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Supplementary information

A meta-analysis of projected global food demand and population at risk of hunger for the period 2010–2050

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A meta-analysis of global food demand and population at risk of hunger projections for the period 2010-2050 - Supplementary Information

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Contents

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A Construction of Global Food Security Projections Database

A.1 Harvesting of global food security projections

As part of the systematic literature review, we identified which global food security indicators were quantitatively assessed by the selected studies. In line with previous research (Dijk and Meijerink 2014), global food security assessments mainly covered four food security indicators: food demand (measured in kcal/cap/day), population at risk of hunger (measured as number or share of persons being undernourished), food prices (for maize, rice and wheat) and childhood undernutrition (measured as the number or share of children being undernourished). A few studies provided projections for comparable indicators but defined at a different scales (e.g. total food price instead of crop specific prices or demand expressed in value instead of energy terms) as well as other indicators, such as stunting (Lloyd et al. 2011; Ishida et al. 2014) and protein consumption (Billen, Lassaletta, and Garnier 2015; Msangi and Batka 2015; Medek, Schwartz, and Myers 2017). Figure S1 shows the coverage of the four main indicators by the selected studies. For practical reasons we decided to focus on the two indicators with the highest coverage: Per capita food demand (65%) and population at risk of hunger (37%).

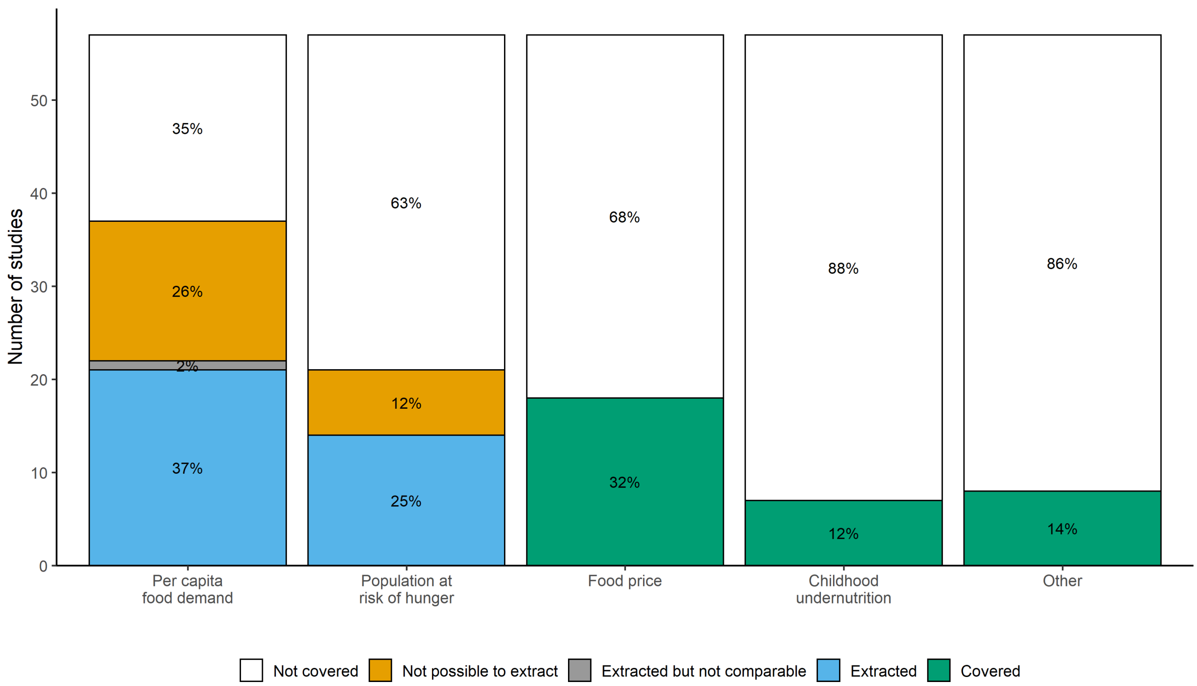

Figure S1: Coverage of the main food security indicators by the 57 selected studies from the systematic literature review. Only for food demand (expressed in kcal/cap/day) and population at risk of hunger (measured as number or share of persons being undernourished) an effort was made to extract the data and therefore a decomposition of the coverage into (1) Not possible to extract, (2) Extracted but no comparable and (3) Extracted is presented. For food price (for maize, rice and wheat), childhood undernutrition (measured as the number or share of children being undernourished) and a number of other indicators only the total number of studies that covered these indicators is presented but no further actions were undertaken to harvest the data.

Where possible we harvested data from the supplementary information and from the main paper itself. In a few cases, we were able to use the WebPlotDititizer tool (https://automeris.io/WebPlotDigitizer/) to extract information that was only presented in the form of charts. If data was still missing, we also tried to contact the authors, who sometimes provided additional information. Out of the 57 selected studies, we were able to extract relevant information from 26 studies (46%), including 21 (38%) for per capita food demand and 14 (25%) for population at risk of hunger (Figure S2).

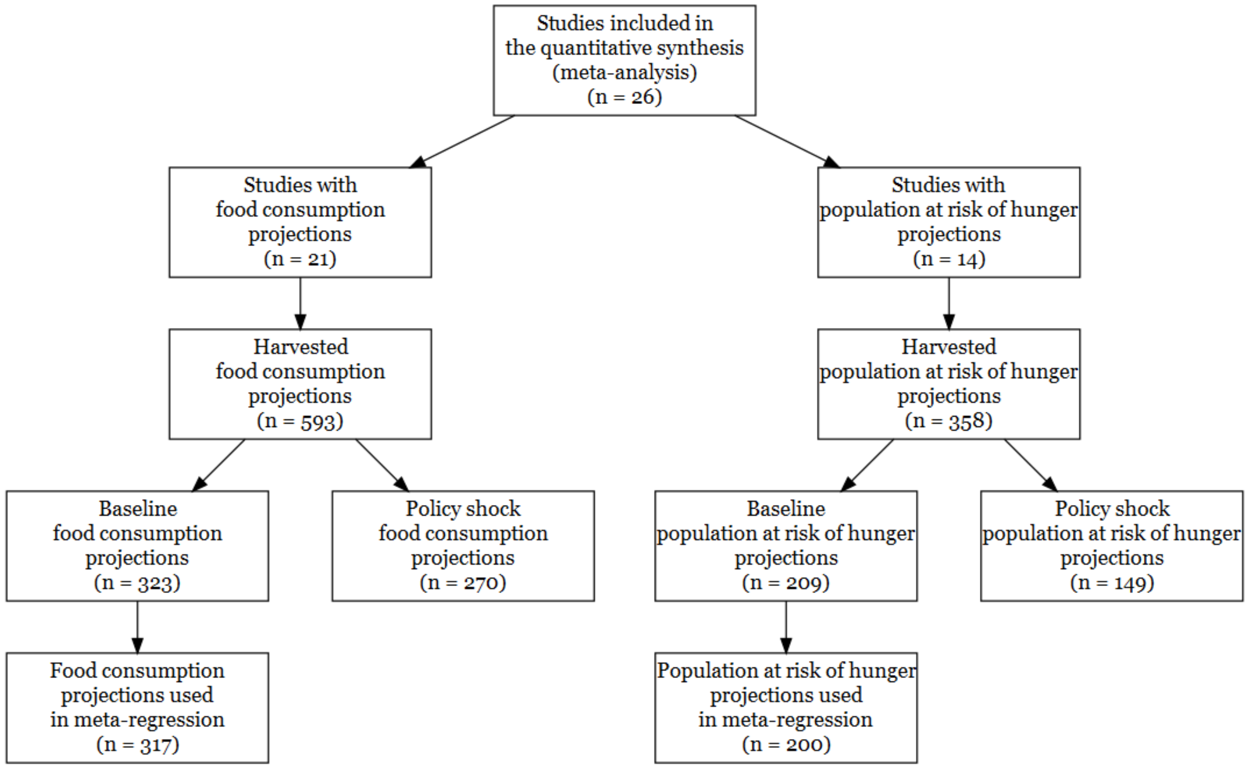

Figure S2: Selection of studies and projections for quantitative synthesis and meta-regression. Several studies present projections for per capita food consumption as well as population at risk of hunger. A small number of baseline projections could not be mapped to the SSPs/RCPs (Figure S4) or were considered as outliers (see text) and were therefore excluded from the meta-regression.

Figure S3 shows for each of the 26 studies, which indicators could be extracted. The following reasons prevented us from extracting data from all studies:

1. *Indicator not presented.* Not all studies presented projections for per capita demand and population at risk of hunger.
2. *Incomplete quantitative information.* In many cases only growth figures were presented, while base year information was missing.
3. *Not possible to digitize information.* Sometimes the data was only provided in the form of maps or charts from which it was impossible to extract information
4. *Not possible to map projections to the SSPs or RCPs.* Due to different assumptions, several projections could not be mapped to one of the SSPs or RCPs.
5. *Differences in the definition of an indicator.* In a few cases, the harvested data appeared not to be comparable with data from other studies due to differences in definition. This was the for instance the case for Tilman et al. (2011), who presented food demand projections in kcal/cap/day but also appear to include the demand for feed, resulting in much larger values.

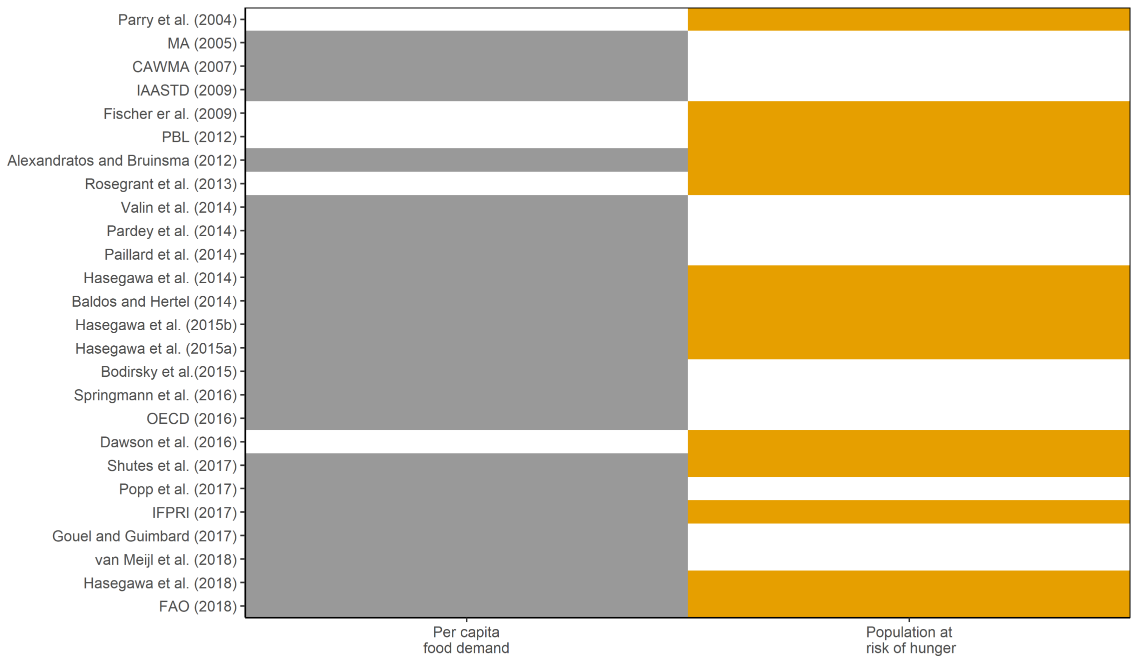

Figure S3: Coverage of per capita food demand and population at risk of hunger

A.2 Mapping to the SSPs and RCPs

We were able to harvest data for 593 per capita food demand and 358 population at risk of hunger projections (Figure S2). To make the projections comparable across studies we mapped the scenario assumptions underlying the projections to the Shared Socio-economic Pathways (SSPs). The SSPs are a set of five storylines that describe potential but realistic global futures: Sustainability (SSP1), Middle of the Road (SSP2), Regional Rivalry (SSP3), Inequality (SSP4) and Fossil-fueled Development (SSP5) (Vuuren et al. 2017; O'Neill et al. 2017). They were designed for climate change assessments but are increasingly used for the evaluation of other global issues. Around 88-90% of the harvested projections were already based on the SSP framework (Figure S4).

For the remaining studies, we used Vuuren et al. (2012) and Vuuren and Carter (2014), who demonstrated that assumptions of many global socio-economic scenarios (including the SSPs) are comparable and can be classified into five archetypal scenario 'families.' We assumed that projections based on the SSPs and projections based on scenarios with the same characteristics (i.e. belonging to the same 'family') can be directly compared. In all other cases, we reviewed the storylines and assumptions underlying the projections and allocated them to the SSPs with comparable characteristics. We labeled all projections that were produced using the SSP storylines as 'Pure' SSP projections. Projections that were based on different storylines and/or drivers but belonged to the same scenario family as one of the SSPs were labeled as 'Derived' SSP projections. In a few cases, we were not able to categorize the projections and therefore labeled them as 'No Class' (Table S1)

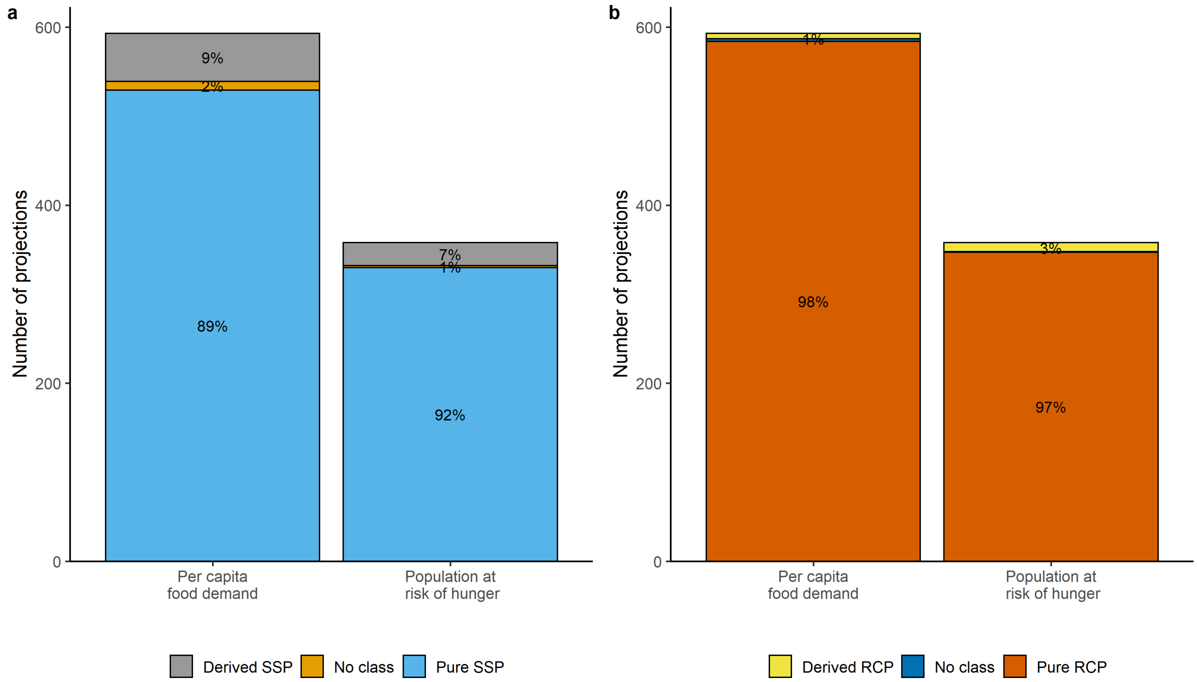

Figure S4: Mapping of projections (including baseline and policy shock types) to the SSPs (a) and RCPs (b). Pure SSPs/RCPs are projections that use the SSP/RCP framework. Derived SSPs/RCPs are projections that were mapped to the SSPs/RCPs using. No class refers to projections that could not be mapped to the SSPs/RCP.

We used the Representative Concentration Pathways (RCPs) framework to compare different climate change scenarios. The RCPs are a set of scenarios to reflect different potential climate outcomes used in recent IPCC climate assessment reports (Vuuren et al. 2011). They were designed to be combined with the SSPs as part of a scenario 'matrix' that encompasses the full spectrum of future socio-economic and climate change pathways (Vuuren et al. 2014). Already around 97-98% of the projections use the RCPs as input (Figure S4). Similar to the SSP mapping, we distinguished between 'Pure,' 'Derived' and 'No class' RCPs. Drawing upon Vuuren and Carter (2014) and our own analysis, we mapped the majority of climate change projections to the RCPs (Table S2).

Study	SSP1	SSP2	SSP3	SSP4	SSP5	No class
Alexandratos and Bruinsma (2012)		Baseline				
Baldos and Hertel (2014)		baseline, co2_fert, demand_only, no_co2				
Bodirsky et al.(2015)	B1	B2	A2		A1	
CAWMA (2007)						Pessimistic rainfed
Dawson et al. (2016)		A1B_ccsm30, A1B_cgcm31, A1B_echam5, A1B_hadcm3, A1B_ipsl, A1B_nocc				
FAO (2018)	Toward Sustainability	Business As Usual		Stratified Societies		
Fischer er al. (2009)			REF-01			
Gouel and Guimbard (2017)		trend				
IAASTD (2009)		Reference scenario				High AKST, High AKST High, Low AKST, Low AKST Low
MA (2005)	TechnoGarden		Order from Strength			Adapting Mosaic, Global Orchestration
OECD (2016)	Sust_GrnC, Sust_Infr, Sust_Irrg, Sust_none, Sust_RobV, Sust_TrdC			RegG_GrnC, RegG_Infr, RegG_Irrg, RegG_none, RegG_RobV, RegG_TrdC	Glob_GrnC, Glob_Infr, Glob_Irrg, Glob_none, Glob_RobV, Glob_TrdC	
Paillard et al. (2014)	Agrimonde 1					Agrimonde GO
Pardey et al. (2014)		midline				
Parry et al. (2004)	B1	B2	A2		A1F2	
PBL (2012)		Trend				
Shutes et al. (2017)	ECO		TLTL		FFANF	ONEPW

Table S1: Mapping of projections (including baseline and policy shock types) to the SSPs based on Vuuren et al. (2012) and Vuuren and Carter (2014) and authors' analysis. The table shows the mapping of Derived SSPs as well as No class scenarios that could not be mapped to the SSPs.

Study	RCP2.6	RCP4.5	RCP6.0	RCP8.5	No class
Baldos and Hertel (2014)				no_co2	co2_fert
Bodirsky et al.(2015)		B1	B2	A1, A2	
CAWMA (2007)					
Dawson et al. (2016)			A1B_ccsm30, A1B_cgcm31, A1B_echam5, A1B_hadcm3, A1B_ipsl		
Paillard et al. (2014)	Agrimonde 1				Agrimonde GO
Parry et al. (2004)		B1	A1F2, B2	A2	

Table S2: Mapping of projections (including baseline and policy shock types) in the Global Food Security Projections Database to the RCPs based on Vuuren and Carter (2014) and authors' analysis. The table only shows the mapping for Derived RCPs as well as No class scenarios that could not be mapped to the RCPs.

A.3 Baseline and policy shock projections

We divided the projections into two types: baseline and policy shock projections (S5. The first type is based on the assumptions of baseline scenarios, which assume that socio-economic development, including global food security will be determined by future changes in the socioeconomic drivers (and associated major policy changes that can regarded as exogenous to the analysis) (Dellink, Mensbrugghe, and Saveyn 2020). The SSPs are considered as baseline scenarios. The second type are baseline scenarios extended with assumptions on additional policies to investigate the impact of those policies on global food security. The difference between the baseline and policy shock projection is a measure of policy impact (Börjeson et al. 2006).

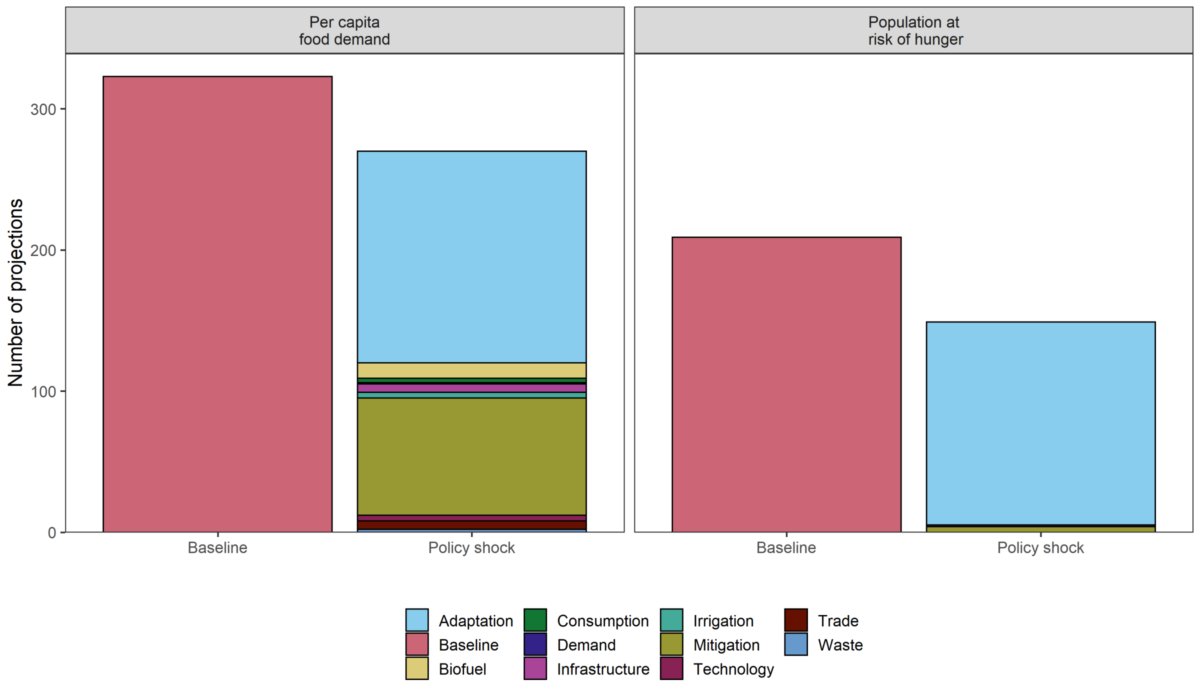

Figure S5: Number of baseline and policy shock projections.

A.4 Further harmonization

After the SSP and RCP mapping, we made additional adjustments to the data to make them comparable. First, we used simple linear interpolation to impute missing data, e.g. in cases where the data was only available for the base year and a few intermediate years up to 2050. Second, we calculated global food demand (in 1e15 kcal) by multiplying food demand per capita with study- and projection-specific population projections. Where possible, we took the population projections from the selected studies. If these were not available we used population data from the source that was referenced. Three sources of population projections were used in the selected studies: the Shared Socio-economic Pathways (SSP Database 2016), the Special Report on Emissions Scenarios (SRES) (Nakicenovic et al. 2000) and the UN World Population Prospects (https://population.un.org/wpp). Third, where needed we converted prevalence of undernourishment projections into population at risk of hunger series using the collected information on population projections. Finally, we converted all projections in an index with base year 2010 and subsequently multiplied with 3-year average base year variables from FAO (2020) to create the final series.

B Meta analysis

We separately analyzed the baseline and policy shock projections in our database. The baseline projections can relatively easily be compared using a meta-regression approach as the underlying assumptions are comparable. The policy shock projections, on the other hand, use a wide number of assumptions to assess the impact of a large number of different policies and are therefore much harder to compare. For this reason, we started by analyzing the plausible bandwidth of the baseline projections and, subsequently, compare this with the range of policy shock projections (Figure S8).

For each of the three food security indicators and including only baseline projections that could be mapped to the SSPs/RCPs (Figure S2), we ran a mixed model meta-regression function including a combination of fixed and random effects to derive SSP- and RCP-specific point estimates and confidence intervals (see Methods in main manuscript). We added random effects for both study and model as we assume that, although comparable, outcomes will vary both across studies and models because of differences in study and model design. The projections in our sample can be regarded as random samples of all projections that could have been observed. Under these assumptions a random effects model (as opposed to a fixed effects model) is recommended for meta-analysis (Borenstein et al. 2009). We also included fixed effects for all SSP-RCP combinations and dummy variables for pure (as opposed to derived) SSP and RCP scenarios. The latter account for the differences between projections that use the SSP drivers and storylines as input and projections that use comparable but not identical assumptions. Using information from our analysis of the selected studies and used methodologies, we also investigated the impact of additional projection and study-level determinants. At the projection level, we included the base year of the model and the methodology (CGE, PE, other model, statistical extrapolation and expert input). At the study level, we added type of publication (journal article, book (chapter) and working paper/report), year of publication and single or multi-model study.

To select the models with the best fit, we applied the step-down strategy, which starts with a model that includes all fixed and random effects, followed by the stepwise removal of fixed effects with a p-value larger than 0.1 and random effects with a p-value larger then 0.1 (Diggle et al. 2002; Zuur et al. 2009; Kuznetsova, Brockhoff, and Christensen 2017). The results show that models with only random effects for study and model, and fixed effects for pure SSP and pure RCP have the best fit. Depending on the food security indicator, one of the random and fixed effects was sometimes dropped. All other explanatory variables were always dropped, independent of the indicator. For model comparability and from a theoretical perspective, we decided to select the same model for all three variables, including random effects for study and model and fixed effects for pure SSP and pure RCP.

Table S3 shows the details of the estimated models. We decided to exclude the population at risk of hunger projections from Dawson, Perryman, and Osborne (2016) from the meta-analysis. The model used by Dawson, Perryman, and Osborne (2016) is not able to incorporate the impact of technological change and trade on population at risk of hunger, resulting in extreme values (i.e. more than 40 times above $q_{0.75} + IQR$, whereas above 3 is already considered as an extreme outlier). Including these observations resulted in biased model estimates.

Figure S6 and Figure S7 depict pairwise p-value plots to bilaterally compare the difference between SSP-NOCC estimated means and between NOCC and RCP8.5 estimated means. Pairwise p-value plots for bilateral comparison of SSP-NOCC estimated means. Pairwise comparisons were performed with the emmeans R package (Russel 2020), using the Satterthwaite's degrees of freedom method and the Tukey adjustment for p-values. Each comparison is associated with a vertical line segment whose horizontal position is determined by the p-value of that comparison. SSPs/NOCC and RCP8.5 are plotted on the vertical scale, and p-values are plotted on the horizontal scale. The p-value scale is nonlinear, stretching out smaller p values and compressing larger ones. A large number of pairwise SSP-NOCC comparisons have p-values lower than 0.05, which indicates that the difference between the estimated means is 'significant.' In contrast, nearly all NOCC-RCP8.5 have p-values around 1, which suggests that there is no statistical difference in the estimated means of no climate change and extreme climate change projections.

	P.c. food demand	T. food demand	Pop. at risk of hunger
Constant	18.15***	59.28***	−69.41***
	(2.75)	(4.22)	(11.36)
SSP1.NOCC	0.60	−9.68***	−11.06***
	(0.76)	(1.13)	(2.04)
SSP3.NOCC	−7.98***	0.01	45.85***
	(0.67)	(0.98)	(2.04)
SSP4.NOCC	−4.89***	−7.28***	39.89***
	(1.31)	(1.94)	(5.55)
SSP5.NOCC	3.58***	−3.84*	−13.94***
	(1.08)	(1.63)	(3.66)
SSP1.RCP2.6	3.02***	−8.29***	−14.50***
	(0.87)	(1.31)	(2.85)
SSP2.RCP2.6	−0.78	−0.91	3.08
	(0.88)	(1.31)	(2.78)
SSP3.RCP2.6	−8.02***	2.22	49.45***
	(0.90)	(1.34)	(2.85)
SSP1.RCP4.5	1.91*	−9.10***	−13.51***
	(0.95)	(1.42)	(2.82)
SSP2.RCP4.5	−1.27	−1.65	5.19
	(0.99)	(1.47)	(2.85)
SSP3.RCP4.5	−8.36***	1.97	52.97***
	(0.99)	(1.47)	(2.85)
SSP4.RCP4.5	−5.35*	2.53	
	(2.12)	(3.45)	
SSP1.RCP6.0	2.56**	−8.56***	−14.64***
	(0.88)	(1.31)	(2.85)
SSP2.RCP6.0	−0.93	−1.53	4.28
	(0.86)	(1.29)	(2.82)
SSP3.RCP6.0	−8.31***	1.79	49.39***
	(0.88)	(1.31)	(2.85)
SSP5.RCP6.0			−10.36
			(6.11)
SSP1.RCP8.5	1.72	−9.78***	−11.56***
	(0.99)	(1.47)	(2.85)
SSP2.RCP8.5	−1.19	−2.05*	6.98**
	(0.64)	(0.96)	(2.68)
SSP3.RCP8.5	−8.48***	2.53	55.61***
	(0.97)	(1.44)	(2.84)
SSP4.RCP8.5	−3.60	−10.59*	65.43***
	(3.27)	(4.69)	(6.41)
SSP5.RCP8.5	2.31	−1.21	
	(1.79)	(2.84)	
Pure SSP	−1.83*	−2.51	10.03
	(0.92)	(2.00)	(13.87)
Pure RCP	−4.55*	−6.42	3.12
	(1.83)	(3.66)	(7.06)
AIC	1581.02	1801.26	1222.85
BIC	1674.99	1895.24	1302.01
Log Likelihood	−765.51	−875.63	−587.43
Num. obs.	317	317	200
Num. groups: study_short	20	20	13
Num. groups: model	18	18	13
Var: study_short (Intercept)	0.33	10.24	532.70
Var: model (Intercept)	83.37	107.09	129.67
Var: Residual	6.82	14.04	22.87

$^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$

Table S3: Meta-regression models for percentage change in per capita food consumption, total food consumption and population at risk of hunger for the period 2010-2050. SSP2.NOCC is used as reference for the SSP.RCP interactions.

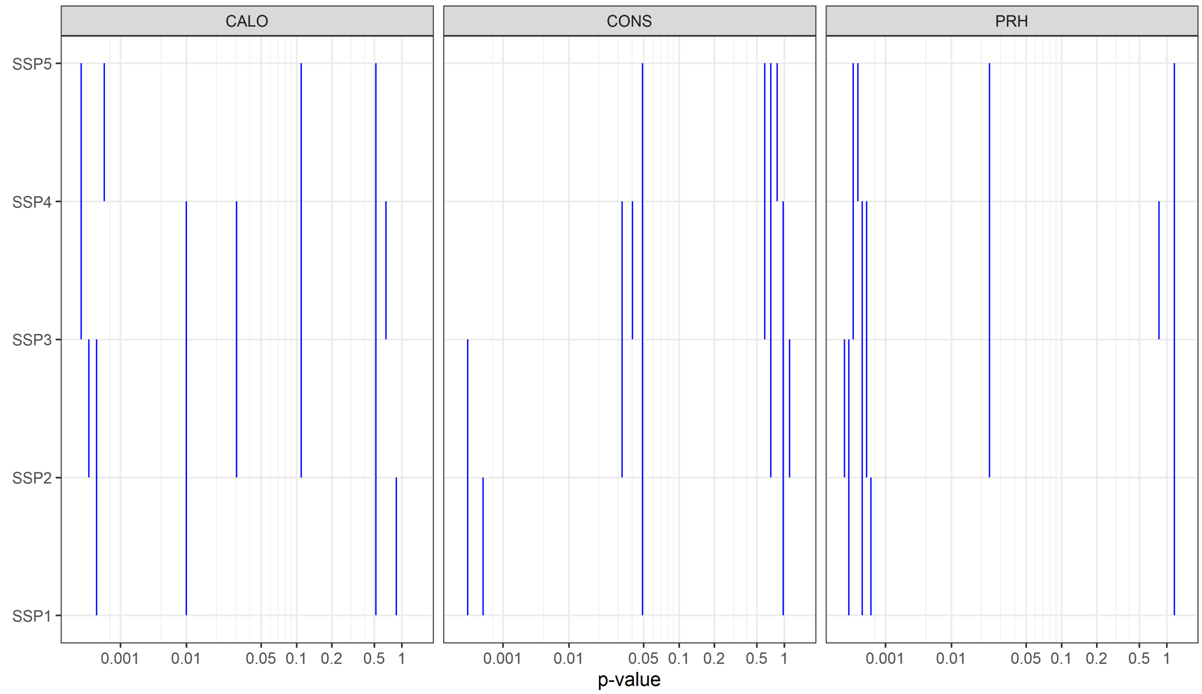

Figure S6: Pairwise p-value plots for bilateral comparison of NOCC-SSP estimated means per food security indicator. P-values are bounded by 1 but are slightly spread to avoid overplotting.

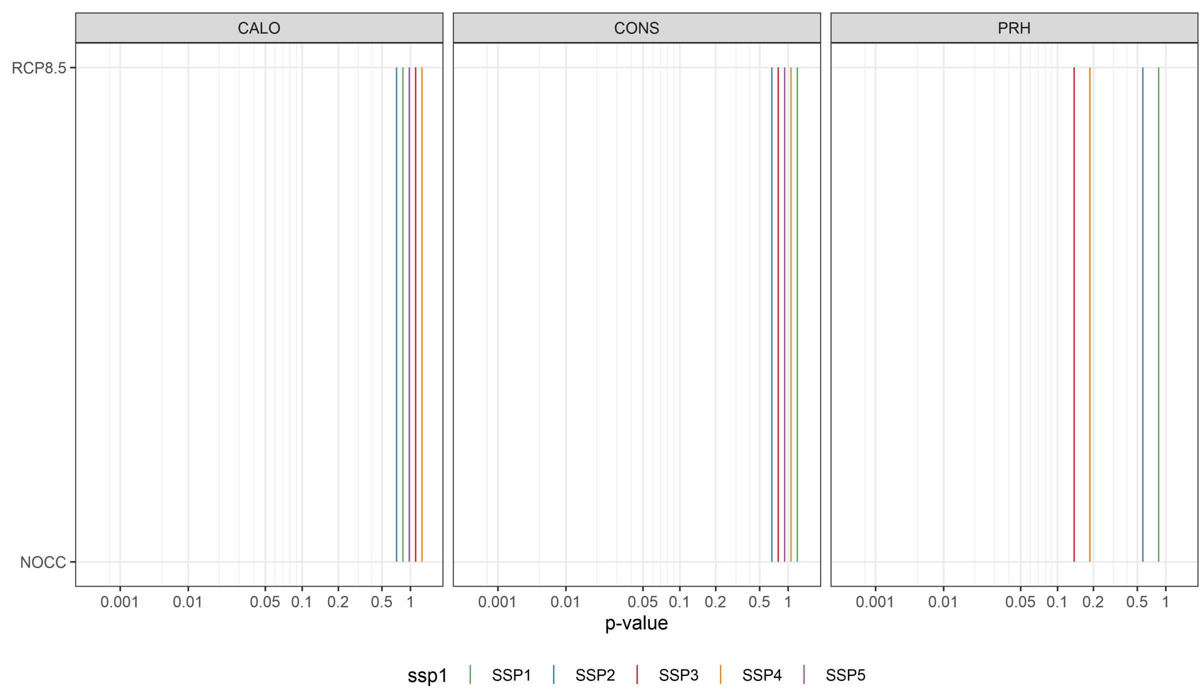

Figure S7: Pairwise p-value plots for bilateral comparison of NOCC and RCP8.5 estimated means for each SSP per food security indicator. P-values are bounded by 1 but are slightly spread to avoid overplotting.

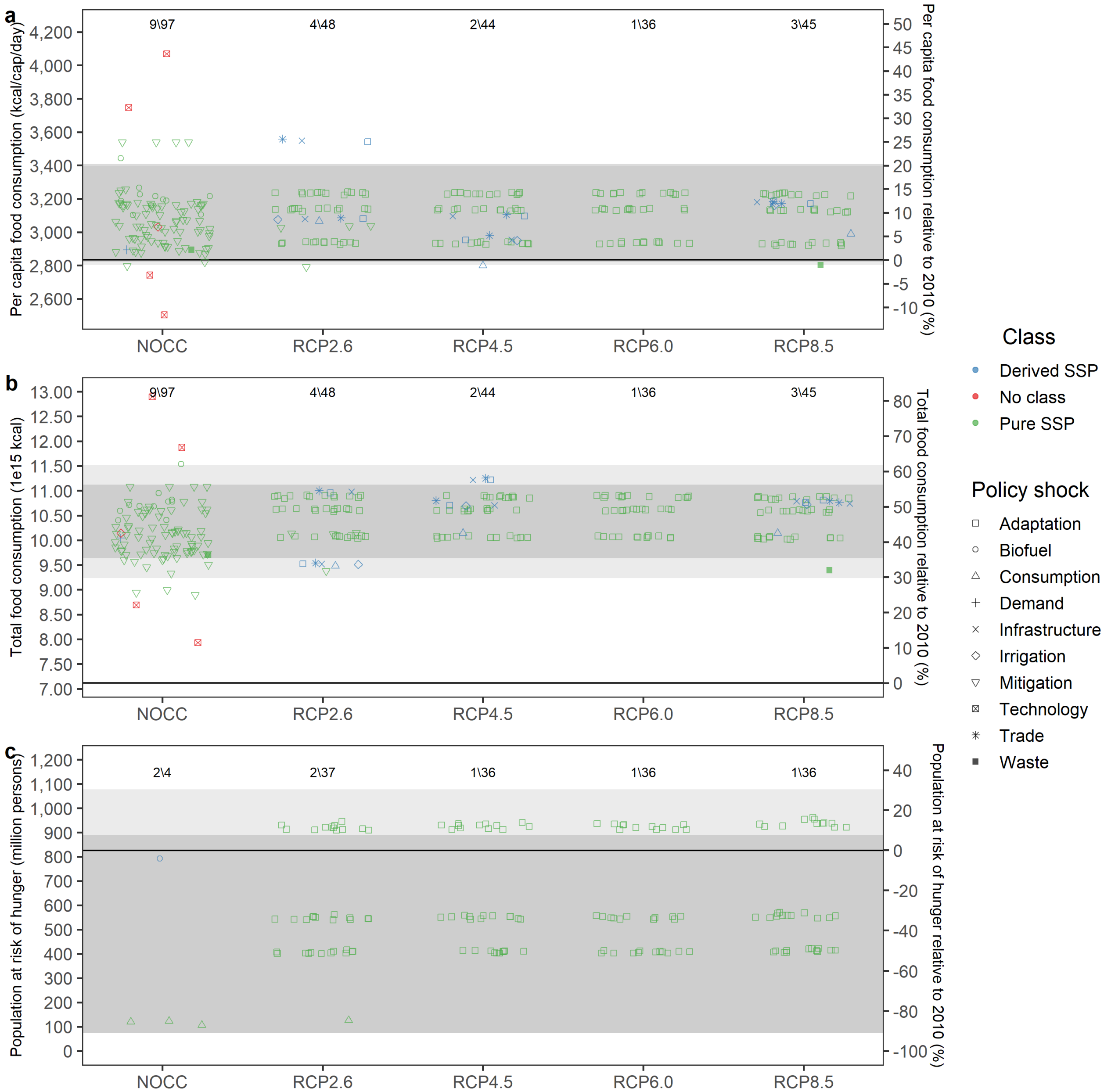

Figure S8: Comparison of baseline and policy shock projections with the derived plausible range of projections. a per capita food demand, b total food demand and c population at risk of hunger. The numbers on top refer to the number of studies/number of projections in the figure. The dark and light grey shaded areas demarcate the plausible range of projections using the 95% confidence interval across all NOCC SSP and all RCP SSP projections, respectively. See Manuscript for details.

C Impact of methodology on projections

Table S4 formally compares the impact of methodology on the size and direction of global food security projections. We distinguished between five different approaches: (1) computable general equilibrium (CGE) model (reference), (2) partial equilibrium (PE) model, (3), other model, (4) statistical extrapolation and (5) expert input. Other model include biophysical (Agribiom), econometric models (iAP) and integrated assessment (IMAGE) models. Apart from the other model group in the estimation for per capita food demand, there is no evidence that methodology has an impact.

	Per capita food demand	Total food demand	Pop. at risk of hunger
Constant	24.53^{***}	66.01^{***}	-67.60^{***}
	(3.99)	(5.78)	(13.72)
PE model	−6.13	−5.22	−5.88
	(4.83)	(5.90)	(9.89)
Other model	-15.43^{*}	−14.29	2.70
	(6.26)	(7.85)	(15.27)
Statistical extrapolation	−7.50	−8.35	
	(9.35)	(11.67)	
Expert input	−11.02	−14.82	5.52
	(9.70)	(12.38)	(30.67)
SSP.RCP interaction	Yes	Yes	Yes
Pure SSP	Yes	Yes	Yes
Pure RCP	Yes	Yes	Yes
AIC	1559.87	1780.60	1206.22
BIC	1668.88	1889.61	1295.27
Log Likelihood	−750.93	−861.30	−576.11
Num. obs.	317	317	200
Num. groups: study_short	20	20	13
Num. groups: model	18	18	13
Var: study_short (Intercept)	0.22	9.61	604.12
Var: model (Intercept)	73.63	107.56	155.04
Var: Residual	6.84	14.07	22.86

$^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$

Table S4: Meta-regression models for percentage change in per capita food consumption, total food consumption and population at risk of hunger for the period 2010-2050, including dummy variables to test for the impact of methodology on projections.

D Selection bias

Our study might have been affected by two types of selection bias. The first is publication bias, which is of major concern in systematic literature reviews and meta-analysis. It generally refers to the bias that is introduced when the selected studies mostly include scientific studies that are published in journals, which tend to present 'significant' findings, while working papers and reports (i.e. unpublished studies) with contrasting results are not sufficiently covered (Borenstein et al. 2009).

Many global food security assessments are produced by international institutions such as the International Food Policy Research Institute (IFPRI) (Nelson et al. 2010), The Food and Agriculture Organization (FAO) (Alexandratos and Bruinsma 2012), the International Water Management Institute (IWMI) (Comprehensive Assessment of Water Management in Agriculture 2007) and the United Nations Environment Programme (UNEP) (UNEP 2007, 2012) that tend to release their findings in policy reports. For this reason, we searched extensively for grey literature in the search phase of the systematic literature review. Out of the 57 selected studies 18 (32%), were unpublished at the time of our analysis.

To formally test if there were differences in the direction and size of published and unpublished global food security projections, we added a dummy variable to our meta-analytical model that distinguishes between both groups of studies. As several reports were published by scientific publishers (e.g. Millennium Ecosystem Assessment 2005; IAASTD 2009; UNEP 2012), we separately tested for differences with journal articles only and the combination of journal articles and book (chapters) (Table S5). The coefficients of all dummy variables are relatively small and insignificant, which indicates that publication bias probably did not affect our analysis.

Apart from selection bias, another potential source of bias is the possibility of non-randomness in the selection of studies for which quantitative information was extracted (Figure S1). To investigate this we compared the characteristics of these studies with those for which data was missing. Figure S9 shows the differences for methodology, single or multi-model study, published or unpublished study, study year and scenario type, which are the variables for which we collected information as part of the systematic literature review. The comparison suggests that the two groups of studies are broadly comparable and do not provide evidence for potential selection bias related to the extraction of projections. Finally, we also summarized the main outcomes of studies that presented per capita demand and population at hunger projections but for which data could not be extracted (Table S6 and Table S7). A comparison shows considerable overlap between the results of these studies and our estimated plausible range of projections, confirming our main findings.

	Journal only			Journal and book		
	P.c. food demand	T. food demand	Pop. at risk of hunger	p.c food demand	T. food demand	Pop. at risk of hunger
Constant	17.80***	55.91***	−67.35***	16.87***	56.01***	−67.35***
	(3.01)	(4.58)	(13.03)	(2.97)	(4.77)	(13.03)
Published in journal	−0.07	4.00	−6.11			
	(0.88)	(2.24)	(17.38)			
Published in journal or book				0.83	3.21	−6.11
				(0.83)	(2.11)	(17.38)
SSP.RCP interaction	Yes	Yes	Yes	Yes	Yes	Yes
Pure SSP	No	Yes	Yes	No	Yes	Yes
Pure RCP	Yes	Yes	Yes	Yes	Yes	Yes
AIC	1585.10	1796.71	1217.21	1584.15	1797.71	1217.21
BIC	1679.08	1894.45	1299.67	1678.12	1895.44	1299.67
Log Likelihood	−767.55	−872.36	−583.61	−767.08	−872.86	−583.61
Num. obs.	317	317	200	317	317	200
Num. groups: study_short	20	20	13	20	20	13
Num. groups: model	18	18	13	18	18	13
Var: study_short (Intercept)	0.60	8.76	578.35	0.14	8.40	578.35
Var: model (Intercept)	79.21	100.59	131.29	78.36	104.96	131.29
Var: Residual	6.89	14.06	22.87	6.96	14.09	22.87

$^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$

Table S5: Meta-regression models for percentage change in per capita food consumption, total food consumption and population at risk of hunger for the period 2010-2050, including dummy variables to test for the impact of (un)published studies on projections. Pure SSP dummy was removed from per capita food demand models to avoid singularity issues.

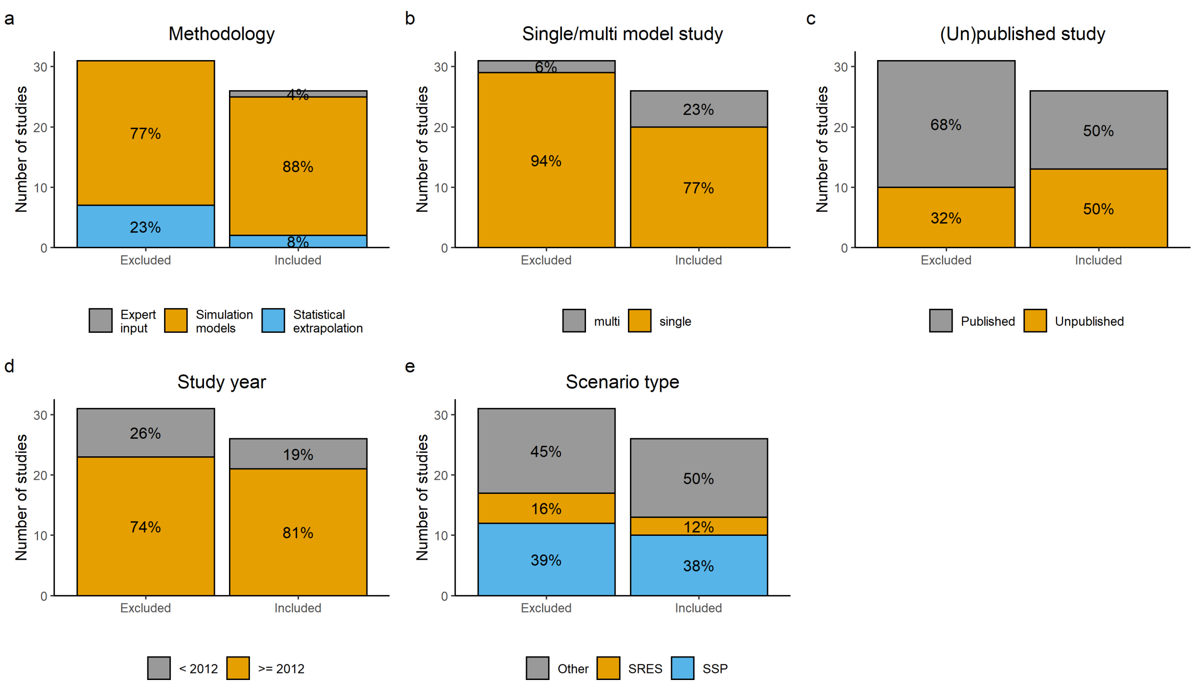

Figure S9: Comparison of characteristics between studies for which projections are in/excluded in the Global Food Security Projections Database. Published studies consists of journal articles and books or book chapters. Published studies include journal articles and book (chapters), unpublished studies include working papers, reports and conference proceedings.

Study	Data availability	Scenarios	Results	Analysis
Bijl et al. (2017)	Projections only presented in graphical format	SSP1-3	Global kcal/cap/day is~3500 (SSP1), ~3200 (SSP2) and ~3100 (SSP3)	Within 95% SSP1-3 range apart from SSP1, which is slightly higher
CAWMA (2007)	Policy shock projections only	UN population projections and variations	Cannot be assessed	Cannot be assessed
Fujimori et al. (2018)	Projections only presented in graphical format and in relative form	SSP1-3	Cannot be assessed	Cannot be assessed
Havlik et al. (2015)	Projections only presented in graphical format and in relative form	SSP4-5, RCP2.6-8.5	Global per capita food consumption in SSP4-5 decreases to ~ 0.5-1.5% for the period 2000-2050	Cannot be assessed
Keating and Carberry (2010)	Base year values not presented	UN population projections and variations	Global per capita food consumption is between 2775-3590 kcal/cap/day in 2050	Overlapping with 95% SSP1-5 range but higher maximum value
Kii et al. (2013)	Projections not presented	SRES	Cannot be assessed	Cannot be assessed
Laborde (2017)	Projections only presented in graphical format and in relative form	FOODSECURE	Cannot be assessed	Cannot be assessed
Millennium Institute (2013)	Base year values not presented	UN population projections and variations	Global per capita food consumption is ~3100 kcal/cap/day in 2050	Within 95% SSP2 range
Mosnier et al. (2014)	Projections only presented in graphical format and in relative form	SRES	Cannot be assessed	Cannot be assessed
Msangi and Rosegrant (2009)	Projections only presented in graphical format and in relative form	SRES	Cannot be assessed	Cannot be assessed
Nelson et al. (2010)	Projections only presented in relative format	SRES	Cannot be assessed	Cannot be assessed
Obersteiner et al. (2016)	Projections only presented in graphical format	SSP1-3	Global per capita food consumption is ~2250 kcal/cap/day (SSP1), ~2500 kcal/cap/day (SSP2) and ~2400 kcal/cap/day (SSP3) in 2050	Outside 95% SSP1-3 range, do not seem comparable
Odegard and Van der Voet (2014)	Base year values not presented	SRES	Global per capita food consumptionis between 2800-2900 kcal/cap/day in 2050	Within 95% SSP1-5 range
Tilman et al. (2011)	Calorie consumption is expressed in total crop calories, including feed	UN population projections	100–110% increase in total calorie demand	Cannot be assessed
UNEP (2007)	Projections only presented in graphical format	GEO4 scenarios	Global per capita food availability is ~3000-4000 kcal/cap/day in 2050	Outside 95% SSP1-3 range, do not seem comparable
UNEP (2012)	Projections only presented in graphical format	GEO5 scenarios	Global per capita food availability is ~2700-4000 kcal/cap/day in 2050	Overlapping with 95% SSP1-5 range but higher maximum value
Valin et al. (2013)	Projections only presented in graphical format and in relative form	SSP2 and variations	Cannot be assessed	Cannot be assessed

Table S6: Narrative analysis of studies for which per capita food demand could not be extracted.

Study	Data availability	Scenarios	Results	Analysis
Baldos and Hertel (2015)	Projections only presented in relative format	SSPs, various climate change scenarios	Cannot be assessed	Cannot be assessed
Bijl et al. (2017)	Projections only presented in graphical format	SSP1-3	Total population at risk of hunger in SSP1-3 decreases to ~250 million people in 2050	Within 95% SSP1-3 range
Fischer at al. (2005)	Projections only presented in graphical format and for developing country group	SRES	Total population at risk of hunger decreases to ~200-700 million people in 2050	Within 95% SSP1-5 range
Fujimori et al. (2018)	Projections only presented in graphical format and/or in relative form	SSP2, various climate change scenarios	Total population at risk of hunger in SSP2 decreases to ~238 million people in 2050	Within 95% SSP2 range
Hertel and Baldos (2016)	Projections only presented in graphical format and/or in relative form	SSPs	Cannot be assessed	Cannot be assessed
Millennium Institute (2013)	Base year values not presented	UN population projections and variations	% total population at risk of hunger decreases to 3.6% in 2050	Within 95% SSP2 range
Parry et al. (2005)	Base year values not presented and results largly presented in graphical format	UN population projections, various climate change scenarios	Total population at risk of hunger decreases to 641 million people in 2050	Somewhat higher than the 95% SSP2 range

Table S7: Narrative analysis of studies for which population at risk of hunger could not be extracted.

Finally, we investigated if the four projections (one implemented by two models) for which data was extracted but could not be mapped to the SSPs/RCPs were in line with our findings. Figure S10 compares these No class projections with the plausible range of projections based on the 95% confidence interval from the meta-analysis for the year 2050. Only Global Orchestration (IMPACT) for per capita food consumption is a clear outlier as it is somewhat higher that the maximum range. Also ONEWP (GLOBIOM) can be considered as an outlier as it assumes no climate change but is positioned outside the no climate change bandwidth. The rest of the observations are located within the estimated bandwidth of projections for the three food security indicators.

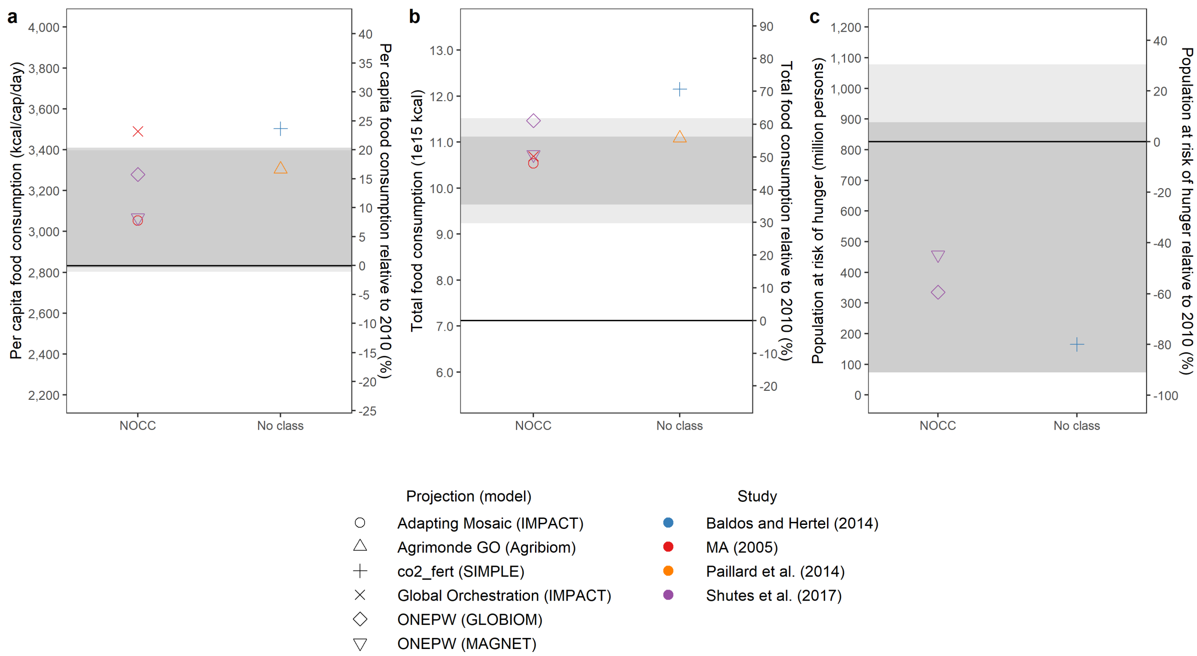

Figure S10: Comparison of No class SSP and/or RCP projections with the derived plausible range of projections. a per capita food demand, b total food demand and c population at risk of hunger. The dark and light grey shaded areas demarcate the plausible range of projections using the 95% confidence interval across all NOCC SSP and all RCP SSP projections, respectively. See Manuscript for details.

E Selected studies for the systematic literature review

Alexandratos, N. and J. Bruinsma. “World agriculture towards 2030/2050: The 2012 Revision.” Rome, 2012.

Baldos, U. L. C. and T. W. Hertel. “Debunking the â€˜new normal’: Why world food prices are expected to resume their long run downward trend.” In: *Global Food Security* 8 (Mar. 2016), pp. 27-38. ISSN: 22119124. DOI: 10.1016/j.gfs.2016.03.002.

Baldos, U. L. C. and T. W. Hertel. “Global food security in 2050: The role of agricultural productivity and climate change.” In: *Australian Journal of Agricultural and Resource Economics* 58.4 (2014), pp. 554-570. ISSN: 14678489. DOI: 10.1111/1467-8489.12048.

Baldos, U. L. C. and T. W. Hertel. “The role of international trade in managing food security risks from climate change.” In: *Food Security* 7.2 (Apr. 2015), pp. 275-290. ISSN: 1876-4517. DOI: 10.1007/s12571-015-0435-z.

Bijl, D. L., P. W. Bogaart, S. C. Dekker, E. Stehfest, B. J. M. de Vries, and D. P. van Vuuren. “A physically-based model of long-term food demand.” In: *Global Environmental Change* 45 (2017), pp. 47-62. ISSN: 09593780. DOI: 10.1016/j.gloenvcha.2017.04.003.

Billen, G., L. Lassaletta, and J. Garnier. “A vast range of opportunities for feeding the world in 2050: Trade-off between diet, N contamination and international trade.” In: *Environmental Research Letters* 10.2 (2015). ISSN: 17489318 (ISSN). DOI: 10.1088/1748-9326/10/2/025001.

Bodirsky, B., S. Rolinski, A. Biewald, I. Weindl, A. Popp, and H. Lotze-Campen. “Global Food Demand Scenarios for the 21st Century.” In: *PLOS ONE* 10.11 (Nov. 2015). Ed. by A. Belgrano, p. e0139201. ISSN: 1932-6203. DOI: 10.1371/journal.pone.0139201.

Comprehensive Assessment of Water Management in Agriculture. *Water for Food, Water for Life: A Comprehensive Assessment of Water Management in Agriculture.* London: Earthscan, 2007.

Dawson, T. P., A. H. Perryman, and T. M. Osborne. “Modelling impacts of climate change on global food security.” In: *Climatic Change* 134.3 (2016), pp. 429-440. ISSN: 01650009 (ISSN). DOI: 10.1007/s10584-014-1277-y.

FAO. *The future of food and agriculture - alternative pathways to 2050.* Tech. rep. Rome: Food and Agriculture Organization, 2018.

Fischer, G., E. Hizsnyik, S. Prieler, M. Shah, and V. V. H. *Biofuels and food security.* Tech. rep. The OPEC Fund for International Development (OFID), 2009.

Fischer, G., M. Shah, F. N. Tubiello, and v. V. H. “Socio-economic and climate change impacts on agriculture: an integrated assessment, 1990-2080.” In: *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences* 360.1463 (2005), pp. 2067-2083. ISSN: 0962-8436.

Fujimori, S., T. Hasegawa, J. Rogelj, X. Su, P. Havlik, V. Krey, K. Takahashi, and K. Riahi. “Inclusive climate change mitigation and food security policy under 1.5 â—¦ C climate goal.” In: *Environmental Research Letters* 13.7 (2018). ISSN: 17489326. DOI: 10.1088/1748-9326/aad0f7.

Gouel, C. and H. Guimbard. *Nutrition Transition and the Structure of Global Food Demand.* Tech. rep. April. CEPI, 2017.

Hasegawa, T., S. Fujimori, P. Havlik, H. Valin, B. L. Bodirsky, J. C. Doelman, T. Fellmann, P. Kyle, et al. “Risk of increased food insecurity under stringent global climate change mitigation policy.” In: *Nature Climate Change* 8.8 (Aug. 2018), pp. 699-703. ISSN: 1758-678X. DOI: 10.1038/s41558-018-0230-x.

Hasegawa, T., S. Fujimori, Y. Shin, K. Takahashi, T. Masui, and A. Tanaka. “Climate change impact and adaptation assessment on food consumption utilizing a new scenario framework.” In: *Environmental Science and Technology* 48.1 (2014), pp. 438-445. ISSN: 0013936X (ISSN). DOI: 10.1021/es4034149.

Hasegawa, T., S. Fujimori, Y. Shin, A. Tanaka, K. Takahashi, and T. Masui. “Consequence of Climate Mitigation on the Risk of Hunger.” In: *Environmental Science and Technology* 49.12 (2015), pp. 7245-7253. ISSN: 0013936X (ISSN). DOI: 10.1021/es5051748.

Hasegawa, T., S. Fujimori, K. Takahashi, and T. Masui. “Scenarios for the risk of hunger in the twenty-first century using Shared Socioeconomic Pathways.” In: *Environmental Research Letters* 10.1 (2015), p. 014010. ISSN: 1748-9326. DOI: 10.1088/1748-9326/10/1/014010.

Havlik, P., H. Valin, M. Gusti, E. Schmid, E. Leclère, N. Forsell, M. Herrero, N. Khabarov, et al. *Climate change impacts and mitigation in the developing world: an integrated assessment of the agriculture and forestry sectors.* Tech. rep. Washington; USA: World Bank, 2015.

Hertel, T. W. and U. L. C. Baldos. “Attaining food and environmental security in an era of globalization.” In: *Global Environmental Change* 41 (2016), pp. 195-205. ISSN: 09593780. DOI: 10.1016/j.gloenvcha.2016.10.006.

Hunter, M. C., R. G. Smith, M. E. Schipanski, L. W. Atwood, and D. A. Mortensen. “Agriculture in 2050: Recalibrating Targets for Sustainable Intensification.” In: *BioScience* (2017), pp. 386-391.

IAASTD. *Agriculture at a crossroad - global report.* Washington DC: Island Press, 2009.

IFPRI. *Global Food Policy Report 2017.* Washington, D.C.: International Food Policy Research Institute, 2017.

Ishida, H., S. Kobayashi, S. Kanae, T. Hasegawa, S. Fujimori, Y. Shin, K. Takahashi, T. Masui, et al. “Global-scale projection and its sensitivity analysis of the health burden attributable to childhood undernutrition under the latest scenario framework for climate change research.” In: *Environmental Research Letters* 9 (2014) 0.6 (May. 2014), pp. 1-9. ISSN: 1748-9326. DOI: 10.1088/1748-9326/9/6/064014.

Keating, B. A. and P. S. Carberry. “Sustainable production, food security and supply chain implications.” In: *Aspects of biology* (2010), pp. 7-19.

Kii, M., K. Akimoto, and A. Hayashi. “Risk of hunger under climate change, social disparity, and agroproductivity scenarios.” In: *Environmental Modeling & Assessment* 18.3 (2013), pp. 299-317. ISSN: 1420-2026.

Laborde, D. “An illustration of the 2050 Toolbox: Using the MIRAGRODEP model to investigate four stakeholders’ scenarios.” In: *Deliverable 7.4: Long-term supply, food and non-food demand drivers, contrasting scenarios and their impact on FNS: A report on long-term supply, food and non-food demand drivers, contrasting scenarios and their impact on FNS based on the Toolbox 2050.* 2017, pp. 76-115.

Linehan, V., S. Thorpe, C. Gunning-Trant, E. Heyhoe, K. Harle, M. Hormis, and K. Harris-Adams. “Global food production and prices to 2050: Scenario analysis under policy assumptions.” In: *43rd ABARES Outlook conference.* Canberra, 2013.

Lloyd, S. J., R. Sari Kovats, Z. Chalabi, R. S. Kovats, and Z. Chalabi. “Climate Change, Crop Yields, and Undernutrition: Development of a Model to Quantify the Impact of Climate Scenarios on Child Undernutrition.” In: *Environmental Health Perspectives* 119.12 (Aug. 2011), pp. 1817-1823. ISSN: 0091-6765. DOI: 10.1289/ehp.1003311.

Medek, D. E., J. Schwartz, and S. S. Myers. “Estimated Effects of Future Atmospheric CO2 Concentrations on Protein Intake and the Risk of Protein Deficiency by Country and Region.” In: *Environmental health perspectives* 125.8 (2017), pp. 87001-87002. ISSN: 15529924 (ISSN). DOI: 10.1289/ehp41.

Meijl, H. van, P. Havlik, H. Lotze-Campen, E. Stehfest, P. Witzke, I. P. Dom’inguez, B. L. Bodirsky, M. van Dijk, et al. “Comparing impacts of climate change and mitigation on global agriculture by 2050.” In: *Environmental Research Letters* 13.6 (Jun. 2018), p. 064021. ISSN: 1748-9326. DOI: 10.1088/1748-9326/aabdc4.

Millennium Ecosystem Assessment. *Ecosystems and human well-being: synthesis.* Washington, DC: Island Press, 2005.

Millennium Institute. *Global food and nutrition scenarios.* Tech. rep. Washington, DC: Millennium Institute, 2013.

Mosnier, A., M. Obersteiner, P. Havlik, E. Schmid, N. Khabarov, M. Westphal, H. Valin, S. Frank, et al. “Global food markets, trade and the cost of climate change adaptation.” In: *Food Security* 6.1 (2014), pp. 29-44. ISSN: 18764517 (ISSN). DOI: 10.1007/s12571-013-0319-z.

Msangi, S. and M. Batka. *Major trends in diets and nutrition: A global perspective to 2050.* 2015. DOI: 10.1108/s1574-871520150000015023.

Msangi, S. and M. Rosegrant. "World agriculture in a dynamically-changing environment." In: *Expert Meeting on How to feed the World in 2050.* Rome: Food and Agriculture Organization of the United Nations, 2009.

Nelson, G., M. Rosegrant, A. Palazzo, I. Gray, C. Ingersoll, R. Robertson, S. Tokgoz, T. Zhu, et al. *Food security, farming, and climate change to 2050: Scenarios, results, policy options.* Washington, D.C.: International Food Policy Research Institute, 2010. DOI: 10.2499/9780896291867.

Obersteiner, M., B. Walsh, S. Frank, P. Havlik, M. Cantele, J. Liu, A. Palazzo, M. Herrero, et al. "Assessing the land resourceâ€"food price nexus of the Sustainable Development Goals." In: *Science Advances* 2.9 (Sep. 2016), p. e1501499. ISSN: 2375-2548. DOI: 10.1126/sciadv.1501499.

Odegard, I. Y. and E. van der Voet. "The future of food - Scenarios and the effect on natural resource use in agriculture in 2050." In: *Ecological Economics* (2014). ISSN: 09218009. DOI: 10.1016/j.ecolecon.2013.10.005.

OECD. *Alternative Futures for Global Food and Agriculture.* OECD, Feb. 2016. ISBN: 9789264247758. DOI: 10.1787/9789264247826-en.

Paillard, S., S. Treyer, B. Dorin, and Eds. *Agrimonde - Scenarios and Challenges for Feeding the World in 2050.* Ed. by S. Paillard, S. Treyer and B. Dorin. Dordrecht: Springer Netherlands, 2014. ISBN: 978-94-017-8744-4. DOI: 10.1007/978-94-017-8745-1.

Pardey, P. G., J. M. Beddow, T. M. Hurley, T. K. M. Beatty, and V. R. Eidman. "A Bounds Analysis of World Food Futures: Global Agriculture Through to 2050." In: *Australian Journal of Agricultural and Resource Economics* 58.4 (2014), pp. 571-589. ISSN: 14678489. DOI: 10.1111/1467-8489.12072.

Parry, M. L., C. Rosenzweig, A. Iglesias, M. Livermore, and G. Fischer. "Effects of climate change on global food production under SRES emissions and socio-economic scenarios." In: *Global Environmental Change* 14.1 (2004), pp. 53-67. ISSN: 09593780 (ISSN). DOI: 10.1016/j.gloenvcha.2003.10.008.

Parry, M., C. Rosenzweig, M. Livermore, and P. T. R. S. B. "Climate change, global food supply and risk of hunger." In: *Philosophical transactions of the Royal Society of London. Series B, Biological sciences* 360.1463 (2005), pp. 2125-38. ISSN: 0962-8436. DOI: 10.1098/rstb.2005.1751.

PBL Netherlands Environmental Assessment Agency. *Roads from Rio +20: Pathways to achieve global sustainability goals by 2050.* Tech. rep. The Hague: PBL Netherland Environmental Assessment Agency, 2012.

Popp, A., K. Calvin, S. Fujimori, P. Havlik, F. Humpenöder, E. Stehfest, B. Bodirsky, J. P. Dietrich, et al. "Land-use futures in the shared socio-economic pathways." In: *Global Environmental Change* 42 (Jan. 2017), pp. 331-345. ISSN: 09593780. DOI: 10.1016/j.gloenvcha.2016.10.002.

Robinson, S., D. Mason-D'Croz, S. Islam, N. Cenacchi, B. Creamer, A. Gueneau, G. Hareau, U. Kleinwechter, et al. *Climate change adaptation in agriculture ex ante analysis of promising and alternative crop technologies using DSSAT and IMPACT.* Washington; USA, 2015.

Rosegrant, M. W., S. Tokgoz, and P. Bhandary. "The new normal? A tighter global agricultural supply and demand relation and its implications for food security." In: *American Journal of Agricultural Economics* 95.2 (2013), pp. 303-309. ISSN: 0002-9092.

Shutes, L., H. Valin, E. Stehfest, v. D. M, M. Kuiper, v. M. H, A. Tabeau, M. Verma, et al. "Food and Nutrition Security and Sustainability in Long-Term Projections: An Assessment of the FoodSecure Scenarios." In: *Deliverable 7.4: Long-term supply, food and non-food demand drivers, contrasting scenarios and their impact on FNS: A report on long-term supply, food and non-food demand drivers, contrasting scenarios and their impact on FNS based on the Toolbox 2050.* 2017, pp. 3-32.

Smeets Kristkova, Z., M. van Dijk, and H. van Meijl. "Projections of long-term food security with R&D driven technical changeâ€"A CGE analysis". In: *NJAS - Wageningen Journal of Life Sciences* 77.Supplement

C (2016), pp. 39-51. ISSN: 1573-5214. DOI: https://doi.org/10.1016/j.njas.2016.03.001.

Springmann, M., D. Mason-D'Croz, S. Robinson, T. Garnett, H. C. J. Godfray, D. Gollin, M. Rayner, P. Ballon, et al. "Global and regional health effects of future food production under climate change: a modelling study." In: *The Lancet* 387.10031 (May. 2016), pp. 1937-1946. ISSN: 0140-6736. DOI: 10.1016/S0140-6736(15)01156-3.

Tilman, D., C. Balzer, J. Hill, and B. L. Befort. "Global food demand and the sustainable intensification of agriculture." In: *Proc. Natl Acad. Sci.* 108.50 (2011), p. 20260. ISSN: 0027-8424. DOI: 10.1073/pnas.1116437108.

UNEP. *GEO-4 Global Environment Outlook - Environment for development.* Tech. rep. Valetta: United Nations Environment Programme, 2007.

UNEP. *GEO5 Global Environmental Outlook: Environment for the Future We Want.* Tech. rep. Valetta: United Nations Environment Programme, 2012.

Valin, H., P. Havlik, A. Mosnier, M. Herrero, E. Schmid, and M. Obersteiner. "Agricultural productivity and greenhouse gas emissions: Trade-offs or synergies between mitigation and food security?" In: *Environmental Research Letters* 8.3 (2013), pp. 1-9. ISSN: 17489326 (ISSN). DOI: 10.1088/1748-9326/8/3/035019.

Valin, H., R. D. Sands, v. d. M. D, G. C. Nelson, H. Ahammad, E. Blanc, B. Bodirsky, S. Fujimorii, et al. "The future of food demand: understanding differences in global economic models." In: *Agricultural Economics* 45 (2014), pp. 51-67.

Wiebe, K., H. Lotze-Campen, R. Sands, A. Tabeau, V. d. M. D, A. Biewald, B. Bodirsky, S. Islam, et al. "Climate change impacts on agriculture in 2050 under a range of plausible socioeconomic and emissions scenarios." In: *Environmental Research Letters* 10 (2015) (2015).

F References

Alexandratos, N., and J. Bruinsma. 2012. "World agriculture towards 2030/2050: The 2012 Revision." ESA Working Paper. Rome: Food; Agriculture Organization of the United Nations.

Billen, G, L Lassaletta, and J Garnier. 2015. "A vast range of opportunities for feeding the world in 2050: Trade-off between diet, N contamination and international trade." *Environmental Research Letters* 10 (2). https://doi.org/10.1088/1748-9326/10/2/025001.

Borenstein, Michael, Larry V. Hedges, Julian P. T. Higgins, and Hannah R. Rothstein. 2009. *Introduction to Meta-Analysis*. Chichester, UK: John Wiley & Sons, Ltd. https://doi.org/10.1002/9780470743386.

Börjeson, Lena, Mattias Höjer, Karl-Henrik Dreborg, Tomas Ekvall, and Göran Finnveden. 2006. "Scenario types and techniques: Towards a user's guide." *Futures* 38 (7): 723–39. https://doi.org/10.1016/J.FUTURES.2005.12.002.

Comprehensive Assessment of Water Management in Agriculture. 2007. *Water for Food, Water for Life: A Comprehensive Assessment of Water Management in Agriculture*. London: Earthscan.

Dawson, T P, A H Perryman, and T M Osborne. 2016. "Modelling impacts of climate change on global food security." *Climatic Change* 134 (3): 429–40. https://doi.org/10.1007/s10584-014-1277-y.

Dellink, Rob, Dominique van der Mensbrugghe, and Bert Saveyn. 2020. "Shaping baseline scenarios of economic activity with CGE models: introduction to the special issue." *Journal of Global Economic Analysis* 5 (1): 1–27. https://doi.org/10.21642/jgea.050101af.

Diggle, Peter J., P. Heagarty, K. Y. Liang, and S. L. Zeger. 2002. *Analysis of Longitudinal Data*. Second Edi. Oxford: Oxford University Press.

Dijk, Michiel van, and Gerdien Meijerink. 2014. "A review of global food security scenario and assessment studies: Results, gaps and research priorities." *Global Food Security* 3 (3-4): 227–38. https://doi.org/10.1016/j.gfs.2014.09.004.

FAO. 2020. "Food security indicators." http://www.fao.org/economic/ess/ess-fs/ess-fadata/en/%7B/#%7D.XiYStoh7mcw.

IAASTD. 2009. *Agriculture at a crossroad - global report*. Washington DC: Island Press.

Ishida, Hiroyuki, Shota Kobayashi, Shinjiro Kanae, T Hasegawa, Shinichiro Fujimori, Yonghee Shin, Kiyoshi Takahashi, Toshihiko Masui, Akemi Tanaka, and Yasushi Honda. 2014. "Global-scale projection and its sensitivity analysis of the health burden attributable to childhood undernutrition under the latest scenario framework for climate change research." *Environmental Research Letters* 9 (2014) 0 (6): 1–9. https://doi.org/10.1088/1748-9326/9/6/064014.

Kuznetsova, Alexandra, Per B. Brockhoff, and Rune H. B. Christensen. 2017. "lmerTest Package: Tests in Linear Mixed Effects Models." *Journal of Statistical Software* 82 (13). https://doi.org/10.18637/jss.v082.i13.

Lloyd, Simon J., R. Sari Kovats, Zaid Chalabi, R. Sari Kovats, and Zaid Chalabi. 2011. "Climate Change, Crop Yields, and Undernutrition: Development of a Model to Quantify the Impact of Climate Scenarios on Child Undernutrition." *Environmental Health Perspectives* 119 (12): 1817–23. https://doi.org/10.1289/ehp.1003311.

Medek, D E, J Schwartz, and S S Myers. 2017. "Estimated Effects of Future Atmospheric CO2 Concentrations on Protein Intake and the Risk of Protein Deficiency by Country and Region." *Environmental Health Perspectives* 125 (8): 87001–2. https://doi.org/10.1289/ehp41.

Millennium Ecosystem Assessment. 2005. *Ecosystems and human well-being: synthesis*. Washington, DC: Island Press.

Msangi, S, and M Batka. 2015. "Major trends in diets and nutrition: A global perspective to 2050." Emerald Group Publishing Ltd. https://doi.org/10.1108/s1574-871520150000015023.

Nakicenovic, N, Joseph Alcamo, G Davis, Bert de Vries, Joergen Fenhann, Stuart Gaffin, Kenneth Gregory, and Arnulf Grubler. 2000. "Special report on emissions scenarios (SRES)."

Nelson, GC, MW Rosegrant, A Palazzo, I Gray, C. Ingersoll, Richard Robertson, S. Tokgoz, et al. 2010. *Food security, farming, and climate change to 2050: Scenarios, results, policy options.* Washington, D.C.: International Food Policy Research Institute. https://doi.org/10.2499/9780896291867.

O'Neill, Brian C., Elmar Kriegler, Kristie L. Ebi, Eric Kemp-Benedict, Keywan Riahi, Dale S. Rothman, Bas J. van Ruijven, et al. 2017. "The roads ahead: Narratives for shared socioeconomic pathways describing world futures in the 21st century." *Global Environmental Change* 42 (January): 169–80. https://doi.org/10.1016/j.gloenvcha.2015.01.004.

Russel, Lenth. 2020. "emmeans: Estimated Marginal Means, aka Least-Squares Means." https://cran.r-project.org/package=emmeans.

SSP Database. 2016. "SSP Database (Shared Socioeconomic Pathways) - Version 1.1." https://tntcat.iiasa.ac.at/SspDb.

Tilman, David, Christian Balzer, Jason Hill, and Belinda L Befort. 2011. "Global food demand and the sustainable intensification of agriculture." *Proc. Natl Acad. Sci.* 108 (50): 20260. https://doi.org/10.1073/pnas.1116437108.

UNEP. 2007. "GEO-4 Global Environment Outlook - Environment for development." Valetta: United Nations Environment Programme; Progress Press Ltd.

———. 2012. "GEO5 Global Environmental Outlook: Environment for the Future We Want." Valetta: United Nations Environment Programme.

Vuuren, Detlef P. van, and Timothy R. Carter. 2014. "Climate and socio-economic scenarios for climate change research and assessment: reconciling the new with the old." *Climatic Change* 122 (3): 415–29. https://doi.org/10.1007/s10584-013-0974-2.

Vuuren, Detlef P. van, Jae Edmonds, Mikiko Kainuma, Keywan Riahi, Allison Thomson, Kathy Hibbard, George C. Hurtt, et al. 2011. "The representative concentration pathways: An overview." *Climatic Change* 109 (1): 5–31. https://doi.org/10.1007/s10584-011-0148-z.

Vuuren, Detlef P. van, Marcel T J Kok, Bastien Girod, Paul L. Lucas, and Bert de Vries. 2012. "Scenarios in Global Environmental Assessments: Key characteristics and lessons for future use." *Global Environmental Change* 22 (4): 884–95. https://doi.org/10.1016/j.gloenvcha.2012.06.001.

Vuuren, Detlef P. van, Elmar Kriegler, Brian C. O'Neill, Kristie L. Ebi, Keywan Riahi, Timothy R. Carter, Jae Edmonds, et al. 2014. "A new scenario framework for Climate Change Research: Scenario matrix architecture." *Climatic Change* 122 (3): 373–86. https://doi.org/10.1007/s10584-013-0906-1.

Vuuren, Detlef P. van, Keywan Riahi, Katherine Calvin, Rob Dellink, Johannes Emmerling, Shinichiro Fujimori, Samir KC, Elmar Kriegler, and Brian C. O'Neill. 2017. "The Shared Socio-economic Pathways: Trajectories for human development and global environmental change." *Global Environmental Change* 42 (January): 148–52. https://doi.org/10.1016/j.gloenvcha.2016.10.009.

Zuur, Alain F., Elena N. Ieno, Neil Walker, Anatoly A. Saveliev, and Graham M. Smith. 2009. *Mixed effects models and extensions in ecology with R.* Statistics for Biology and Health. New York, NY: Springer New York. https://doi.org/10.1007/978-0-387-87458-6.

G Systematic literature review protocol

A Systematic Review of Global Food Security Projections up to 2050: Protocol

September 2017, updated December 2020[1]

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Roles and responsibilities

Marie Luise Rau led the systematic literature review. She organized the study design, drafted the protocol, maintained contacts with the library and students that provided research support and contributed to the review, screening and coding of the studies. She holds a Master-level certificate Research Synthesis for Policy and Practice from the University of London/England and has considerable experience in conducting systematic literature reviews. Michiel van Dijk contributed to designing and writing the research protocol, the design of the coding framework and the review and screening of the studies. Yashar Saghai provided input to the design of the review. The systematic review will be supported by information specialists from the Wageningen University and Research (WUR) library, who have experience with conducting and supporting systematic literature reviews. In addition, students from the university will be involved to support the screening of the studies.

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[1] Updated affiliations and added funding and Annex A and B.

1 Introduction

Ending hunger and achieve food security and improved nutrition at global level is one of the United Nations' 17 Sustainable Development Goals (SDGs). To achieve this goal policy-makers need to have insights in future pathways of global food security and their main drivers. The most cited study that provides long-run projections on agricultural production and demand is the "World agriculture towards 2030/2050" report, conducted by the FAO. The interim report (FAO, 2006) found that global agricultural production volume would need to be increased by 70% in 2050 to meet the projected global demand for food. This number was subsequently scaled down to 60% in the 2012 revision of the report (Alexandratos & Bruinsma, 2012).

To estimate the 60% increase in agricultural production needed, the WAT2050 combined expert opinions on the expected improvements of future yield with global population projections and expected changes in diets. A number of other studies have used econometric approaches (Tilman & Clark, 2014) or global integrated assessment models (Ishida et al., 2014) to conduct similar analysis. In contrast to the WAT2050, which only provides one 'business as usual' scenario, these studies often consider multiple scenarios to capture the uncertainty associated with key drivers, in particular income and population growth, and technological change, and present projections on other global food security outcomes such as food prices, calorie consumption and people at risk of hunger.

Surprisingly, research that systematically compares global assessments of food security is limited. Such research would help to answer questions like: What are relevant indicators for global food security? What is a plausible range of values for these global food security indicators in the future? Which factors are drivers of global food security? Which drivers are mainly addressed in projections of global food security? Which methods or measurements are used and what is the impact on food security outcomes? In previous work (van Dijk & Meijerink, 2014), we tried to answer these questions for 12 well-known studies about global food security. Since then, a substantial number of new studies have appeared that are not covered in our first study.

The aim of this project is to conduct a systematic review on global food security and modelling studies in order to (1) provide insights on the bandwidth of key global food security projections and (2) provide explanations on why the results of the projections may differ. As part of the review, data on global food security drivers and outcomes will be harvested from selected studies and further processed to allow for cross comparison. Following the approach used in climate change research, which also heavily relies on scenario analysis and modelling, all data will be stored in the Global Food Security Projections database that can be used to benchmark upcoming global food security scenario studies.

In order to identify and map the existing literature on the topic, we conduct a systematic review by following the guidelines for the qualified application of systematic review by the Evidence for Policy and Practice Information and Co-ordinating Centre (EPPI centre, University of London).

This protocol will be used as the guiding document throughout the entire process of conducting the systematic on global food security projections.

2 Objective and specific goals

The objective of the research is to conduct a systematic literature review of recent global food security projection and quantitative scenario studies that provide trends to 2050. The systematic review is used to answer the following research questions:

- What is the bandwidth of quantitative findings regarding future food security?
- What are the (main) characteristics of global food modelling scenarios that have been developed since 2000 (e.g. methodologies, drivers, scenarios and indicators?
- Why do these studies arrive at different outcomes?

We will use the conventional definition of food security as a reference: *"food security exists when all people, at all times, have physical and economic access to sufficient safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life"* (FAO, 1996). This definition covers the four dimensions of food security: (1) food availability, (2) food accessibility; (3) food stability and (4) food utilization.

We will draw upon the experience from previous research (in particular van Dijk & Meijerink, 2014) to demarcate the study selection and to structure the information retrieval. Relevant findings from Van Dijk and Meijerink (2014) include (1) the observation that no relevant global food security modelling studies have been published prior to the year 2000; (2) socio-economic scenarios that determine the food security outcomes can be grouped into a limited number of scenario families; (3) a list of major drivers that are used as input by most global food security projection studies; and (4) a list of main indicators that are used to capture the dimensions of food security, in particular, food consumption, food price, child malnutrition and undernourishment. If sufficient (quantitative) information on global food security drivers and outcomes can be harvested from the studies in the systematic review, a meta-analysis will be conducted that aims to explain the differences in results between the studies.

3 Research question

The specific research question addressed in this review is: What is the range of projections of future global food security with a time horizon of up to 2050? As the projections are determined by the approach that is used to create the projections (e.g. type of simulation model or statistical approach) as well as the driving forces that determine the direction of the projections, we also use the results of the systematic review to answer the following sub-questions: Which approaches have been used in the modelling studies and which drivers have been considered in the projections of global food security?

4 Selection criteria

We use the following criteria to select the studies:

- ***Exclusion on topic.*** To implement the search, we will use several key words that describe the most common indicators to measure the dimensions of food security, such as food consumption, food supply, food production, undernourishment and food prices that capture the four dimensions of food security.
- ***Exclusion on geography*.** The focus of the review is on global studies and therefore country and regional studies will be excluded.
- ***Exclusion on date.*** Studies published prior to 2000 will be excluded.
- ***Exclusion on language.*** Studies written in another language than English will be excluded.
- ***Exclusion on quantification.*** Studies that do not include a quantification of food security projections or scenarios will be excluded;
- ***Exclusion on projection horizon.*** Only studies with a projection horizon up to 2050 or beyond will be included for data extraction;
- ***Exclusion on repetition.*** In case updates are available of the same study or report (e.g. the FAO World Agriculture Towards 2050 (WAT) studies), only the most recent version will be included in order to avoid repletion and ensure that the latest data will be collected.

5 Search strategy

The search strategy follows several steps. We will first search for studies by using combinations of search terms, as described further below in this section. Note that we will also consider the references of the studies that are identified as relevant and that are thus included in the assessment of the systematic review (snowballing). This will complement the list of studies found in the searches.

Several data sources will be searched, including searches of the grey literature. Searching for grey literature is expected to be challenging. For the grey literature, we will use the results of grey literature of other searches on the topic of global food security and will complement the list with studies that we have identified in our own searches of the grey literature. These grey literature searches on the one hand relies on the information about projects with unpublished reports by experts and key researchers but on the other hand would also include Google searches, i.e. best hits in Google (scholar). The search results will be reported in a PRISMA flow chart that illustrates the number of records found and accounts for the various steps of the search process in a transparent manner.

5.1 Data sources and searching approaches

In the search, various sources of information mentioned below will be used in order to identify relevant studies. In particular,

Journal articles and other publications registered in bibliographic scientific databases

Electronic search engines of bibliographic databases will be searched by using the combinations of search terms defined below. Among the bibliographic databases are Science Direct, as well as Scopus and ISI Web of Knowledge (Social Sciences Citation Index subset) all of which allow for conducting full text but also specialized searches on indexed subheadings and/or keywords with a possible thesaurus option to use synonyms of the search terms applied. Wageningen UR library experts will support the search. The library has access to the following bibliographic databases: Scopus, Cab Abstracts, Agris (FAO database), Econlit, Google Scholar, ABI/Inform, AgEcon search. Search databases will be refined and set-up in cooperation with Wageningen UR library experts.

Grey literature

- *Specific electronic search engines – online databases*: In addition to bibliographic searches delivering references of peer-reviewed journal articles as well as other referenced material, we will use other search engines for identifying grey literature. These searches involve systematic online search as well as hand searches, depending on the search engines. For Google scholar, the best hits (first two pages) will be considered for the search. The searches will deliver links to newsletters, working papers, conference contributions and possibly other formats of the grey literature.
- *Specialist websites of organizations and institutes – hand search:* the websites of organizations and institutes involved in global food security analysis will be used to identify the grey literature (e.g. FAO, IFPRI and IIASA). The grey literature is potentially rather broad with detailed information about existing projects and hopefully more detailed analysis.
- *Contact with experts:* Entry into some potentially relevant studies is achieved by consulting with experts working on the topic.

Snowballing exercise:

A 'snowballing' exercise will be conducted on all references given by the studies that present or summarize global food security reviews as they are assumed to bring together important literature. For this purpose, a list of reviews studies was prepared by the team (Annex A).

5.2 Search terms and combinations

Following our earlier review (van Dijk & Meijerink, 2014), we derived search terms for conducting the literature searches, in particular the literature searches of bibliographic scientific databases and specific search engines and databases. Table 1 lists the groups of search terms, corresponding with the selection criteria. The groups of search terms will be combined with 'AND', while we use 'OR' within the groups of search terms

Table 1: Overview of groups of search terms

Criteria	Search terms
Topic: Food security	food OR nutrition
Topic: Projection and/or scenario	future OR prospect OR projection* OR scenario* OR foresight OR forecast OR transition
Topic: Quantitative approach	Model* OR regression OR "CGE" OR "PE" OR "computable general equilibrium" OR "partial equilibrium" OR quantitative OR trend* OR quantification
Global coverage	Global OR global-scale OR "developing countries" OR Asia OR "Latin America" OR "South America" OR Africa OR world*
Food security indicators	Feed* OR Food consumption OR Food demand OR Food production OR Food regime OR Food security OR Food supply OR Food system OR Undernutrition OR Underweight OR undernourishment OR calor* OR Diet* OR land use OR people at risk of hunger OR price OR Protein OR Stunting OR Wasting
Year of publication	2030 OR 2050 OR 2100 OR long-term OR long term
Additional: Model*	globiom OR impact OR aglink OR magpie OR aim OR farm OR gtem OR gcam OR magnet OR mirage OR gtap OR envisage OR eppa

*Only used for google scholar search.

5.3 Screening and selection of studies

The searches generate lists of potentially relevant studies on global food security that will be merged and stored into Endnote (digital library). After removing duplicates, the studies found in the searches will be screened by title, abstract and text. For the screening we will transfer the list of relevant studies to the Evidence for Policy and Practice Information and Co-ordinating Centre (EPPI) tool, which is a specialized software for systematic literature reviews and particularly useful for the screening and coding of the studies under review. The literature screening will consist of two phases. A first selection will be made by screening the title and abstract, followed by a full text screening for studies that are identified as being relevant. In case of doubt, the study under review will be evaluated by a second reviewer. If needed, the research team will discuss the details of the respective study. This means that we do not consider cross-checking or screening by pairs of reviewers for all records due to constraints of time and budget. Discussing the relevance of studies in case of doubt is expected to be sufficient to ensure a high-quality outcome of the screening. The screening of abstracts will be supported by one or two Master students of Wageningen University and Research (WUR).

The inclusion/exclusion criteria will be applied in the screening in order to ensure that relevant studies are identified for being included in the database. This means that only those studies meeting the inclusion criteria will be considered in the full text assessment of the systematic review.

6 Data extraction

6.1 Study-level information

We will build a questionnaire in the EPPI tool to systematically extract and code the following information from the studies selected in the screening process (see Annex B for a draft version):

- Meta information: Author, publication date, publication type, author affiliation
- Which methodology is used (e.g. type of model, statistical approach) in the study?
- Which scenarios are looked at (e.g. SRES, SSPs or other)?
- Which food security indicators are considered (e.g. for food demand, food supply, undernourishment, etc.) in the study?
- Which drivers are considered (e.g. GDP, population and technical change) in the study?

In general, the code should be rigorous but flexible enough to allow for the possibility of adding and open questions, rather than determine and thus presume answers or categories of questions. Using the key wording and coding, a high-level understanding about the nature and contribution of the research can be achieved.

In the data extraction, we will assess in detail those studies that are identified as relevant and thus are included in the systematic review. The data information asked for by the code/questionnaire will be extracted, entered and stored in the coding tool provided with the EPPI tool. The coding of information will be supported by one or two Master students of Wageningen University and Research (WUR).

6.2 Model projections

As the key objective of our systematic review is to assess the bandwidth of global food security projections, we will make an effort to harvest all detailed information about the global food security projections from the studies. Similar to our previous study (van Dijk & Meijerink, 2014), we will use the R software (R Core Team, 2018) to process and analyze the data so comparison can be made, where possible. If the necessary data is not available or incomplete, we will try to contact the authors for additional information. Finally, all data will be stored in a Global Food Security Projections Database that contains comparable data on all global food security projection studies published in the year 2000 and onwards. For each of the studies the following information will be stored: (1) basic information (e.g. authors, institution and year); (2) design (e.g. type of model); (3) drivers (e.g. yield, GDP and population growth) and (4) global food security scenario results (e.g. calorie availability, food prices and people at risk of hunger). The database will be used as a basis for descriptive and visual analysis, among others showing the bandwidth and distribution of assumptions on key drivers and various food security output indicators. The database will be become open source and published at the same time with a scientific article that summarizes the main results of the systematic review.

7 References

Alexandratos, N., & Bruinsma, J. (2012). *World agriculture towards 2030/2050: The 2012 Revision* (ESA Working Paper No. 12–03). Rome.

FAO. (1996). *Rome declaration on world food security and world food summit plan of action*. Rome.

FAO. (2006). *World agriculture: towards 2030/2050 Interim report*. Rome: Food and Agriculture Organization of the United Nations. https://doi.org/10.1016/S0264-8377(03)00047-4

Ishida, H., Kobayashi, S., Kanae, S., Hasegawa, T., Fujimori, S., Shin, Y., … Honda, Y. (2014). Global-scale projection and its sensitivity analysis of the health burden attributable to childhood undernutrition under the latest scenario framework for climate change research. *Environmental Research Letters*, *9 (2014) 0*, 1–9. Retrieved from doi:10.1088/1748-9326/9/6/06401

R Core Team. (2018). R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing. Retrieved from https://www.r-project.org/

Tilman, D., & Clark, M. (2014). Global diets link environmental sustainability and human health. *Nature*, *515*(7528), 518–522. https://doi.org/10.1038/nature13959

van Dijk, M., & Meijerink, G. (2014). A review of global food security scenario and assessment studies: Results, gaps and research priorities. *Global Food Security*, *3*(3–4), 227–238. https://doi.org/10.1016/j.gfs.2014.09.004

Annex A: Global food security review studies

Bourgeois, R. (2016). Food insecurity: The future challenge. *IDS Bulletin*, *47*(4), 71–84. https://doi.org/10.19088/1968-2016.156

Dijk, M. van, & Meijerink, G. (2014). A review of global food security scenario and assessment studies: Results, gaps and research priorities. *Global Food Security*, *3*(3-4), 227–238. https://doi.org/10.1016/j.gfs.2014.09.004

Godfray, H. C. J., Beddington, J. R., Crute, I. R., Haddad, L., Lawrence, D., Muir, J. F., … Toulmin, C. (2010). Food security: the challenge of feeding 9 billion people. *Science (New York, N.Y.)*, *327*(5967), 812–818. https://doi.org/10.1126/science.1185383

Godfray, H. C. J., & Robinson, S. (2015). Contrasting approaches to projecting long-run global food security. *Oxford Review of Economic Policy*, *31*(1), 26–44. https://doi.org/10.1093/oxrep/grv006

Hertel, T. W. (2011). The global supply and demand for agricultural land in 2050: A perfect storm in the making? *American Journal of Agricultural Economics*. https://doi.org/10.1093/ajae/aaq189

Hertel, T. W., Baldos, U. L. C., & Mensbrugghe, D. van der. (2016). Predicting Long-Term Food Demand, Cropland Use, and Prices. *Annual Review of Resource Economics*, *8*(1), 417–441. https://doi.org/10.1146/annurev-resource-100815-095333

Hubert, B., Rosegrant, M., Boekel, M. A. J. S. van, Ortiz, R., C.M. Jolly, D. Aggarwal, … U. Kulkar. (2010). The Future of Food: Scenarios for 2050. *Crop Science*, *50*(Supplement_1), S–33. https://doi.org/10.2135/cropsci2009.09.0530

Keating, B. A., Herrero, M., Carberry, P. S., Gardner, J., & Cole, M. B. (2014). Food wedges: Framing the global food demand and supply challenge towards 2050. *Global Food Security*, *3*(3-4), 125–132. https://doi.org/10.1016/j.gfs.2014.08.004

Le Mouël, C., & Forslund, A. (2017). How can we feed the world in 2050? A review of the responses from global scenario studies. *European Review of Agricultural Economics*, *10*(8), 1–51. https://doi.org/10.1093/erae/jbx006

McNeill, K., Macdonald, K., Singh, A., & Binns, A. D. (2017). Food and water security: Analysis of integrated modeling platforms. *Agricultural Water Management*, *194*, 100–112. https://doi.org/10.1016/j.agwat.2017.09.001

Reilly, M., & Willenbockel, D. (2010). Managing uncertainty: a review of food system scenario analysis and modelling. *Philosophical Transactions of the Royal Society B*, *365*(1554), 3049–3063. https://doi.org/10.1098/rstb.2010.0141

Wood, S., Ericksen, P., Stewart, B., Thornton, P. K., & Anderson, M. (2010). Lessons learned from international assessments. In J. Ingram, P. Erickson, & D. Liverman (Eds.), *Food security and global environmental change* (pp. 46–62). London: Earthscan.

Zurek, M. (2006). *A short review of global scenarios for food systems analysis*.

Annex B: EPPI Tool Questionnaire V1.0

- A_Meta information (ID = 4289037) [Not selectable (no checkbox)]
  Some info on the study, background
  - A.1_Name of the key institutions that facilitated the study (ID = 4289038) [Not selectable (no checkbox)]
    - World Bank (ID = 4289039) [Selectable (show checkbox)]
    - IFPRI (ID = 4289040) [Selectable (show checkbox)]
    - IIASA (ID = 4289041) [Selectable (show checkbox)]
    - JRC/EU (ID = 4289042) [Selectable (show checkbox)]
    - FAO (ID = 4289043) [Selectable (show checkbox)]
    - OECD (ID = 4289044) [Selectable (show checkbox)]
    - PBL (ID = 4297340) [Selectable (show checkbox)]
    - UNEP (ID = 4297341) [Selectable (show checkbox)]
    - academic (ID = 4297342) [Selectable (show checkbox)]
    - Other, please specify in info box (ID = 4289045) [Selectable (show checkbox)]
    - Unknown (ID = 4289046) [Selectable (show checkbox)]
  - A.2_Main topic of the study - food security effect of .... (ID = 4164196) [Not selectable (no checkbox)]
    - Food demand (ID = 4164197) [Selectable (show checkbox)]
    - Food supply/availability (ID = 4164198) [Selectable (show checkbox)]
    - Climate change (ID = 4164199) [Selectable (show checkbox)]
    - Environment (biodiversity) (ID = 4164200) [Selectable (show checkbox)]
    - Food prices (ID = 4164201) [Selectable (show checkbox)]
    - Water (ID = 4164202) [Selectable (show checkbox)]
    - Other - please specify in the info box. (ID = 4164203) [Selectable (show checkbox)]
  - A.3_Aim of the study - please mark the text (ID = 4164206) [Not selectable (no checkbox)]
- B_Methodology (ID = 4164193) [Not selectable (no checkbox)]
  - B.1_Which quantitative methodology is used to make the food security projections? (ID = 4164194) [Not selectable (no checkbox)]
    - Simulation models (GTAP, integrated assessment models...) (ID = 4289070) [Selectable (show checkbox)]
    - Statistical models, estimation/regression (ID = 4289071) [Selectable (show checkbox)]
    - Expert inputs (ID = 4289072) [Selectable (show checkbox)]
    - Combined methods, please specify (ID = 4289073) [Selectable (show checkbox)]
    - Other, please specify (ID = 4289092) [Selectable (show checkbox)]
  - B.2_For simulation models... (ID = 4164195) [Not selectable (no checkbox)]
    - B.2.1_What is the key/most important model used? (ID = 4289074) [Not selectable (no checkbox)]
      - ABARES (ID = 4297343) [Selectable (show checkbox)]
      - agLINK (ID = 4297344) [Selectable (show checkbox)]
      - Agrobiom (ID = 4297345) [Selectable (show checkbox)]
      - AIM (ID = 4297346) [Selectable (show checkbox)]
      - CAPRI (ID = 4297347) [Selectable (show checkbox)]
      - ENVISAGE (ID = 4297348) [Selectable (show checkbox)]
      - EPPA (ID = 4297349) [Selectable (show checkbox)]
      - FARM (ID = 4297350) [Selectable (show checkbox)]
      - GCAM (ID = 4297351) [Selectable (show checkbox)]
      - GLOBE (ID = 4297352) [Selectable (show checkbox)]
      - GLOBIOM (ID = 4297353) [Selectable (show checkbox)]
      - GTAP (ID = 4297354) [Selectable (show checkbox)]
      - GTEM (ID = 4297355) [Selectable (show checkbox)]
      - IMAGE (ID = 4297356) [Selectable (show checkbox)]
      - IMPACT (ID = 4297357) [Selectable (show checkbox)]
      - MAGNET (ID = 4289075) [Selectable (show checkbox)]
      - MAgPIE (ID = 4297358) [Selectable (show checkbox)]

        - MIRAGE (ID = 4297359) [Selectable (show checkbox)]
        - SIMPLE (ID = 4297360) [Selectable (show checkbox)]
        - Watersim (ID = 4297361) [Selectable (show checkbox)]
        - WFS (ID = 4297362) [Selectable (show checkbox)]
        - Others, please specify (ID = 4289076) [Selectable (show checkbox)]
      - B.2.2_Which kind of model is used (key/most important model)? (ID = 4289081) [Not selectable (no checkbox)]
        - General equilibrium model (ID = 4289082) [Selectable (show checkbox)]
        - Partial equilibrium model (ID = 4289083) [Selectable (show checkbox)]
        - Bio-physical/biomass model (ID = 4289084) [Selectable (show checkbox)]
        - Integrated assessment model (ID = 4289085) [Selectable (show checkbox)]
        - Other, please specify if possible (ID = 4289086) [Selectable (show checkbox)]
      - B.2.3_Which other models are used? Please specify by marking the text. (ID = 4289077) [Not selectable (no checkbox)]
    - B.3_For statistical models... (ID = 4289087) [Not selectable (no checkbox)]
      - B.3.1_Which approach is taken? (ID = 4289088) [Not selectable (no checkbox)]
        - Accounting identity (ID = 4289089) [Selectable (show checkbox)]
        - Regression (ID = 4289090) [Selectable (show checkbox)]
        - Other, please specify by marking the text. (ID = 4289091) [Selectable (show checkbox)]
    - For expert input (ID = 4289093) [Not selectable (no checkbox)]
      - B.4.1_Please describe the approach - marking in the text. (ID = 4289094) [Not selectable (no checkbox)]
    - B.5_For mixed methods (ID = 4289095) [Not selectable (no checkbox)]
      - B.5.1_Please describe how methods are mixed - marking the text (ID = 4289096) [Not selectable (no checkbox)]
- C_Geographic coverage (ID = 4289097) [Not selectable (no checkbox)]
    - C.1_Which countries/regions are covered? (ID = 4289160) [Not selectable (no checkbox)]
      - Global (ID = 4289162) [Selectable (show checkbox)]
      - Regional: developed countries in general (ID = 4289167) [Selectable (show checkbox)]
      - Regional: developing countries in general (ID = 4289163) [Selectable (show checkbox)]
      - Regional: Asia (ID = 4289164) [Selectable (show checkbox)]
      - Regional: Africa (ID = 4289165) [Selectable (show checkbox)]
      - Regional: Latin America (ID = 4289166) [Selectable (show checkbox)]
      - Others, please specify (ID = 4297387) [Selectable (show checkbox)]
- D_Sectoral coverage (ID = 4297364) [Not selectable (no checkbox)]
    - D.1_Which sectors, commodities are covered? (ID = 4297386) [Not selectable (no checkbox)]
      - Food (ID = 4298958) [Selectable (show checkbox)]
      - Agriculture (ID = 4298957) [Selectable (show checkbox)]
      - Total cereals (ID = 4297365) [Selectable (show checkbox)]
      - Total crops/plant products (ID = 4297366) [Selectable (show checkbox)]
      - Maize (ID = 4297367) [Selectable (show checkbox)]
      - Wheat (ID = 4297368) [Selectable (show checkbox)]
      - Rice (ID = 4297369) [Selectable (show checkbox)]
      - Livestock/animal products (ID = 4297370) [Selectable (show checkbox)]
      - Others, please specify (ID = 4297371) [Selectable (show checkbox)]
- E_Food security indicators (ID = 4289109) [Not selectable (no checkbox)]
    - E.1_Which indicators? Please describe how they are computed by marking the text. (ID = 4289110) [Not selectable (no checkbox)]
      - Agricultural production (ID = 4298959) [Selectable (show checkbox)]
      - Food production (ID = 4298960) [Selectable (show checkbox)]
      - Food prices (ID = 4289111) [Selectable (show checkbox)]
      - Undernourishment (ID = 4289113) [Selectable (show checkbox)]
      - Child malnutrition (ID = 4289114) [Selectable (show checkbox)]
      - Other, please specify. (ID = 4289115) [Selectable (show checkbox)]
- F_Scenarios (ID = 4289116) [Not selectable (no checkbox)]

- F.1_How many scenarios are analysed, Please specify in text box and mark text (ID = 4289157) [Selectable (show checkbox)]
- F.2_Start year of projection, please state in info box (ID = 4289158) [Selectable (show checkbox)]
- F.3_End year of projection, please state in info box (ID = 4289159) [Selectable (show checkbox)]
- F.4_Characterisation of scenario approach (ID = 4289117) [Not selectable (no checkbox)]
  - Explorative scenario analysis (ID = 4289118) [Selectable (show checkbox)]
  - Projections - what if? (ID = 4289119) [Selectable (show checkbox)]
  - Normative analysis (ID = 4289120) [Selectable (show checkbox)]
  - Mixture of scenarios (ID = 4289121) [Selectable (show checkbox)]
  - Others, please specify in info box and marking the text (ID = 4309995) [Selectable (show checkbox)]
- F.5_Which SSP scenarios are modelled? Please tick and mark text. (ID = 4297372) [Not selectable (no checkbox)]
  - none (ID = 4309996) [Selectable (show checkbox)]
  - SSP1 (ID = 4297373) [Selectable (show checkbox)]
  - SSP2 (ID = 4297374) [Selectable (show checkbox)]
  - SSP3 (ID = 4297375) [Selectable (show checkbox)]
  - SSP4 (ID = 4297376) [Selectable (show checkbox)]
  - SSP5 (ID = 4298961) [Selectable (show checkbox)]
  - A1 (SRES) (ID = 4297377) [Selectable (show checkbox)]
  - A2 (SRES) (ID = 4297378) [Selectable (show checkbox)]
  - B1 (SRES) (ID = 4297379) [Selectable (show checkbox)]
  - B2 (SRES) (ID = 4297380) [Selectable (show checkbox)]
  - Others, please mark in the text. (ID = 4297381) [Selectable (show checkbox)]

- G_Drivers (ID = 4289126) [Not selectable (no checkbox)]
  - G.1_Which key drivers are considered on the supply side? Please tick and mark the text. (ID = 4289128) [Not selectable (no checkbox)]
    Defintion and reasoning by marking text.
    - Technical change (via changes in yields, total factor productivity...) (ID = 4289136) [Selectable (show checkbox)]
    - Climate change (ID = 4289137) [Selectable (show checkbox)]
    - Land (degradation) (ID = 4289140) [Selectable (show checkbox)]
    - Water (scarcity) (ID = 4289141) [Selectable (show checkbox)]
    - Ecosystem services (ID = 4289142) [Selectable (show checkbox)]
    - Aquaculture (ID = 4289143) [Selectable (show checkbox)]
    - Post harvest losses and storage (ID = 4289144) [Selectable (show checkbox)]
    - Alternative sources of supply (insects, algae...) (ID = 4289145) [Selectable (show checkbox)]
    - Others, please specify. (ID = 4289146) [Selectable (show checkbox)]
  - G.2_Which key drivers are considered on the demand side? Please tick and mark the text. (ID = 4289127) [Not selectable (no checkbox)]
    Defintion and reasoning by marking text.
    - Population growth (ID = 4289129) [Selectable (show checkbox)]
    - Economic growth (ID = 4289130) [Selectable (show checkbox)]
    - Biofuels & bioeconomy (ID = 4289131) [Selectable (show checkbox)]
    - Diet and changes in consumer preferences (ID = 4289132) [Selectable (show checkbox)]
    - Urbanisation (ID = 4289133) [Selectable (show checkbox)]
    - Poverty and inequality (ID = 4289134) [Selectable (show checkbox)]
    - Food waste (ID = 4289135) [Selectable (show checkbox)]
    - Others, please specify. (ID = 4289147) [Selectable (show checkbox)]
- H_Results (ID = 4297385) [Not selectable (no checkbox)]
  - H.1_Results for which food security indicators? Please tick and mark the text. (ID = 4289150) [Not selectable (no checkbox)]
    Availbale and where to find them (marking the text)
    - Food prices (ID = 4289152) [Selectable (show checkbox)]

    - Agri-food production in kcal/cap/day (ID = 4289153) [Selectable (show checkbox)]
    - Child malnutrition (ID = 4289155) [Selectable (show checkbox)]
    - Undernourishment (ID = 4289154) [Selectable (show checkbox)]
    - Other, please specify (ID = 4289156) [Selectable (show checkbox)]
    - G.1_Which key drivers are considered on the supply side? Please tick and mark the text. (ID = 4316287) [Not selectable (no checkbox)]
- H.2_Results for which supply side drivers? Please tick and mark the text. (ID = 4316286) [Not selectable (no checkbox)]
  Availbale and where to find them (marking the text)
    - Ecosystem services (ID = 4316295) [Selectable (show checkbox)]
    - Water (scarcity) (ID = 4316294) [Selectable (show checkbox)]
    - Alternative sources of supply (insects, algae...) (ID = 4316301) [Selectable (show checkbox)]
    - Post harvest losses and storage (ID = 4316299) [Selectable (show checkbox)]
    - Land (degradation) (ID = 4316293) [Selectable (show checkbox)]
    - Technical change (via changes in yields, total factor productivity...) (ID = 4316291) [Selectable (show checkbox)]
    - Climate change (ID = 4316292) [Selectable (show checkbox)]
    - Aquaculture (ID = 4316297) [Selectable (show checkbox)]
    - Others, please specify. (ID = 4316304) [Selectable (show checkbox)]
- H.3_Results for demand side drivers? Please tick and mark the text. (ID = 4316288) [Not selectable (no checkbox)]
  Available and where to find them?
    - Population growth (ID = 4316302) [Selectable (show checkbox)]
    - Economic growth (ID = 4316303) [Selectable (show checkbox)]
    - Biofuels & bioeconomy (ID = 4316305) [Selectable (show checkbox)]
    - Diet and changes in consumer preferences (ID = 4316296) [Selectable (show checkbox)]
    - Urbanisation (ID = 4316289) [Selectable (show checkbox)]
    - Poverty and inequality (ID = 4316290) [Selectable (show checkbox)]
    - Food waste (ID = 4316298) [Selectable (show checkbox)]
    - Others, please specify. (ID = 4316300) [Selectable (show checkbox)]
- H.4_Is there an annex with data? Please mark in the text. (ID = 4297383) [Selectable (show checkbox)]
    - Yes, please state where to find the data (web link) and/or mark the text. (ID = 4289170) [Selectable (show checkbox)]
    - No (ID = 4289169) [Selectable (show checkbox)]
    - Unknown (ID = 4289171) [Selectable (show checkbox)]