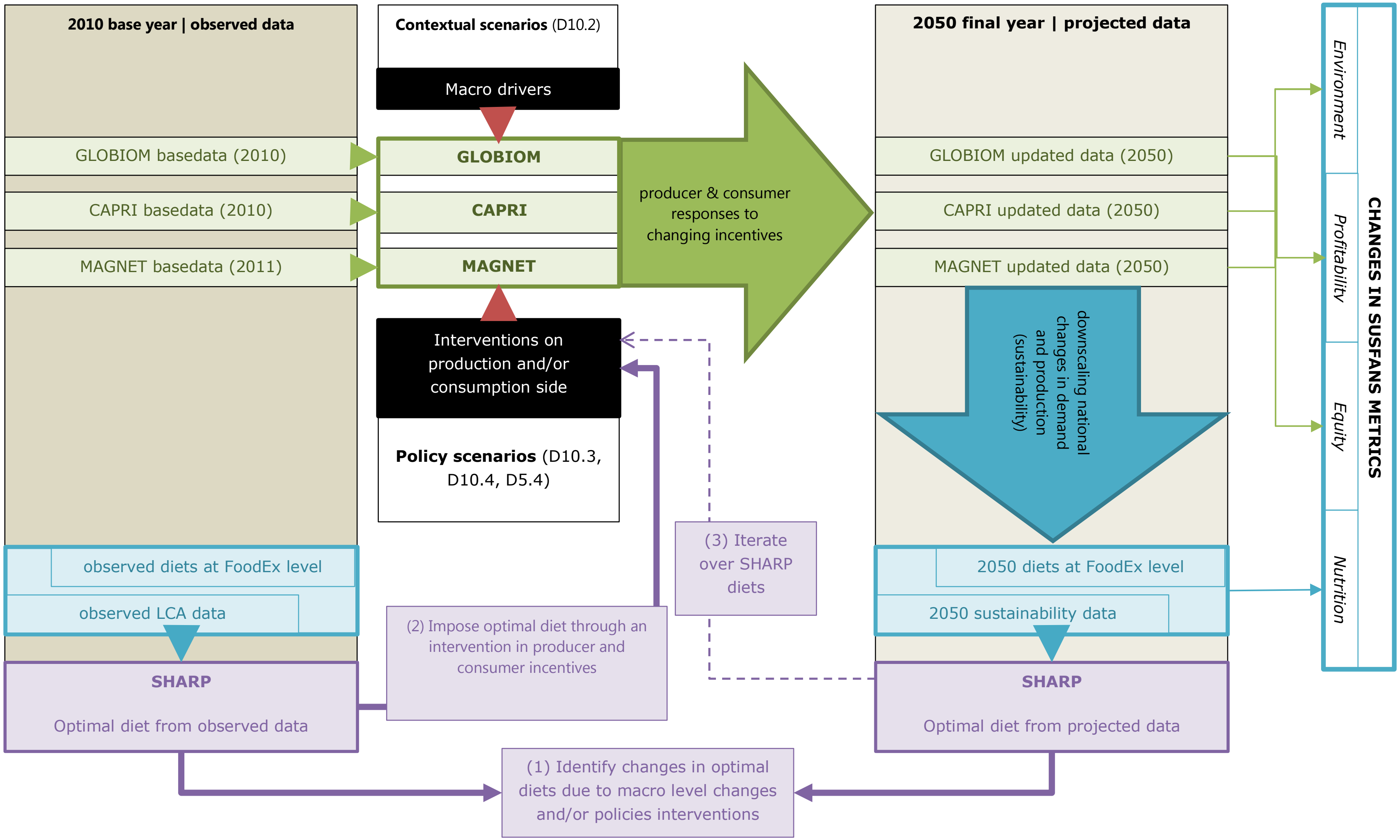


Figure 1 does not make the time dimension in projections explicit, nor the different paradigms driving the choice of diets at macro and micro level. Figure 2 therefore zooms in changing in diets and food systems over time.
The three macro models are calibrated on observed data for the base year set at 2010 for the SUSFANS simulations[3]. Using projections of macro drivers like GDP, population (including demographic composition in terms of age and sex as well as education) and technical change in crop and livestock production (defined in D10.1), each model updates its database to represent the food system in 2050, the final year of the SUSFANS scenarios. To explore the sensitivity to the underlying assumptions three different contextual scenarios are run, as well as decomposition scenarios only altering one driver to disentangle the impact of each driver (reported in D10.2).

The scenarios are evaluated in terms of the SUSFANS metrics, of which the environment, profitability and equity metrics can be covered by the macro models. As stated above the nutrition metrics as defined in WP1 can only be computed from the FoodEx data and therefore it is necessary to establish a link between FoodEx and the macro models. Using either the simple but rough approach used for the MAGNET GENuS module (solid lines in Figure 1), or a more elaborate linking through primary products (dashed lines in Figure 1), the FoodEx data can be projected to 2050 allowing the computation of the nutrition metrics. Using private household demand from the macro models to update the FoodEx database ensures a consistent set of drivers for all SUSFANS metrics.
The 2050 FoodEx database can be used as input for running the SHARP model in 2050. In addition to an update of the observed diets this is likely to also require an update of the sustainability indicators associated with each FoodEx product. For example GHG emissions will change due to changes in production levels and technologies in between 2010 and 2050. Thus in order to run SHARP for 2050 relevant changes in the production systems need to be downscaled to the sustainability indicators used by SHARP.

The purple boxes highlight different options for connecting between the macro models and SHARP. Option 1 is a top-down approach (from macro models to SHARP) with no feedback from SHARP to the macro models, exploring how changes in the food system alter the optimal diet according to SHARP. It relies on the downscaling of macro model results to FoodEx detail in terms of products and population details as well as sustainability characteristics of products. Note that even if the latter step is not made, the results from the SHARP model for 2050 will be different due to different “observed” demand patterns which define

[3] MAGNET actually starts from Version 9 of the GTAP database which represents the world economy in 2011.

the space in which SHARP searches for an optimal diet. In other words, if only the downscaling to FoodEx as needed for the metrics is achieved, relevant input for SHARP model is already generated.

Option 2 is to impose the optimal diet computed by SHARP from observed (2010) data in the macro models. This is a bottom-up approach exploring how the food system changes when a large scale change in diets occurs which may lead to undesirable outcomes not accounted for in the optimization with static/given diet and sustainability data used in SHARP. To implement this link we not only need to bridge a gap from micro to macro level, which amounts to a relatively straightforward aggregation, but also a different paradigm on consumer diets. SHARP optimizes diets from a health, sustainability and preferability perspective but so far does not account for relative prices nor incomes of consumers. The macro models on the other hand calibrate a demand system based on observed changes in consumer purchase decisions when prices and income change. Due to data limitations all non-price considerations are lumped together in price and income elasticities, see also the discussion on how the models capture consumer behaviour in D1.3. There is thus no obvious connection between the SHARP diets and the (endogenous) consumer demand in the macro models.

The bottom-up link from SHARP to the macro models thus requires an intermediate step defining the intervention in consumer and/or producer incentives to move towards the SHARP diets. There are various options available from a technical point of view like imposing the diet through (costless) taste-shifts ("a miracle occurs and everyone suddenly eats optimally"), taxes and/or subsidies either at producer or consumer level, or defining lower/upper bounds on purchases in which case final diets may still differ. While extreme scenarios like costless taste-shifts are easy to implement and useful for exploring the food system implications of a massive diet shift, they do underestimate the actual costs and possibilities of achieving the desired change in diets. A key challenge here is thus to define an intervention/policy which can be envisaged in the current socio-economic setting for example based on historical changes in diets (to gauge the speed and direction in which diets may change) or evidence on the costs and impacts of information campaigns, scope for (self) regulation by industry etc.

Finally, option 3 combines option 1 and 2 and is the most demanding and involves an iterative approach where SHARP is run on the outcomes of the macro models and a new policy/intervention is implemented if the optimal diet differs from the macro model results. There is nothing inherent in the combined modelling system to guarantee convergence to stable solution achieving the optimal diet, and the iteration may therefore spiral into an never-ending loop.

POPULATION SUB-GROUPS FOR EUROPEAN DIET ASSESSMENTS

An important contribution of the SUSFANS toolbox to existing work on assessing diets simultaneously from a nutritional and sustainability perspective is the use of (detailed) intake data as opposed to (FAO based) availability data used in for example Springmann et al. (2016) and in the GENuS nutrtition module added to MAGNET (D9.2). In addition the FoodEx intake data are available at individual level, capturing subnational diversity not available from the FAO national numbers.

The first section defines relevant population subgroups based on the observed diversity analysed in WP7, scope for policy or other diet interventions in a forward looking framework as used in SUSFANS and maximizing the amount of data from the macro models when establishing the link to the micro level. The second section describes the diets by sub-group as observed and when extrapolated to 2010, the common starting point for the SUSFANS toolbox . The final section compares intake based national averages from FoodEx to the GENuS availability based data, highlighting the importance of working with intake data when assessing diets.

The SHARP FoodEx-based database provides individual level intake data given a perspective on the variability in diets across the populations not available from national level database like the often used FAOSTAT food balance sheets. To simplify both analysis and reporting of changes in diets we stratify the population in subgroups based on observed diversity, scope for targeted interventions and maximizing the scope for linking to the macro models.

Mertens et al. (2018) assess the socio-economic diversity in diets for the four SUSFANS case study countries based on four dimensions: age (working versus retirement age groups), gender, education and BMI.

Table 1 summarizes their findings. Gender is strongly correlated with eating habits in all four countries, followed by less strong associations for age and education. BMI has least explanatory power, is not part of the drivers in the models and there is no obvious way of tracking BMI in the projections given the level of aggregation in the macro models.

Table 1: Significant differences in eating pattern by subgroup

	Age				Gender				Education				BMI			
Fruit	D	C	I	F	D	C	I	F	D	C	I	-	-	-	-	-
Vegetables	D	-	-	F	D	C	I	F	D	C	-	-	D	-	I	F
Legumes	D	-	-	F	D	C	-	-	D	-	-	F	-	-	-	-
Red & processed meat	D	-	I	-	D	C	I	F	D	C	-	F	-	C	-	F
Alcohol	D	C	I	F	D	C	I	F	-	-	I	-	-	-	I	F

Note: significant (p value <0.05) differences by country, D= Denmark, C = Czech Republic; I = Italy and F= France; - denotes an insignificant difference; derived from Table 3 in Mertens et al. (2017).

Given the forward looking analyses in SUSFANS ideally we would substantiate the population stratification with longitudinal studies of factors associated with diet choices that are stable over time. Few longitudinal diet studies, however, exist (Arabshahi et al. 2011). Most studies are based on cross-section data as in the FoodEx data used in SUSFANS, making it hard to work out the importance of population characteristics for the rate of change in diets over time. The existing literature therefore does not provide a clear answer on how to stratify the population in a stable manner over time.

While Popkin (2006) provides an elaborate overview of changes in diets and associated drivers but offers few clues on stratifying the population. While obesity is universal across rural and urban location (a dimension not captured in our classification), in high income countries like the SUSFANS countries overweight is more prevalent for women with a low-socio economic status. Socio-economic status correlates with education levels which is part of the FoodEx dataset. National trends show adult obesity preceding child obesity, suggesting a link between generations over time. The FoodEx data, however, do not contain data on children therefore prevent inclusion of this intergenerational dimension. While income changes figure prominently in the global focussed analysis of Popkin (2006), these are less relevant in the European context than for currently low and middle income countries going through massive income and diet changes.

A study of four (mutually exclusive) mother-child cohorts each followed over a 6-7 year period in China shows that children move faster to a western diet than adults. The effect, however, is less strong for later cohorts living in a period when incomes are higher and western style food is both cheaper and more available (Dearth-Wesley et al. 2011). Although finding an age-related difference in speed of diet transition this seems less relevant for an European setting where the socio-economic situation is more stable than in China since the early 1990s.

More comparable to the European context is an Australian longitudinal study covering the 1992-2007 period by Arabshahi et al. (2011). They find an overall increase in dietary quality despite a decrease in cereals and overall food variety. The exception is a decrease of fruit intake for men as group, while younger men with a higher occupational level show a greater improvement in diet quality. Behaviour like physical activity levels and hormone replacement therapy of women are also found associated more improvements in diet quality. These findings support the use of gender and education (as proxy for occupation or socio-economic status) for stratification.

In terms of age the evidence is inconclusive: while the Australian longitudinal study found younger groups to be faster but a Minnesota study found the reverse (Arabshahi et al. 2011). Mertens et al. (2018) use two very broad age groups, working versus retirement age, thus ignoring variability in diet within the working population. This rough age distinctions resonates with a general observed trend in reduced intake and variety by elderly due to dietary restrictions, dental issues as well as negative social factors due to physical limitations and social isolation (Drewnowski and Shultz 2001).

Apart from observed differences in diets across population groups policy design and objectives may also be a reason to distinguish population subgroups. Existing reviews of European policies to promote healthy eating (Brambila-Macias et al. 2011; FAO 2017) only show targeting of children at schools, maternal education in low income European countries and targeting of people in the workplace. The FoodEx data only covers people of 18 and over, and none of the case study countries is low-income. The age group of 18 to 64 covers the working population, although we lack data in the FoodEx surveys on employment status. There this does not seem to be a compelling policy-design reason to further stratify the population. Given the potentially regressive character of food taxes or more generally the costs of a healthy diet in relation to the socio-economic status (see for example Darmon and Drewnowski 2015) maintaining a population sub-division including working versus retirement age and on education level help to enrich the population level results in terms of inclusiveness.

Looking ahead towards the potential economic benefits of an improved diet it also seems worthwhile to separate the working age from the retirement age population[4] since it would allow the development of a feedback mechanism from improved health and thus productivity into the economies labour endowments - while improved diets and health of retirees is a desirable goal in itself because of

[4] Note that the distinction is rather rough in not capturing country differences in retirement age nor the planned increases in retirement age following the increased life-expectancy.

increased wellbeing, in economic terms it only helps to reduce health expenditures but will not increase productivity of the working population. Developing the framework further towards health and productivity feedbacks is beyond the scope of SUSFANS, but having the age grouping already included improves the starting point for possible future work in this area.

OPERATIONALIZING THE TOOLBOX

So far we outlined the conceptual approach to the SUSFANS toolbox and developed a stratification of the population relevant from both a diet and a broader inclusiveness perspective within the boundaries of the available data. In order to operationalize the model linkages described in Figure 1 and Figure 2 several steps are needed in terms of post-processing model outputs to allow a meaningful connection. In the light of the ambition to include population group specific changes in incomes alongside the national level price changes the discussion below focuses on the link between MAGNET and SHARP. A key reason for this focus is the explicit modeling of various processed foods in MAGNET which comprise an important part of European diets. CAPRI and GLOBIOM model demand in terms of primary equivalents, and are less obvious candidates for projecting diet patterns. While links to CAPRI and GLOBIOM are less elaborate in terms of scope of variables that can be exchanged, but linkages in terms of primary products offer more detail including more details in terms of environmental indicators that can be exchanged.

We first detail steps needed to establish a top-down link, from MAGNET to SHARP, tackling differences in data sources, product definitions and time periods. We then shortly discuss how the nutrition and health metrics can now projected forward alongside the other SUSFANS metrics derived from the macro models. In this process we also highlight the option to analyze the scope for reformulation against the backdrop of changing diets over time. We then detail the additional steps needed to establish a link with the two agricultural sector models not explicitly modeling demand for processed foods, which will allow us to capture changes in the sustainability indicators due to food system changes. The toolbox has been designed to allow optimal diets identified by SHARP to be translated into diet changes suitable for imposition in the macro models. Once SHARP becomes operational the upward linkages can thus build on the experience gained in the top-down links translating macro scenarios to micro level diet changes. Finally, associated with parallel work on formulating diet scenarios from a policy instrument as well as nutritional perspective in D10.3, additional data on prices and incomes are also (roughly) translated to micro level to allow a first assessment of the sub-national distributional impacts of changes in the food system.

Top-down linking from MAGNET to SHARP

While conceptually outlining the links between the model already proved to be a challenge, underscored by the complexity of Figure 1 and Figure 2, operationalizing adds a next layer of complexity combining data from different sources and disciplines. Figure 3 condenses the step-by-step procedure in a matrix formed vertically by type of data (external input data (orange row), methodologies changing data (blue row) and resulting output files (green row)). Horizontally we define the different levels connected through the toolbox: national level with a global scope (first column), EU member state level (second column), socio-economic groups within EU member state level (Third column) and individual intake data (fourth column). A third dimension that we need to consider is time, with data sources having different reference years while we project forwards in SUSFANS from 2010 to 2050 in 10-yeat steps.

We start in the top-left corner with the global national level data in the MAGNET database marked by A (reference year 2011) and scenario drivers B (2010-2050) describing changes in exogenous parameters of the three macro models (thus assuring a consistent scenario implementation across the three macro models). While the macro models and thus most drivers operate at national level, the SUSFANS scenario database also include sub-national changes in demographic composition (see D10.1 for more detail). Using the MAGNET database and scenario drivers the MAGNET model describes how the global economy changes over time, including global food system adjustments.

The results of the MAGNET model are then processed[5], extracting results for the EU member states on which the downscaling in SUSFANS focuses. One result of these two methodological steps is a data file describing national level changes in household demand for food (results file 1, covering 2010-2050). The changes in demand are presented as an index normalized at 1 for 2010, and a mapping from 19 MAGNET food sectors to 955 FoodEx codes is made in the processing step. With these changes the MAGNET results are transformed to a format suitable for connection to the SHARP database.

We then shift attention to the last column in Figure 3, the individual intake data in the SHARP database (input file C). SUSFANS uses data from national level surveys in four countries, but these refer to different years: Czech Republic 2003-2004; Denmark 2005-2008; France 2006-2007; and Italy 2005-2006. The first step

[5] The processing includes a simple back-casting run to move the 2011 reference year to 2010 based on 2011 to 2010 GDP and population projections.

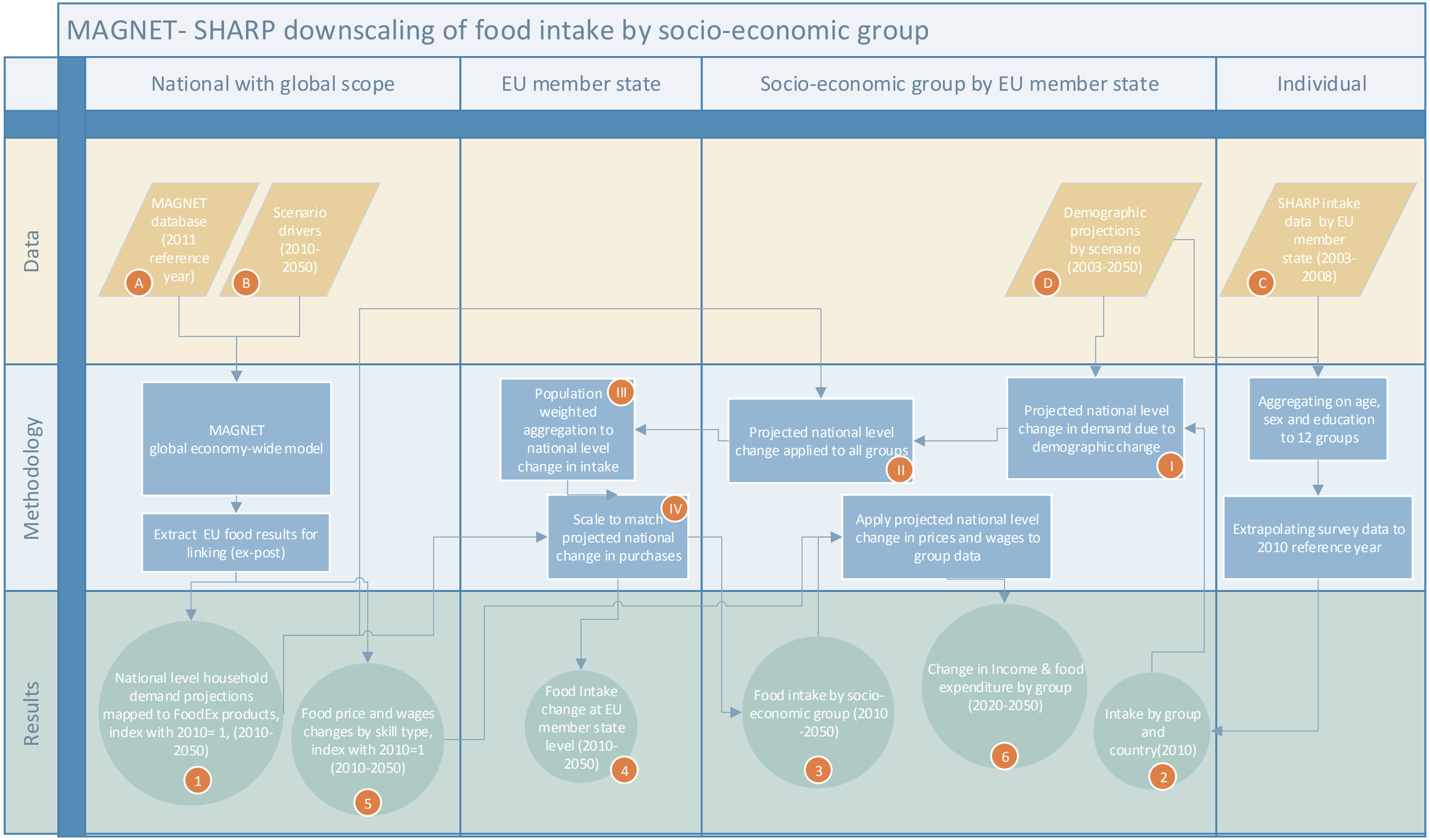
at the micro level is thus to project the survey data to the shared SUSFANSE reference year of 2010 used by all models. Lacking data we need to assume diets are relatively stable between 2003 and 2010. We do however have data on changes in the demographic composition of the four countries covering the 2003-2010 periods (input file D taken from the IIASA SSP database described in Kc and Lutz 2017).

There may also be a bias in the survey samples compared to the actual demographic composition in the survey year. The first step is thus to stratify the population into the 12 groups introduced before, using the group population sizes from Kc and Lutz (2017) with the average diet by group computed from the SHARP database. This step assures that national averages computed from the SHARP database are consistent with the demographic data used in the projections. The second step is then to adjust the group sizes for each country to the 2010 numbers (results file 2, intake data by socio-economic group in 2010).

From the diets by group in 2010 (results file 2) we now proceed by updating the demographic weight of each group according to the changes in weights in each In this step (methodology I) we thus keep diets fixed at 2010, any changes in national level indicators are due to the projected demographic transition (ageing) in Europe.

We then make the connection to MAGNET's projections of changes national household demand (results file 1), applying the country, scenario, time-period and product specific change to each demographic group (methodology II). Due to the demographic changes, this may however introduce an inconsistency in the micro and macro level results. To adjust for any such inconsistency we compute the national average percentage change for each year (method III) and compare these national level changes to the MAGNET results (file 1) to determine a scaling factor. If there is no inconsistency the scaling factor will be 1. In all other cases the intake by group will be adjusted with the same factor, which assures we have consistent national level changes without introducing unfounded differences in response by group. The result of these steps is the intake data by socio-economic group, by country and scenario for 2010-2050 (results file 3).

Figure 3: Operationalizing the SUSFANS toolbox for MAGNET and SHARP



In addition the scaling procedure yields the percentage change in intake at national level (results file 4). Combining these data with country–specific food composition tables that are part of the SHARP database allows a comparison with the nutrition data in the macro models (in part developed within the SUSFANS project, like the GENuS module in MAGNET). In line with existing evidence (Gobbo et al. 2015) these differences are large and can be explained by a variety of factors:

- the use of USDA food composition tables for EU countries in GEnUS versus country specific table in SHARP
- GEnUS computes consumption as residual from other reported flows while SHARP is based on multiple day diet records or 24 hour recalls
- GEnUS has a primary product focus and does not capture processing of food (with potential losses) nor additives like salt
- Food losses & waste are only partly reflected in the FAO data on which GEnUS is based and there is no explicit consideration of pet food.

Nutrition and health metrics and scope for reformulation

Using the projected intake data by socio-economic group for 2010 to 2050, by country and scenario provides the input data needed for the food based SUSFANS metrics. Using the group sizes the food based intake summaries can be computed for the four case study countries using the methodology outlined in D1.3 and already applied to the survey data in Mertens et al. (2018).

For the nutrition based intake summaries the projected intake of FoodEx commodities by socio-economic group are combined with the country specific food composition tables also included in the SHARP database. Again using the same protocol applied in Mertens et al. (2018) to the original survey data, the SUSFANS nutrition based metrics can now be projected forward alongside the profitability, environmental and equity indicators from the macro model. Since these diet metrics are based on the MAGNET scenarios they are also harmonized in terms of macro level scenario assumptions used by all three macro models (i.e. the SUSFANS drivers as described in D10.1).

The underlying assumption in the computation of the nutrition metrics is that the food composition does not change over time, i.e. each gram of FoodEx product has a fixed set of nutritional indicators associated to it. It is of course possible to explore the potential for reformulation interventions, if these can be translated to changes in nutritional value of products at FoodEx2 level. This would then form an additional scenario, alongside the shared macro level scenarios, only implemented at the micro level. Such a reformulation scenario, however, would be cast in the context of macro driven changes in micro-level diets over time – it would use the projected changes in diet from MAGNET with a time-dependent food composition table representing reformulation efforts by industry. Such an exercise would thus yield insights in the scope for reaching nutritional objectives through reformulation without having to fix diets at the currently observed pattern.

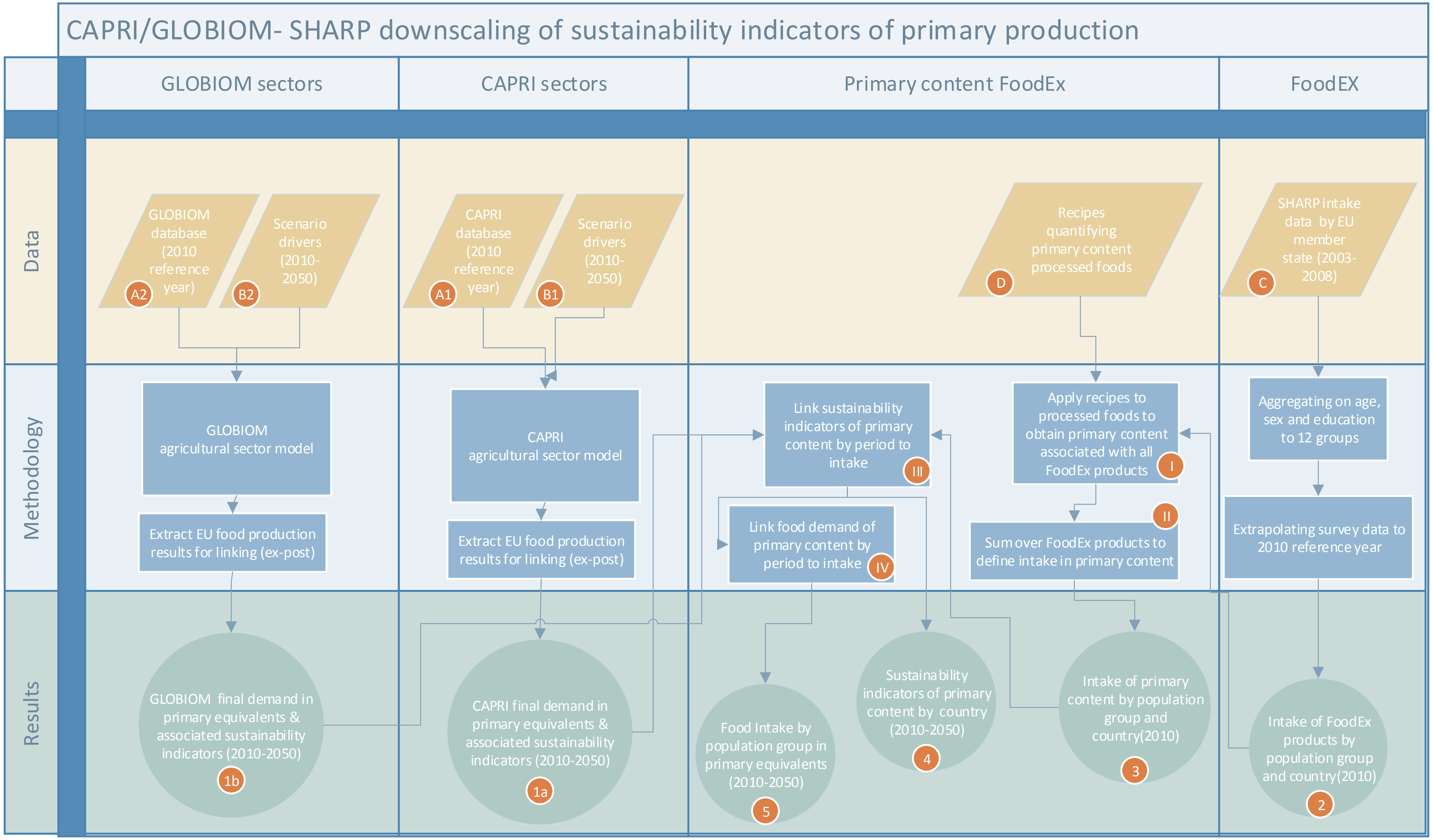
The third set of nutrition metrics refers to the energy balance, or more specifically to the already high BMI scores in Europe. The change in BMI is the result of energy (calorie) intake and energy use through physical activity. While modelling changes in physical activity is beyond the scope of the SUSFANS models, the food composition tables do include calories. The downscaling thus provide at least part of the equation, showing projected changes in energy intake. It needs to be explored if this provides sufficient basis to project changes in overweight and obesity. For now the focus is on the food and nutrition based metrics which are fully covered by the SUSFANS tools.

Additional steps to link to CAPRI and GLOBIOM

Connecting the SHARP database to CAPRI and GLOBIOM requires additional steps. The agricultural sector models use FAO consumption data to model consumer demand. These FAO data, however, focus on primary products. Thus while offering a wealth of detail in terms of products and production methods, they do not capture the transformation of primary products into processed foods which comprise a major part of the consumer diet. We therefore need to construct a link between the primary agricultural products in CAPRI and GLOBIOM and the products as the appear in the shopping basket of the consumers.

To operationalize this link we can build on the work in in WP7 when adding the sustainability indicators to the SHARP database. To be able to connect primary production related sustainability indicators to the FoodEx products in the SHARP database data on recipes are collected. These recipes describe the primary product content in physical terms for a given unit of processed food. Figure 4 presents a condensed version of the additional steps needed to link.

Figure 4: Downscaling sustainability indicators from CAPRI and GLOBIOM to SHARP



CAPRI and GLOBIOM to SHARP. While similar in presentation as Figure 3 note that the columns now refer to the product detail in each step, to highlight that in addition to the steps described above for linking to MAGNET product classification are aligned based on primary content.

The first two columns are similar to the one for MAGNET, shortly summarizing how either CAPRI or GLOBOIM use their respective databases and the shares SUSFANS scenario drivers from D10.1 to project (among other things) food demand in primary equivalents and the associated changes environmental indicators for 2010-2050 (results file 1a and 1b). The last column is similar to Figure 3, summarizing the population stratification and bringing the survey data to the common 2010 reference year in results file 2 (for simplicity the use of demographic data for this step is not made explicit).

The third column then describes the way in which the databases are connected. These steps are similar for linking to either CAPRI or GLOBIOM and for simplicity are only presented once while signalling a possible link to CAPRI (file 1a) or GLOBIOM (file 1b).

The main challenges is to determine the primary content in the FoodEx products. While in the case of MAGNET we rely on the explicit primary versus processed food sectors to map to FoodEx here we use the recipe database (input file D). Applying these recipes to the food intake by group and country allows us to describe the intake in primary equivalents. Note that in the case of products consumed without further processing, for example fresh fruit, the recipes are simply a one-to-one mapping of a FoodEx product to a primary product. In the case of composite dishes, like pizza, the recipes describe the main components (like wheat, tomatoes, and milk). Note that to arrive at primary products suitable for linking to CAPRI and GLOBIOM several recipes may need to be combined (e.g. converting pizza dough to wheat flour and subsequently converting flour to wheat grain). The end result is a mapping of FoodEx products to one (e.g. fresh fruit) or multiple primary products (e.g. pizza) in allowing us to present intake by group and country in 2010 in terms of primary content while maintaining the FoodEx codes (results file 3).

Expressing the sustainability indicators per unit or primary product we can now connect the changes in sustainability indicators over the 2010-2050 period from either CAPRI or GLOBIOM to the SHARP intake data (step II), resulting in a database which first of all yields a country and scenario specific database of sustainability indicators by FoodEx code for the 2010-2050 period (results file 4). In case of the SUSFANS contextual scenarios (REF0, REF+,REF-) this database can be used in SHARP to assess the robustness of diets from an environmental perspective. Thus if a FoodEx commodity scores well in environmental terms in 2010 and therefore would be included in the optimal diet according to SHARP, it may no longer qualify so if autonomous changes in the food system towards 2050 are accounted for. A hypothetical example could be an increased use of herbicides and pesticides in specific crops due to spread of pest and diseases following climate change. Another example would be a shift in trade flows which changing the regional sourcing of products consumed in the EU member states. Such a link would add to the existing literature defining future diets based on static LCA indicators.

A final step in the linking could be a connection to the project demand from CAPRI or GLOBIOM (step III), which could give an alternative projection of future demand in primary equivalent terms (results file 5). Translating this back to FoodEx codes is challenging since it requires an optimization procedure to consistently (i.e. not generating products that cannot be produced given the changes in primary production) map the changing primary products back to fresh and processed products using the recipes as constraints. We therefore opt to use MAGNET for projection future demand at FoodEx level, while the comparative advantage in terms of sustainability indicators of CAPRI and GLOBIOM can be used to increase the robustness over time of the SHARP diet recommendations.

The connection to intake in primary equivalents (file 5) is however relevant for translating SHARP diets to diet scenarios applicable for CAPRI or GLOBIOM, i.e. a bottom-up linking of SHARP. Having an alternative diet then amounts to replacing group intake date in file 2 with the optimized data and going through steps I to III to create an alternative results file 5. From these two versions of intake in primary equivalents the percentage change by time period relative to the chosen contextual scenario can be computed and implemented in CAPRI or GLOBIOM.

Using the toolbox to impose SHARP diets

While the discussion so far has focussed on top-down linking to permit a computation of future nutrition and health related metrics, the same linkages can be used to impose a SHARP diet once the SHARP model becomes operational. The SHARP database to which MAGNET and the other macro models connect feeds the SHARP model. The SHARP model on its turn results in optimal diet for each of the population groups, depending on a range of indicators.

This optimal diet, which is not necessarily the same for all groups, can be seen as new SHARP database which needs to be made time-specific. Changes can be almost instantaneous, i.e. imposed in full by 2020, or phased in over the 2020-2050 period. When this time dimension has been made explicit an alternative (optimal) version of results file 3 in Figure 3 is made. Using the population weights by period these data can be aggregated to national level generating an alternative version of results file 4. Since the intake data from SHARP are in physical quantities, and a mapping from SHARP to MAGNET (or the other macro level models using the recipe approach described above) is available, the SHARP diet can be translated in a percentage change at MAGNET level using the difference between the top-down and bottom-up (optimal) versions of results file 4. This comparison effectively defines the targeted divergence from the diet trajectories in each of the SUSFANS contextual scenarios. Depending on whether REF0, REF- or REF+ is used as a reference scenario the optimal diet from SHARP may imply a higher or lower change in projected diets.

Having a percentage change in diet at MAGNET food group level and by period the target diet is properly defined. The question for MAGNET, or any of the other macro models, is then to select appropriate policy instruments to reach the target diet. This choice can be informed by the review of diet policies in D10.3.

Assessing inclusiveness of diet changes and policies

Figure 3 has a number of files and steps not yet discussed since they are not directly related to the SUSFANS nutrition and health metrics. The metrics were the initial focus of the toolbox, lacking a methodology to project them forward alongside the indicators from the other models. In the context of developing the diet scenarios for D10.3 it, however, became clear that the affordability of healthy diets features prominently in the discussion on how to reach a national change in diets. While taxes and subsidies have clear effects on consumer purchases and are relatively straightforward policy instruments, they raise concerns on their potentially regressive nature alongside a whole range of concerns about interfering with individual choice especially of those with lower socio-economic status (Fox and Smith 2011). Poorer household spent a larger part of their income on food and some argue against for example taxes on meat arguing it makes it a luxury product beyond the reach of the poor. While we lack micro data on food expenditures and their share in total household expenditure, we have a number of variables that appear promising in the context of affordability of food and inclusiveness (or not) of policy interventions.

The population stratification used in the toolbox separates the working (18-64) and (potentially) retired ages (65 and up). Retirement generally has a strong impact on income, disconnecting it from wages but instead increasing (at best) according to a general price index to maintain purchasing power of retirees. As an economy-wide model MAGNET includes a general price index which could be used as a first and very rough variable to project future incomes of the retired population. The working population has been stratified based on education which can be mapped into the MAGNET unskilled (no or only primary and intermediate education) and skilled (high educated). Such a mapping allows us to project changes in wages to income changes. This of course this abstracts from other sources of income the various groups may have (land, capital, government transfers). Using the percentage change in general price index for retirees and wages for the working age groups we thus construct a very simple proxy for changes in income by population group (results file 5).

Alongside the quantity changes used from MAGNET to update the intake data (results file 1), we can also obtain consumer price changes using the same mapping from MAGNET to FoodEx codes (results file 5). Combining the changes in diets by socio-economic group (results file 3) with food price changes gives the percentage change in the cost of diets. This can then be compared to the rough approximation of changes in income giving a first clue on changes in affordability of healthier and sustainable diets for different income groups (results file 6). While nowhere near a full micro-level assessment of the interplay of income and price and demand changes, given the currently available tools it provides a first glimpse at the distributional implications of food system changes from both price and income side with more sub-national detail than available in MAGNET.

DISCUSSION AND CONCLUSIONS

Changing consumer diets is considered to be one of the most effective entry points for a transformation towards more sustainable food systems in the EU. In this process, nutritional health can be regarded as a potential driver of change. Shifts towards EU diets that are more plant-based provide potential health benefits and have the potential to reduce environmental pressure. Yet there can also be a trade-off, as shifts in current consumption of calorie-dense and nutrient-poor foods towards more fresh and nutrient-dense products could aggravate environmental pressures. Reduced food loss and food waste appears to escape this trade-off, but have been associated with a political economy around declining profitability and increasing expenditures of non-essential food in the consumer budget. Therefore, it is important to integrate nutritional, socioeconomic and environmental perspectives in the assessment of directions of change in food systems and diets.

This deliverable describes the conceptualization of the SUSFANS toolbox, a subnational population stratification capturing socioeconomic diversity from a diet and policy perspective and the operationalization of the toolbox for different purposes (health and nutrition metrics, imposing SHARP diets, deriving sustainability indicators for SHARP that capture changes in the food system and a rough assessment of distributional implications of food system changes).

As such the toolbox operationalizes the (input and output) linkages between the various models (WP7, 8, 9) via model linking and up- and downscaling of information. The results indicators are processed into signals for assessing three dimensions of FNS (food availability, access and utilization) and the environmental, economic and health dimensions of sustainability of FNS in the EU. The toolbox builds on the SUSFANS conceptual framework (from WP1) and is applied in case studies (WP5), foresight (WP10) and policy analysis (WP11).

The SUSFANS toolbox contributes to the existing literature on food system assessment from an environmental and health perspective in two major ways:

First, this is the first scientific framework to incorporate nutritional detail in the assessment of food consumption shifts at the aggregate level for 4 European dietary patterns. This involves three key achievements that build strongly on earlier work in SUSFANS (Mertens, 2018; Kuiper et al. 2018) and have been implemented in the toolbox: (i) harmonisation of food intake data across 4 EU countries, and use of food intake data as opposed to food availability data for European countries; (ii) accounting for sub-national distributions in food intake across 12 population groups, with a full handshake between the food groups in the micro level (nutrition surveillance) data and food groups in the macro level database; (iii) relying on country-specific as opposed to generic food composition tables to assess nutritional content. Heroic assumptions are needed to map the aggregate macro level food definitions to micro level products and population groups. These assumptions can potentially undermine the nutritional validity of model results.

Second, this is the first extension of an integrated assessment framework with the capacity to quantify counterfactual, possibly future scenarios for European food systems in terms of their nutritional impact of dietary changes. This is driven by linking the framework that uses the SHARP data for quantifying shifts in food intake to the models that stand out in terms of capacity to model EU agriculture and its policies (CAPRI), livestock systems (GLOBIOM) and economy-wide effects including endogenous income changes (MAGNET).

The connections between the macro models and micro data allow us to project changes in the SUSFANS nutrition metrics, thus permitting a coherent assessment of future synergies and trade-offs between environment, profitability, nutrition and equity as envisaged in the design of the project.

Future research

While important strides are made in the current version of the SUSFANS toolbox there are clear limitations which call for future work. Foremost challenge is that the complexity of consumer behaviour change is poorly reflected. Ideally a full-fledge micro-level model of consumer behaviour would be included in the toolbox, capturing not only individual or household level responses to prices as done for example in the DIET model (Irz et al. 2015, 2016) but also variability in income sources. Food purchases are the end results of the interplay between prices and income changes (linked to food but also non-food sectors), moderated by habits, sociocultural considerations and other non-monetary drivers of consumer behaviour. While SHARP offers an innovative approach to assess diets from multiple angles, it is not designed to provide clues on consumer responses to changing circumstances. While there is some recent work on estimating diverse income and price response by socio-economic group (see for example Muhammad et al. 2017), these do not reach the level of detail to track especially changes in choice of processed foods which comprises a big part of European diets. And as already discussed at length in D1.4, the databases used to estimate consumer responses only implicitly capture the non-monetary drivers, showing diversity in consumer responses to changing prices and income without allowing an "unpacking" of the underlying consumer drivers or concerns. Getting a better understanding of these drivers at national level could be key for steering consumer behaviour with non-monetary instruments like taxes and subsidies. Lacking such rich model of micro level consumer choices the SUSFANS toolbox can only track the more aggregate changes captured by the demand systems in MAGNET, CAPRI and GLOBIOM. Any demand changes within these aggregates are effectively ignored in the current set-up thus limiting the extent to which dynamics of consumer choice are captured.

A possible future extension of the toolbox would be to explicitly track the changes in nutritional status or health over time. From a methodological point of view this would link to vintage human capital growth models that make demographics changes explicit, adding a feedback loop on health/productivity or death rates based on the cumulative effects of (un-)healthy diets. Such an extension could explore the potential system dynamics around potentially large future benefits of preventive interventions which may not render immediately visible returns and may therefore be hard to justify during government budget negotiations.

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