Targets for Sustainable and Resilient Agriculture (TSARA)

Working Package 2 – Progress Report

SDG-2 Indicators – Deliverables D2.1 & D2.2

Juliana D. B. Gil, Pytrik Reidsma, Martin van Ittersum

Plant Production Systems Group
Wageningen University and Research
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1. Introduction

The second working package (WP 2) of the research project Targets for Sustainable and Resilient Agriculture (TSARA) aims to "*identify the indicators to be used in the project. It agrees on a preliminary list of indicators to be used to assess the SDGs and their precise definition, starting from the proposed list of indicators for the SDGs. Then, it adapts this list of indicators according to the results of country assessments (WP1) and stakeholder consultations (WP5). Finally, it explores 2030 and 2050 targets for indicators per country according to the results of country assessments (WP1) and stakeholder consultations (WP5).*" Major tasks of WP2 include:

1. The development of a preliminary list of indicators and their precise definition
2. Validation of the preliminary list of indicators
3. Exploration of 2030 and 2050 targets for indicators per country

This report summarizes tasks 1 and 2. Concerning task 1, it starts with a brief discussion on SDGs and the focus of TSARA with regards to SDG-2, followed by a review of existing policies and the selection of indicators. Concerning task 2, it presents a summary of stakeholder consultations conducted in the Netherlands for the validation of this exercise. The determination of specific threshold values per indicator as well as the exploration of 2030/50 targets for indicators per country are both still in progress and will be completed with additional workshops to be held in the other TSARA countries as well as modeling results.

2. SDGs, SDG-2, targets and indicators

As argued in Gil et al. (*draft*), the SDGs have been framed generically, aligned with the idea of country-led implementation. SDGs and their respective targets are therefore not meant to be overly prescriptive but, instead, offer major guidelines that can be translated into context-specific actions. Nevertheless, their operationalization and monitoring require tangible targets, indicators and threshold values (i.e. a minimum value that should be achieved concerning a given indicator). Besides, some level of detail and clear conceptual definitions are important to ensure that minimum standards are met and that countries' performance levels are comparable – but still lack in some sections of SDG-2 proposed by the United Nations.

Recent assessments of the performance of different countries with regards to SDG-2 targets indicate that France, Netherlands and the United Kingdom, the three countries covered in TSARA, are relatively similar and share some of the same challenges (Kroll et al. 2015). Nutrient pollution, for instance, is common amongst them – although the intensity of pollution and the threshold values that would make sense to establish in each context may differ.

With that in mind, we selected the most relevant targets/indicators and, in some cases, also proposed new ones to illustrate their operationalization in France, Netherlands and the United Kingdom. Our selection prioritizes targets 2.3 (productivity), 2.4 (production sustainability) and 2.5 (biodiversity protection) which are areas where all three countries can improve. As food security (the focus of targets 2.1 and 2.2) have already been achieved and face no threat in these three countries, they have not been prioritized. Contrary to less developed nations, for which such targets are extremely relevant and must be directly monitored, statistics on food insecurity are insignificant for France, Netherlands and the UK.

Our suggestions were based on scientific and grey literature on sustainability indicators, as well as on other sets of indicators proposed by organizations working on SDGs (e.g. SDSN, OECD, GRI, Bertelsmann Stiftung). The Eurostat Agri-environmental Indicators (http://ec.europa.eu/eurostat), available for all TSARA countries, were another important source of inspiration. Although designed to be applied at the country-level, the Eurostat indicators could be adapted to the plot/farm level, compatible with the Rothamsted model simulations and FADN. Besides the possibility to compare the TSARA countries with regards to SDG-2 targets, this allows us to check whether aggregate (i.e. national level) and disaggregate (i.e. plot/farm level) converge.

3. Existing policies of relevance to SDG-2

Several policies and regulations already in place in the TSARA countries set sustainability targets, thus being directly relevant to SDG-2indicators. These policies span local, national and regional levels, and can help inform the revision of SDG-2 indicators since they are based on environmental challenges that have already been identified in each context. Besides, the alignment of SDG indicators and local policies favors their mutual implementation on the ground, while TSARA results may be able to indicate the level of compliance and how (much) further improvement can be achieved.

Table 1 compiles examples of such policies applicable to the Netherlands, including domestic regulations, global treaties and EU directives valid for the other TSARA countries as well. It also highlights major sustainability challenges linked to targets 2.3-2.5.

Table 1 - Examples of sustainability policies applicable to the Netherlands and relevant to SDG-2.

	Rationale	Existing policies
Target [2.3]	**[Ag. intensification]** - 75% of the agricultural land is classified as high input per ha. Use of pesticides and herbicides in NL remains the highest in the EU despite significant reductions (NL= 11kg active substance/ha vs. EU= 3.5kg/ha) and are still below policy standards for safeguarding environmental impacts (Rabobank, 2014) - Manure production levels in the Netherlands are high.	- EU Directive on Crop rotation - Dairy Act 2015
Target [2.4]	**[GHG]** In 2012, GHG emissions from agriculture represented approximately 10% of the country's total emissions. Within the ag sector, GHG are mainly from enteric fermentation (41.21%), agricultural soils (35.93%) and manure management (22.86%). Ammonia emission levels are decreasing; the 2010 NEC target has already been achieved. https://unfccc.int/files/ghg_emissions_data/application/pdf/nld_ghg_profile.pdf	- UNFCCC Protocols - National climate change strategy - NEC EU Directive (air pollution; national emission ceilings)
	[Nitrogen] The production of N fertilizers is very energy-intensive. Despite continued growth in the production and value-added of agriculture, the surpluses of N and P have decreased significantly since 2000 but can decrease further. (Statistics NL, 2015)	- Nitrate EU directive - "Dairy Act" of 2015
	[Phosphorus] Demand for P increased in 2013 due to growth in dairy herd and increased phosphate levels in concentrates (PBL, 2016). Phosphate production increased in 2013 due to growth in dairy herd and increased phosphate levels in concentrates. Southern sandy region and loess region remain problematic areas. (PBL, 2016)	- Implementation of new phosphate ceiling following the abolition of the current milk quota.
	[Water] - Irrigation is used in open agriculture in summer, usually overhead sprinkler. (Source: http://www.dutchagrofood.com/english/water-for-food/subjects/water-use-efficiency-in-food-production/)	- Water Framework Directive - Floods EU Directive - National Water Plan 2

	- Groundwater use in the Dutch agriculture is largely dependent on the weather conditions. This caused high abstraction levels in 2003 and 2006. - Problems with water stress (unnatural drainage, water level management) and excessive use of agrochemicals undermine biodiversity. (http://themasites.pbl.nl/balansvandeleefomgeving/2012/wp-content/uploads/PBL_2012_Assessment-of-the-Human-Environment-2012.pdf).	- Delta Programme Klimaatagenda
Target [2.5]	**[seed banks]** There are only 15 public plant collections in NL, of which the most important are CGN and WUR (Source: Dutch Ministry of Agriculture, Nature and Food Quality, 2008). Private sector mostly manages ornamental species. There is a need to improve accessibility of farmers to existing seed banks across the whole country - https://www.wageningenur.nl/en/show/More-vegetable-species-in-the-gene-bank.htm	- International Treaty on Plant Genetic Resources for Food and Agriculture - Strategic Plan for Biodiversity 2011–2020 -Nagoya Protocol on Access and Benefit Sharing - Roadmap to a Resource Efficient Europe - EU Biodiversity Strategy - Natura 2000 - Birds Directive - Habitat Directive
	[biodiversity] - Total biodiversity in Dutch agroecosystems has still been declining over the last decade (Source: PBL, 2010) - Biodiversity is under spatial pressure (the highest in the EU) due to agriculture, followed by population density: http://themasites.pbl.nl/balansvandeleefomgeving/2012/wp-content/uploads/PBL_2012_Assessment-of-the-Human-Environment-2012.pdf - The majority of Dutch farm holdings is specialized in one category of product. http://ec.europa.eu/eurostat/statistics-explained/images/1/19/Figure_2_Number_of_holdings_by_main_type_of_farming_Netherlands_2010.PNG	

4. Proposed indicators

The original UN proposal for SDG-2 includes 5 targets and 11 indicators (Table 2). These include measures directly related to food security and nutrition (targets 2.1 and 2.2), productivity of agricultural systems and famers' income (target 2.3), sustainability of farming practices (target 2.4) and genetic diversity protection (target 2.5). The rationale applied in the revision of the original UN indicators as well as details on the amendments and additions proposed (including sources, units of measurement, etc.) can be found attached, in Gil et al. (*in progress*).

Table 2 – SDG-2 targets and indicators as originally proposed by the United Nations

SDG-2 targets	**Original indicators**
[2.1] By 2030, end hunger and ensure access by all people, in particular the poor and people in vulnerable situations, including infants, to safe, nutritious and sufficient food all year round	[2.1.1] Prevalence of undernourishment
	[2.1.2] Prevalence of moderate or severe food insecurity in the population, based on the Food Insecurity Experience Scale (FIES)
[2.2] By 2030, end all forms of malnutrition, including achieving, by 2025, the internationally agreed targets on stunting and wasting in children under 5 years of age, and address the nutritional needs of adolescent girls, pregnant and lactating women and older persons.	[2.2.1] Prevalence of stunting (height for age <-2 standard deviation from the median of the World Health Organization (WHO) Child Growth Standards) among children under 5 years of age.
	[2.2.2] Prevalence of malnutrition (weight for height >+2 or <-2 standard deviation from the median of the WHO Child Growth Standards) among children under 5, disaggregated by type (wasting and overweight).
[2.3] By 2030, double the agricultural productivity and incomes of small-scale food producers, in particular women, indigenous peoples, family farmers, pastoralists and fishers, including through secure and equal access to land, other productive resources and inputs, knowledge, financial services, markets and opportunities for value addition and non-farm employment.	[2.3.1] Volume of production per labor unit by classes of farming / pastoral / forestry enterprise size.
	[2.3.2] Average income of small-scale food producers, by sex and indigenous status.
[2.4] By 2030, ensure sustainable food production systems and implement resilient agricultural practices that increase productivity	[2.4.1] Percentage of agricultural area under sustainable agricultural practices.

and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters and that progressively improve land and soil quality.	[2.4.2] Percentage of agricultural households using irrigation systems compared to all agricultural households
	[2.4.3] Percentage of agricultural households using eco-friendly fertilizers compared to all agricultural households using fertilizers
[2.5] By 2020, maintain the genetic diversity of seeds, cultivated plants and farmed and domesticated animals and their related wild species, including through soundly managed and diversified seed and plant banks at the national, regional and international levels, and promote access to and fair and equitable sharing of benefits arising from the utilization of genetic resources and associated traditional knowledge, as internationally agreed.	[2.5.1] Number of plant and animal genetic resources for food and agriculture secured in either medium or long-term conservation facilities.
	[2.5.2] Proportion of local breeds classified as being at risk, not-at-risk or at unknown level of risk of extinction.

In total, 25 indicators are proposed for SDG-2 (Table 3), of which 22 are universally applicable[1] and 3 (highlighted in red) are exclusively applicable to TSARA countries. TSARA-exclusive indicators will be simulated at the farm/plot level through the Rothamsted model (Coleman et al., *in review*). In the case of universal indicators, all of them will be measured at the country level through readily available global datasets and seven of them will also be simulated at the farm/plot level through the Rothamsted model. In 2 cases, information specific to each TSARA countries will also be derived from the FADN database.

Section 4.1 describes indicators – both universal and TSARA-specific – available through public databases, whereas section 4.2 describes indicators to be simulated through the Rothamsted landscape model. The selection of indicators to be simulated through the RR model reflects (i) data availability; (ii) the scale of operationalization of some indicators (plot-level results cannot always be extrapolated to the country-level, at which SDGs should be implemented); and (iii) the model's ability to simulate biophysical indicators at a more detailed scale.

Table 3 - Set of targets and indicators to be explored during the TSARA project. Indicators marked with "RR model" will be simulated at the farm/plot level by the TSARA partners from Rothamsted Research. Those, as well as other elements highlighted in red, complement the work presented in Gil et al. (*in progress*).

Targets	Domain	Proposed indicators	Country level	Farm/plot level
2.1	Access to food	2.1.1. Prevalence of undernourishment	FAO/WTO	-
		2.1.2. Per capita food supply variability index.	FAO/WTO	-
		2.1.3. Depth of the food deficit	FAO/WTO	-
2.2	Malnutrition	2.2.1. Prevalence of stunting among children under 5	FAO/WTO	-
		2.2.2.a. Prevalence of wasting among children under 5.	FAO/WTO	-
		2.2.2.b. Prevalence of overweight among children under 5.	FAO/WTO	-
		2.2.3. Prevalence of anemia among pregnant women (%)	FAO/WTO	-
		2.2.4. Average protein supply (gr/caput/day)	FAO/WTO	-
		2.2.5. Prevalence of obesity among adults (%).	CIA's Fact Book	-
2.3	Productivity	2.3.1. Yield gap (%)	GAEZ/GYGA	RR model
	Living income	2.3.2. Rural poverty headcount ratio at national poverty lines (% of rural population).	-	-

[1] For details on stakeholder consultations concerning the proposition of universal indicators, please refer to Section 5. A scientific article showing how these 20 indicators can be applied to different countries is currently under preparation and will be submitted by June 2017.

		2.3.3. Prevalence of farmers earning less than the national minimum wage (%).	World Bank/FADN	RR model
2.4	Water	2.4.1. Water withdrawn by agriculture as a percentage of total water withdrawal (%).	AQUASTAT	-
		2.4.2. Average water productivity in agriculture (kg/m^3/yr)	AQUASTAT	RR model
	Nutrients	2.4.3. Nitrogen use efficiency (kg N kgN^{-1}): NUE = N_{yield} / N_{input}	Zhang et al. 2015	RR model
		2.4.4. Average Nitrogen surplus (ton N km^{-2}): $N_{sur} = N_{input} - N_{yield}$	Zhang et al. 2015	RR model
		2.4.X_R6. Average P balance (kg P/ha UAA/yr)	-	RR model
	GHG emissions	2.4.5. GHG emission intensity of food production (Mg CO_2e M kcal-1).	Carlson et al. 2016	-
		2.4.X_R7. Net CH_4 + N_2O emissions (tons CO_2 eq/ha/yr)	-	RR model
	Soil quality	2.4.6. Average carbon content in the topsoil (% in weight).	JRC/ESDAC	RR model
	Vulnerability	2.4.7. Climate vulnerability index for food [0-1].	ND-GAIN	-
	Pest management	2.4.8. Use of pesticides per area (tons per 1000 ha).	FAOSTAT	RR model
	Bioenergy	2.4.X_R10. Share of UAA used for cultivating energy crops (%)	FADN	RR model
2.5	Genetic diversity	2.5.1. Av. number of gaps in ex-situ collections of selected crop genepools (i.e. CWR genepool gaps).	Ramirez et al. 2009	-
		2.5.2. Proportion of local breeds classified as being at risk out of all breeds whose risk of extinction is known (%).	FAO	-

4.1. Indicators available through public databases

Target 2.1

Indicator 2.1.1. "Prevalence of undernourishment" (%)

- Justification: This is the traditional FAO hunger indicator, adopted as official Millennium Development Goal indicator for Goal 1 (Target 1.9). It is directly related to the achievement of food security.
- Definition according to the FAO metadata: "The prevalence of undernourishment expresses the probability that a randomly selected individual from the population consumes insufficient calories to cover her/his energy requirement for an active and healthy life. The indicator is computed by comparing a probability distribution of habitual daily dietary energy consumption with a threshold level called the minimum dietary energy requirement. Both are based on the notion of an average individual in the reference population. The indicator is calculated in three year averages, from 1990-92 to 2014-16, to reduce the impact of possible errors in estimated Dietary Energy Supply (DES), due to the difficulties in properly accounting of stock variations in major food."
- Source: FAO Food Security Indicators[2] - Access - Tab "v_2.6"

Indicator 2.1.2. "Per capita food supply variability index" (ratio of variability to distance from minimum recommended daily calorie allowance).

- Justification: Per capita food supply variability corresponds to the variability of the "food supply in kcal/caput/day" as disseminated in FAOSTAT. It compares the variations of the food supply across countries and time. Currently, data is available for the period 1990-2013. In our paper,

[2] The FAO Food Security Indicators are available at http://www.fao.org/economic/ess/ess-fs/ess-fadata/en/#.WRGD4tJ96Uk.

we combined it with average food supply to create an index that expresses *variability* while taking into account each country's susceptibility to falling below the average calorie daily allowance recommended by the FAO.

- Calculation: Per capita food supply variability index = a/(b-c), where:
  (a) per capita food supply variability - Stability - Tab "v_3.7"
  (b) per capita calorie supply – Tab "v_A.9"
  (c) recommended average calorie daily allowance by FAO (i.e. 2250 kcal/day)
- Source: FAO Food Security Indicators (specific tabs are indicated above).

Indicator 2.1.3. "Depth of the food deficit" (kcal/caput/day)

- Justification: The depth of the food deficit is an important indicator of how many calories would be needed to lift the undernourished from their status, everything else being constant. It directly complements indicator 2.1.1 (i.e. "Prevalence of undernourishment").
- Definition according to the FAO metadata: The average intensity of food deprivation of the undernourished, estimated as the difference between the average dietary energy requirement and the average dietary energy consumption of the undernourished population (food-deprived), is multiplied by the number of undernourished to provide an estimate of the total food deficit in the country, which is then normalized by the total population. The indicator is calculated in three year averages, from 1990-92 to 2014-16, to reduce the impact of possible errors in estimated DES, due to the difficulties in properly accounting of stock variations in major food. Aggregate values are computed using a weighted population average.
- Source: FAO Food Security Indicators – Access - Tab "v_2.8"

Target 2.2

Indicator 2.2.1. "Prevalence of stunting among children under 5 years of age" (%).

- Justification (FAO): "Child growth is the most widely used indicator of nutritional status in a community and is internationally recognized as an important public-health indicator for monitoring health in populations."
- Definition according to the FAO metadata: "This indicator belongs to a set of indicators whose purpose is to measure nutritional imbalance and malnutrition resulting in undernutrition (assessed by underweight, stunting and wasting) and overweight."
- Source: FAO Food Security Indicators – Utilization - Tab "v_4.4".

Indicator 2.2.2.a. "Prevalence of wasting among children under 5" (%)

- Justification: Wasting is a crucial indicator of malnutrition among children, being directly related to the achievement of food security.
- Definition according to the FAO metadata: Proportion of children under five whose weight for height is more than two standard deviations below the median for the international reference population ages 0-59. This indicator belongs to a set of indicators whose purpose is to measure nutritional imbalance and malnutrition resulting in undernutrition (assessed by underweight, stunting and wasting) and overweight. Child growth is the most widely used indicator of nutritional status in a community and is internationally recognized as an important public-health indicator for monitoring health in populations. In addition, children who suffer from growth

retardation as a result of poor diets and/or recurrent infections tend to have a greater risk of suffering illness and death.

- Source: FAO Food Security Indicators - Tab "v_4.3"

Indicator 2.2.2.b. "Prevalence of underweight among children under 5" (%)

- Justification: Underweight is a crucial indicator of malnutrition among children, being directly related to the achievement of food security.
- Definition according to the FAO metadata: Weight-for-age less than -2 standard deviations of the WHO Child Growth Standards median among children aged 0-5 years. This indicator belongs to a set of indicators whose purpose is to measure nutritional imbalance and malnutrition resulting in undernutrition (assessed by underweight, stunting and wasting) and overweight. Child growth is the most widely used indicator of nutritional status in a community and is internationally recognized as an important public-health indicator for monitoring health in populations. In addition, children who suffer from growth retardation as a result of poor diets and/or recurrent infections tend to have a greater risk of suffering illness and death.
- Source: FAO Food Security Indicators - Tab "v_4.5"

Indicator 2.2.3. "Prevalence of anemia among pregnant women" (%)

- Justification (FAO): "The prevalence of anemia is an important health indicator. When used with other measurements of iron status, the hemoglobin concentration can provide information about the severity of iron deficiency."
- Definition according to the FAO metadata: "Anemia is a condition in which the number of red blood cells (and consequently their oxygen-carrying capacity) is insufficient to meet the body's physiologic needs. (…) Iron deficiency is thought to be the most common cause of anemia globally, but other nutritional deficiencies (including folate, vitamin B12 and vitamin A), acute and chronic inflammation, parasitic infections, and inherited or acquired disorders that affect hemoglobin synthesis, red blood cell production or red blood cell survival, can all cause anemia."
- Calculation: "Prevalence of anemia in pregnant women is the percentage of pregnant women whose hemoglobin level is smaller than 110 grams per liter at sea level. Anemia is a condition in which the number of red blood cells or their oxygen-carrying capacity is insufficient to meet physiologic needs, which vary by age, sex, altitude, smoking status, and pregnancy status. In its severe form, it is associated with fatigue, weakness, dizziness, and drowsiness. Children under age 5 and pregnant women have the highest risk for anemia. The cut-off values for public health significance is 40%. A prevalence of anemia equal or higher than this level signals a severe public health problem."
- Source: FAO Food Security Indicators – Utilization - Tab "v_4.7"

Indicator 2.2.4. "Average protein supply" (g/caput/day)

- Justification: Protein is critical to human health. An estimated 2 billion people suffer from undernutrition – a lack of access to key micronutrients – resulting in major health risks. This indicator provides information on the quality of the diet, thus complementing other indicators concerned with the number of calories ingested by humans per day.

- Definition/calculation according to the FAO metadata: The indicator is calculated in three year averages, from 1990-92 to 2011-13, to reduce the impact of possible errors in estimated DES, due to the difficulties in properly accounting of stock variations in major food.
- Source: FAO Food Security Indicators – Availability - Tab "v_1.4"

Indicator 2.2.5. "Prevalence of obesity among adults" (%)

- Justification: Obesity rates are rapidly increasing in developed and developing countries alike, particularly in urban settings. This trend is affected by many factors including food choices (particularly increased consumption of high-fat, high-sugar and processed foods), sedentary lifestyles, genetics and cultural beliefs. Obesity is associated with a series of infectious and chronic diseases.
- Calculation: Age standardized estimates of prevalence of obesity among adults (18+ years of age). For adults, 'obese' means a body mass index (BMI) greater than 30 kg/m². Although this is not the case in the TSARA countries, it should be noted that alternative definitions and threshold values may be more appropriate for different ethnic populations present in a given country.
- Sources: US CIA's World Factbook (https://www.cia.gov/library/publications/the-world-factbook/rankorder/2228rank.html) and, when available, national surveys available through the World Obesity Federation (www.worldobesity.org).

Target 2.3

Indicator 2.3.1. "Yield gap" (%)

- Justification: Yield gap estimates highlight where there is potential for agricultural production improvement and help identify major causes of rural poverty linked to geographic elements.
- Definition/calculation: Yield gap (Yg) is calculated as the difference between actual yield (Ya) and potential yield (Yp) for irrigated crops, or water-limited yield (Yw) for rainfed crops. In the GYGA, Yp and Yw are simulated considering optimal agronomic management as input (i.e. cultivar maturity, sowing date and planting density) based on dominant practices currently used by farmers.
- Note: GYGA offers the most complete and up-to-date data package for the TSARA countries. For countries where this is not the case, GYGA may be complemented by the FAO's GAEZ project[3], which also provides country-specific values for yield/production gaps. These values have been estimated through the comparison between potential attainable yields and production (see GAEZ v3.0) and actual yields and production from downscaling year 2000 statistics of main food and fiber crops (statistics derived mainly from FAOSTAT and the FAO study AT 2010/30). A comparison between GYGA and GAEZ reveals that their results are generally well aligned.
- Source: Global Yield Gap Atlas (GYGA) - www.yieldgap.org

[3] Agro-ecological Zones (GAEZ) FAO & IIASA - http://www.gaez.iiasa.ac.at/. Further methodological details are available at: http://www.fao.org/nr/gaez/about-data-portal/yield-and-production-gaps/en/#

Indicator 2.3.2. "Rural poverty headcount ratio at national poverty lines" (% of rural population)

- Justification: Rural poverty headcount ratio at national poverty lines corresponds to the percentage of the rural population living below the national poverty lines[4]. This indicator complements indicator 2.3.2 (i.e. changes in average income levels).
- Calculation of national poverty lines (World Bank): "National poverty lines are estimated by combining national poverty headcounts from national sources, reported in the World Bank's databases, with corresponding consumption and income distributions from PovcalNet used for international poverty estimates. Further, because the consumption and income distributions we use are all expressed in per capita PPP terms, the estimated national poverty lines are all expressed in comparable per capita PPP dollars. (…) This produces a series of poverty lines that are closer to the ICP reference year (thereby reducing the sensitivity of the estimate to errors and updates in inflation data)."
- Source: World Bank, Global Poverty Working Group. Poverty and equity database: http://povertydata.worldbank.org/poverty/home/

Indicator 2.3.3. "Prevalence of farmers earning less than the national minimum wage" (%)

- Justification: Farmers' income is crucial for food security, as it allows or constrains farmers' access to inputs as well as food products.
- Definition/calculation: National minimum wages are based on the "Statutory nominal gross monthly minimum wage" proposed by the International Labor Organization (ILO). Values are based on a common currency (USD) so that countries can be compared (see table 2). According to ILO, "In cases where a national minimum wage is not mandated, the minimum wage in place in the capital or major city is used. In some cases, an average of multiple regional minimum wages is used. In countries where the minimum wage is set at the sectoral level or occupational level, the minimum wage for manufacturing or unskilled workers is generally applied." The earning of farmers was calculated per country, based on national statistics.
- Source: National databases & FADN database.

Target 2.4

Indicator 2.4.1. "Water withdrawn by agriculture as a percentage of total water withdrawal" (%)

- Justification: This indicator highlights the pressure on the renewable water resources caused by irrigation.
- Definitions according to the Aquastat metadata: [Agricultural water withdrawal as % of total water withdrawal] = [Agricultural water withdrawal] / [Total water withdrawal] *100.
    - "Agricultural water withdrawal" (10^9 m^3/yr): Annual quantity of self-supplied water withdrawn for irrigation, livestock and aquaculture purposes. It can include water from primary renewable and secondary freshwater resources, as well as water from over-abstraction of renewable groundwater or withdrawal from fossil groundwater, direct

[4] Jolliffe, Dean Mitchell; Prydz, Espen Beer. 2016. *Estimating international poverty lines from comparable national thresholds*. Policy Research working paper; no. WPS 7606; Paper is funded by the Knowledge for Change Program (KCP). Washington, D.C.: World Bank Group. Available at: http://documents.worldbank.org/curated/en/837051468184454513/Estimating-international-poverty-lines-from-comparable-national-thresholds

use of agricultural drainage water, direct use of (treated) wastewater, and desalinated water. Water for the dairy and meat industries and industrial processing of harvested agricultural products is included under industrial water withdrawal.
    - "Total water withdrawal" (10^9 m^3/yr): Annual quantity of water withdrawn for agricultural, industrial and municipal purposes. It can include water from primary renewable and secondary freshwater resources, as well as water from over-abstraction of renewable groundwater or withdrawal from fossil groundwater, direct use of agricultural drainage water, direct use of (treated) wastewater, and desalinated water. It does not include in-stream uses, which are characterized by a very low net consumption rate, such as recreation, navigation, hydropower, inland capture fisheries, etc.
- Source: Aquastat - http://www.fao.org/nr/water/aquastat/data/query/ (variable 4254)

Indicator 2.4.2. "Average water productivity in agriculture" (kg/m^3/yr)

- Definition according to the Aquastat metadata: Annual quantity of self-supplied water withdrawn for irrigation, livestock and aquaculture purposes. It can include water from primary renewable and secondary freshwater resources, as well as water from over-abstraction of renewable groundwater or withdrawal from fossil groundwater, direct use of agricultural drainage water, direct use of (treated) wastewater, and desalinated water. Water for the dairy and meat industries and industrial processing of harvested agricultural products is included under industrial water withdrawal.
- Note: This indicator offers an aggregate measure. It could be that some countries produce more water-intensive crops than others.
- Calculation: Total crop production (megatons) / Total agricultural water withdrawal ($10^9 m^3$/yr)
    - Total crop production - FAOSTAT Database - http://www.fao.org/faostat/en/#data
    - Total agricultural water withdrawal - Aquastat Database >> Water withdrawal by sector (variable 4250) - http://www.fao.org/nr/water/aquastat/water_use/index.stm
- Source: Besides the sources indicated above (available for all countries in the world), finer data on water productivity is available for the TSARA countries at the GYGA website (http://www.yieldgap.org/web/guest/water-productivity).

Indicator 2.4.3. "Nitrogen use efficiency" (kg N kgN-1)

- Justification: Improvements in nitrogen use efficiency (NUE) in crop production are critical for food security, environmental degradation and climate change.
- Definition (Zhang et al. 2015): NUE (kg N kgN^{-1}) is the ratio of outputs (i.e. crop output) to inputs (fertilizer, biological N fixation, manure, deposition): NUE = N_{yield}/N_{input}
- Source: Zhang et al. 2015 Nature (Online Supplementary Material) http://www.nature.com/nature/journal/v528/n7580/abs/nature15743.html#supplementary-information

Indicator 2.4.4. "Average nitrogen surplus" (ton N km^{-2})

- Justification: Nitrogen balance indicates the potential surplus of nitrogen on agricultural land and the associated pressure on soil, air and water.

- Definition (Zhang et al. 2015): Av. nitrogen surplus (N_{sur}) is the difference between inputs (i.e. fertilizer, agricultural biological fixation, manure and deposition) and outputs (i.e. N content in the crop product), which corresponds to the sum of N losses to the environment (either through volatilization, leaching or run-off) plus N recycling within the soil: $N_{sur} = N_{input} - N_{yield}$
- Source: Zhang et al. 2015 Nature (Online Supplementary Material) http://www.nature.com/nature/journal/v528/n7580/abs/nature15743.html#supplementary-information

Indicator 2.4.5. "GHG emission intensity of food production" (Mg CO_2e M $kcal^{-1}$)

- Justification: Agriculture accounts for nearly a third of global GHG emissions (IPCC). Agriculture-related GHG emissions are expected to increase in the future pushed by demand growth, posing further threats to the world's food and climate security. Efforts are needed to reduce GHG emissions coming from the agricultural sector. Indicator 2.4.5 measures the GHG emission intensity of agriculture per country, that is, the level of GHG emissions per food kcal produced. Calculation: "2000-era emissions from a 200-iteration Monte Carlo simulation include CH_4 emissions from rice paddies, CO_2, N_2O, and CH_4 emissions from peatland drainage, and N_2O emissions from manure and synthetic N application. Production intensity includes all crop calories. Food intensity excludes calories dedicated to industrial and non-food uses, and assumes that 12% of the calories used as livestock feed are available in foods for human consumption (Cassidy et al. 2013)."
- Source: Carlson et al., 2015 – Nature Climate Change (Online Supplementary Material 2) https://www.nature.com/nclimate/journal/v7/n1/full/nclimate3158.html#supplementary-information

Indicator 2.4.6. "Average carbon content in the topsoil" (% in weight)

- Justification: Several attempts have been made to identify appropriate indicators of land degradation and to measure it worldwide (Gibbs & Salmon 2015). Soil organic carbon has been defined by EUROSTAT as an appropriate indicator for soil quality. High organic carbon content corresponds to good agro-environmental conditions.
- Notes:
    - The UNEP-funded GLASOD project (http://www.isric.org/projects/global-assessment-human-induced-soil-degradation-glasod) has produced a world map of human-induced soil degradation using an expert-based approach. The results of this project were generated in 1991 and 1998. Although they still feature in the FAOSTAT database as soil quality indicators, a more up-to-date measure is preferred.
    - Better statistics on soil degradation (based on multiple parameters related to the various functions of the soil) will be made available in the future through the new version of the FAO GLADIS dataset.
- Calculation: The data used to generate this indicator are geo-spatial raster data contained in the Harmonized World Soil Database (HWSD) released by FAO, IIASA, ISRIC, ISSCAS, and JRC in 2008 with a spatial resolution of 30 by 30 arc seconds (approximately 1 Km). Spatial data were extracted through appropriate queries from the geo-database and then spatial statistics were calculated at the country level.
- Source: FAOSTAT Database (Item code: 6709, Element code: 7221)

http://www.fao.org/faostat/en/#data/ES

Indicator 2.4.7. "Climate change vulnerability index for food" [0-1]

- Justification: Vulnerability measures the exposure, sensitivity and adaptive capacity towards the negative impacts of climate change. This indicator is based on crucial elements for the achievement of food security and agricultural sustainability.
- Definition: The vulnerability index for food is composed of 6 elements:
    - projected change of cereal yield, incl. rice, wheat and maize (*2040-2069 under RCP4.5 according to results from EPIC, GEPIC, LPJmL, pDSSAT, PEGASUS*);
    - projected population change (*2020-2050*);
    - food import dependency (*1995-2014 – FAOSTAT*);
    - rural population as a share of total population (*1995-2014 – WDI*);
    - capacity to acquire and deploy agriculture technology (e.g. amount of fertilizer use, amount of pesticide use, ability to equip agriculture area with irrigation, the frequency of tractor use and child malnutrition) (*various*).
- Source: ND-GAIN Country Vulnerability Index for food - http://index.gain.org/

Indicator 2.4.8. "Use of pesticides per area" (tons per 1000 ha)

- Justification: Pesticides pose a major threat to genetic diversity in agriculture. Its continued and abusive use may lead to the oversimplification of agroecosystems. The proposition of an indicator related to the use of pesticides per area serves as an incentive to the application of alternative pest control techniques, such as integrated pest management, employment of pest prevention measures, etc.
- Calculation: This indicator includes data on the use of major pesticide groups (insecticides, herbicides, fungicides) and of relevant chemical families. It is measured in tons of active ingredients used in the agricultural sector for crops and seeds.
- Note: A weighted average of the use of pesticides and their associated level of toxicity cannot be calculated at the global level due to data limitations. However, it should be considered at the national level whenever possible (as in the case of the TSARA countries).
- Source: FAOSTAT Database - http://www.fao.org/faostat/en/#data/RP

Target 2.5

Indicator 2.5.1. "Average number of gaps in *ex-situ* collections of selected crop genepools"

- Justification: Indicator 2.5.1 is related to genetic resources for food and agriculture secured in conservation facilities. Data on the complete collection of seedbanks and germplasm banks (incl. which species are secured and what is their country of origin) is limited. However, gaps in the taxonomic and geographic coverage of Crop Wild Relatives[5] in *ex-situ* collections are known and offer a good proxy. A recent study by CIAT and Bioversity International has highlighted these gaps for a number of genepools. The indicator we propose relies on the number of gaps found

[5] Crop wild relatives are wild plant species that are genetically related to cultivated crops. Untended by humans, they continue to evolve in the wild, developing traits – such as drought tolerance or pest resistance – that farmers and breeders can cross with domesticated crops to produce new varieties.

amongst 12 major crops produced and consumed worldwide, given where each species is expected to occur for these crops based on herbarium specimens.

- Calculation: The scores assigned to each country are based on the predominant values shown in figure 1.2 of the FAO report "The Second Report on the State of the World's Plant Genetic Resources for Food and Agriculture" (http://www.fao.org/docrep/013/i1500e/i1500e.pdf).
- Source: http://gisweb.ciat.cgiar.org/gapanalysis/

Indicator 2.5.2. "Proportion of local breeds classified as being at risk out of all breeds whose risk of extinction is known" (%)

- Justification: The risk status of major species offers an indication of the conservation of genetic resources in each country and the need for further action.
- Notes:
    - This indicator is measured relative to the number of species whose risk of extinction is known as a way of reducing distortions among countries with more or less catalogued species. Efforts aimed at species monitoring is a component of SDG 15 ("Life on land").
    - It seems desirable that the proportion of types at risk is as low as possible. However, the more diverse a system is, the more breeds will be relatively rare and therefore more vulnerable to extinction. Likewise, a system with only one or a few abundant breeds has 0% breeds at risk of extinction, but very low diversity. Once again, this underscores the importance of implementing the SDG Agenda in its integrity; SDG 15 deals with biodiversity as a whole and is complementary to indicator 2.5.2.
- Source: FAO report "Status and trends of animal genetic resources", 2016 (Annex 2)

4.2. Indicators to be simulated through the RR model

Target 2.3

Indicator 2.3.1_R1. "Yield Gap" (%)

For the TSARA countries, yield gap values will be simulated at the subnational level (i.e. farm- or plot-level) through the RR model. Simulation results will be presented as production frontiers, determining a "search space" (i.e. a range of options) to be explored vis-à-vis other indicators. The same definition of "yield gap" presented in Section 4.1 applies here: *"Yield gap (Yg) is the difference between Yp (irrigated crops), Yw (rainfed crops) or Ypi (partially- irrigated crops) and actual yield (Ya). Yg is based on Yp, Yw or Ypi simulated using optimal agronomic management as input (i.e. cultivar maturity, sowing date and planting density). (…) Optimum sowing dates, plant density, and cultivar maturity are based on dominant practices currently used by farmers. However, sowing dates, planting density, and cultivar maturity differed from actual practices when there is strong evidence to support using an optimum value, such as published field research that documents higher yields with sowing dates different from those currently used by farmers. In those cases, the optimum sowing date and cultivar maturity are determined within the time constraints of the dominant crop sequence (e.g., areas where more than one crop is grown on the same field each year)."* (Source: GYGA 2017 - http://www.yieldgap.org/glossary#linkYieldGap). Yield gap will be calculated for each individual crop in tons/ha and expressed as a percentage (or ratio of attained vs. potential productivity levels). A whole-farm value may be calculated as a weighted average of the specific crops, based on the area share they correspond to. Grass will be considered a crop type.

Whenever livestock is also involved, a common metric for crops and animals (e.g. calories/ha) will be applied.

Indicator 2.3.3_R2. "Prevalence of farmers earning less than the national minimum wage" (%)

For the TSARA countries, a direct measure of farm income is readily available from the FADN database. The concept of "economic size" indicates the economic return obtained per hectare; when combined with the amount of labor units employed in each farm, it gives an estimate of farmers' earnings. In addition, simulation results from the RR model (particularly the mix and level of production considered) may be combined with market prices to indicate the level of revenues; however, complementary economic modeling might be needed to properly capture the effect of both scale and production costs associated with different management practices on the systems' profitability and on farmers' earnings.

Target 2.4

Indicator 2.4.2_R3. "Average water productivity in agriculture" (kg crop/m^3)

Water productivity reflects how much crop is produced per irrigation water input unit, expressed in "kg crop/m^3 irrigation water". Simulation results from the Rothamsted model are based on the concept of mass balance (which includes soil water content, volume of runoff, leaching and evapotranspiration). As described by Coleman et al. (*in review*), "the soil water model embedded in the Rothamsted model uses a capacity based approach" across three soil layers (Addiscott and Whitmore, 1991; Van Ittersum et al., 2003; van Laar et al., 1997). Although rainfall can be considered in the model (it either infiltrates or runs off under soil water saturation conditions[6]), it is assumed that a fixed proportion of the water that is available to drain moves into the lower layer each day. Drainable water is defined in relation to field capacity. Any water draining out of the bottom soil layer is the drainage. Evapotranspiration is a function of the potential evapotranspiration, the soil water content and the root density. All flows are expressed in terms of volume per day, which can be aggregated into volume per year or expressed in terms of depth/day/ha. Crop-specific characteristics (e.g. how water-intensive a certain crop is) and the influence of e.g. N deficit on water use efficiency by crops are not fully accounted for at the moment, but may be included in the modeling simulations at a later stage.

Indicator 2.4.3_R4. "Nitrogen Use Efficiency" (kg N kgN^{-1})

NUE measurements at the farm- or plot-level are based on the same concept used at the country-level, i.e. the ratio of outputs (i.e. crop output) to inputs (fertilizer, biological N fixation, manure, deposition): $NUE = N_{yield}/N_{input}$. The RR model accounts for the N content in the grain as well as in the straw produced by the plant.

Indicator 2.4.4_R5. "Average nitrogen surplus" (ton N km^{-2})

N surplus indicates potential for soil, air and water pollution associated with an agricultural system. At the farm- or plot-level, it will be simulated according to the OECD methodology described in the Eurostat/OECD Gross Nitrogen Balance Handbook. The gross nitrogen balance lists all inputs and outputs and calculates the gross nitrogen surplus as the difference between total inputs and total outputs. The gross nitrogen surplus per ha is derived by dividing the total gross nitrogen surplus by the

[6] A hill slope model determines where runoff water goes – although I won't make full use of this feature given that a farm type doesn't have a particular topology that we can simulate

reference area (see equation below). The reference area of the current version of balances uploaded in Eurobase is the sum of arable land (L0001), permanent grassland (L0002) and land under permanent crops.

N surplus per area = $\frac{inputs - outputs}{arable\ cropland + permanent\ cropland + grassland}$

The inputs of the N balance are:

- Fertilizers, which consist of:
  - inorganic fertilizers,
  - organic fertilizers (excluding manure).
- Gross manure input, which is calculated from:
  - manure production (nitrogen excretion; no reductions are made for nitrogen losses due to volatilization in stables, storages and with the application to the land);
  - manure withdrawals (manure export, manure processed as industrial waste, non-agricultural use of manure, other withdrawals);
  - change in manure stocks;
  - manure import.
- Others:
  - seeds and planting material;
  - biological fixation by leguminous crops and free living organisms;
  - atmospheric deposition.

The outputs of the gross N balance are:

- Total removal of nitrogen with the harvest of crops (cereals, dried pulses, root crops, industrial crops, vegetables, fruit, ornamental plants, other harvested crops).
- Total removal of nitrogen with the harvest and grazing of fodder (fodder from arable land, permanent and temporary pasture consumption).
- Crop residues removed from the field.

Indicator 2.4.X_R6. "Average phosphorus balance" (kg N/ha UAA/yr)

At the farm- or plot-level, P balance will be simulated according to the OECD methodology described in the Eurostat/OECD Phosphorus Balance Handbook. The phosphorus balance lists all inputs and outputs and calculates the gross phosphorus surplus as the difference between total inputs and total outputs. The gross phosphorus surplus per ha is derived by dividing the total gross phosphorus surplus by the reference area (see equation below). The reference area of the current version of balances uploaded in Eurobase is the sum of arable land (L0001), permanent grassland (L0002) and land under permanent crops.

P surplus per area = $\frac{inputs - outputs}{arable\ cropland + permanent\ cropland + grassland}$

The inputs of the P balance are:

- Fertilizers:
  - inorganic fertilizers,
  - organic fertilizers (excluding manure).
- Gross manure input, which is calculated from:

- manure production (phosphorus excretion);
- manure withdrawals (manure export, manure processed as industrial waste, non-agricultural use of manure, other withdrawals);
- change in manure stocks;
- manure import.

- Others:
    - seeds and planting material;
    - atmospheric deposition.

The outputs of the gross P balance are:

- Total removal of phosphorus with the harvest of crops (cereals, dried pulses, root crops, industrial crops, vegetables, fruit, ornamental plants, other harvested crops).
- Total removal of phosphorus with the harvest and grazing of fodder (fodder from arable land, permanent and temporary pasture consumption).
- Crop residuals removed from the field.

Indicator 2.4.X_R7. "Net CH_4+N_2O emissions/removals related to agriculture" (tons CO_2eq/ha/yr)

This indicator shows a partial balance of GHG emissions at the farm- or plot-level. It accounts for the main sources of methane and nitrous oxide emissions in European countries, according to the UNFCCC tiers used in national emissions inventories:

- Digestive process of ruminants (CH_4)
- Manure storage methods and exposure to oxygen and moisture (CH_4/N_2O)
- Fertilizer application (N_2O)
- Irrigation and tillage methods (N_2O)

Carbon dioxide emissions from conventional tillage practices and burning of agricultural residues are relatively unimportant in the countries covered in the TSARA project – and therefore will not be considered. Although the burning of fossil fuels and the production process of external inputs (e.g. seeds, fertilizers, etc.) are potentially important sources of GHG emission in many European farming systems, indicator 2.4.4. is limited to on-farm agronomic emissions. Emission factors are available in the EU-15 CRF Table Summary 3, Annex 1.2 (http://www.eea.europa.eu//publications/european-union-greenhouse-gas-inventory-2014#tab-data-references). The Global Warming Potential values applied for CH_4 and N_2O are 25 and 298, respectively.

Indicator 2.4.6_R8. "Soil organic matter content" (kg dry OM/ha/yr)

Soil organic matter (SOM) is an important indicator of soil quality and agronomic aptitude. Both absolute SOM values and SOM variations over time are relevant indicators at the farm- or plot-level and will be simulated by the RR model whenever changes are significant over the time horizon considered. Change will be expressed as an average per year, as it will vary according to crop rotations considered.

According to Coleman et al. (*in review*), "the soil organic carbon (SOC) model is based on the Rothamsted carbon model, RothC, (Coleman and Jenkinson, 2014). Soil organic carbon is split into four active compartments and a small amount of inert organic matter (IOM). The four active compartments are Decomposable Plant Material (DPM), Resistant Plant Material (RPM), Microbial Biomass (BIO) and Humified Organic Matter (HUM). Each compartment decomposes by a first-order process with its own rate constant. The IOM compartment is resistant to decomposition. Decomposition of each of the four active pools are modified by rate modifying factors for temperature, moisture and plant retainment.

Indicator 2.4.8_R9. "Toxicity weighted pesticide use per area" (kg/ha/yr)

At the farm- or plot-level, we propose that this indicator be calculated as the volume of pesticide applied per ha multiplied by the average toxicity class. To account for the toxicity level of different pesticides, we adopt the World Health Organization toxicity classification:

- Class I – a: extremely hazardous
- Class I – b: highly hazardous
- Class II: moderately hazardous
- Class III: slightly hazardous

The toxicity should also be weighted per cropland use, as described in Equation 3:

$$TWPU = \frac{\sum_i [Pest_i + WF_i]}{\sum_i LU} \quad (3)$$

Where:

- *i* = subscript denoting different pesticides characterised by their toxicity level (#classes)*
- TWPU = Toxicity weighted pesticide use [kg/ha]
- Pest = Use of each pesticide *i* [kg]
- WF = Weighting factor assigned to each pesticide i, based on WHO toxicity levels [-]
- LU = land on which pesticide *i* is applied [ha]

Indicator 2.4.X_R10. "Share of the total UAA used for the cultivation of energy crops" (%)

Given the focus of FACCE SURPLUS on innovative farming systems and bioenergy, the share of each country's total utilized agricultural area (UAA) dedicated to the production of energy crops is proposed as an additional indicator. Energy crops may include e.g. giant miscanthus, switchgrass, jatropha and fungi.

- At the country level, measured as the share of the total UAA used for energy crops (ECs), e.g. sugar beet, giant miscanthus, switchgrass, jatropha, etc.
    - Ethanol production from sugar beet and cereals.
    - Biodiesel production: Eurostat Energy Statistics.
    - Crop yields: from FADN.
- At the plot level, measured as the amount of ethanol or biofuel
    - Relevant if ECs are included in the Rothamsted model.
    - Crop yields: from the Rothamsted model.
    - The geographic relevance of ECs will be determined by the farm typology.
    - The share of ECs to the total UAA in each country may not be the same as that for landscape/farm levels, in which case assumptions should be made based on typical farming practices/expert opinion.
- For both levels, Eurostat conversion factors can be applied:
    - 1 ton cereals = 3.9 hl ethanol
    - 1 ton sugar beet = 1.0 hl ethanol

- 1 ton rapeseed oil = 0.95 tons biodiesel (41.5 % of rapeseed oil and 54.5 % of rapeseed meal)
- 34 % of cereals are converted to distillers dried grains (DDGS) in the production of ethanol

5. Stakeholder consultations for the validation of the proposed indicators

Consultations with Dutch stakeholders were conducted between August 2016 and April 2017 with the general purposes of introducing it to the general public, map existing debates and initiatives related to SDG-2, understand stakeholders' perception of SDG indicators and establishing communication channels with other actors/institutions working on similar topics.

5.1. Bilateral meetings

Bilateral meetings on the SDGs were held both personally or through teleconferences with representatives from the government, academia, NGOs and private sector. Main points are summarized as follows:

- How is the national debate about the sustainability of agricultural and food systems framed? What is its main focus/angle?

In the Netherlands, emphasis has been placed on agricultural sustainability in general as well as on specific topics such as nitrogen and phosphorus pollution (manure legislation, fertilizer application), water and GHG emissions. Attention has been dedicated to specific industries/farming sectors which have a relatively high environmental impact (e.g. pigs and horticulture). Key at the moment are the numbers related to the livestock sector, involving the end of the milk quota, herd size, application of manure, etc.). In specific cases, businesses (e.g. Unilever) are also concerned with the sources of raw-materials they use along the supply chain. Another important topic is the need to move away from "agricultural" policies to "food systems" policies; there are discussions on the possibility of having a Ministry with that name).

- Where are these questions debated?

In the Netherlands, these questions are currently debated at different organizations and governance instances, including the Government (e.g. Ministry of Economic Affairs, Ministry of Foreign Affairs, Ministry of Infrastructure and Environment), the Dutch Environmental Assessment Agency (PBL), research institutions (different groups within WUR as well as other universities), private businesses (e.g. Unilever, Agrovision) and civil society organizations (e.g. CABI). The interest in the SDGs, particularly agricultural sustainability is rapidly growing, with many organizations incorporating SDG targets into their mission and operating plans. Most of the reports with information on the SDGs released so far have been published by PBL (see "Sustainable Development Goals in the Netherlands. Building blocks for Environmental policy for 2030" by PBL 2016 for a complete mapping of existing policies, regulations and targets applicable to the Netherlands directly relevant for the SDGs). On May 24th, 2016 the Dutch Minister for Foreign Trade and Development has released a letter stating the commitment of different ministries to implement, monitor and report on the SDGs. An inter-ministerial commission has also been formed to debate the SDGs and how they will guide the Government's actions accordingly. The mapping of existing policies and regulations – and how they relate to the SDGs – is under progress.

- What is lacking/needed?

In the Netherlands, the perception of the stakeholders we had contact with is that more needs to be done in terms of (i) defining indicators, (ii) defining implementation/execution plans, and (iii) generating information/conducting assessments of current vs. alternative agricultural scenarios. However, the general perception of the SDGs is positive and the consensus seems to be that the SDGs already provide the justification and legitimacy for certain actions and initiatives. Within the Government, policy makers are willing to pursue the SDG targets and indicators, institutional support exists for SDG-related projects and a lot of what had already been done concerning environmental sustainability can inform the debate on the SDGs and their operationalization. Specific stakeholders from the private sector who we had contact with expressed concerns about the fact that SDG reporting commitments exist at the country-level and the challenge this poses in terms of imports/exports and trade flows. Still according to them, although census and national economic accounts may help, some raw materials come from countries which do not always have a reliable or transparent tracking system.

5.1.2. Seminar with stakeholders

Together with the Dutch Ministry of Economic Affairs (EZ), members of the TSARA research project from Wageningen University held a seminar on indicators for the Sustainable Development Goal 2. The event took place on April 19th, 2017 in The Hague and involved 32 participants from 11 institutions. During the event, presentations were given on (i) the relevance of the SDGs; (ii) the measurement of SDG-related indicators from the perspective of CBS (the Dutch Central Bureau of Statistics); and (iii) how SDG-2 indicators could work in practice, building on examples from Nigeria, Brazil and the Netherlands. The presentations were followed by a collective debate on the suitability, relevance and operationalization of the indicators proposed by the Wageningen team.

The entire seminar was a valuable opportunity to validate the revised set of indicators with stakeholders from the government, academia, NGOs and private sector, exchange ideas about the design and implementation of SDG-2 indicators, as well as discuss TSARA's potential contribution towards their achievement. Participants were receptive to the ideas presented and suggested amendments to the indicators proposed under target 2.5. The workshop minutes and the complete list of participants can be accessed on request.

6. Final considerations

6.1. Next steps in TSARA

Given the focus Rothamsted Model and the availability of data for ex-post monitoring of farm systems, most of the SDG-2 indicators presented in this report are primarily concerned with the biophysical aspects of agricultural sustainability. However, in the next phase of the TSARA project, we intend to combine these indicators with additional metrics related to the social and economic dimensions of agricultural sustainability. In particular, the identification and assessment of trade-offs faced by different farm types between environmental indicators and income are crucial to understand farmers' willingness to engage in transformative actions and, ultimately, move towards SDG-2.

Another next step in the TSARA project concerns broader trade-offs and synergies across SDGs. As stated in Gil et al. (*draft*), food security and agricultural sustainability are intrinsically related to the society, economy and environment – and, as such, may influence (and be influenced by) other SDGs. The pursuit of a certain pathway to food security and agricultural sustainability by a given country may favor or pose challenges to the achievement of sustainability objectives in other specific places and/or at the global level; meeting SDG-2 is likely to involve several synergies and trade-offs amongst SDGs as well as across temporal and spatial scales (PBL, 2016; Weitz et al. 2014; Coopman et al., 2016; Jönsson, 2016; Stechow et al. 2016; Abel et al. 2016).

6.2. Future research avenues

Besides synergies and trade-offs related to the SDGs (mentioned above), some additional points require further research efforts:

- Interlinkages between food production and consumption, sustainable agriculture, climate resilience and environmental protection are country-specific and may vary according to the future economic and climatic scenario considered (Van Vuuren et al. 2015).
- Costs and benefits related to the implementation of each indicator are similar but not necessarily the same amongst UK, NL and FR.
- Given the dynamic nature of indicators, it is important to look at trends instead of current values only when selecting indicators to focus on.
- The Rothamsted model analyzes indicators at the plot-level. However, variations in the scale of operationalization of indicators (e.g. plot, farm, landscape, country) affect the costs and benefits associated with the achievement of different indicators.

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