

Supplementary Information

A GIS-based Simulation Method for Regional Food Potential and Demand

Keyu Bao, Rushikesh Padsala, Volker Coors, Daniela Thrän, and Bastian Schröter

Content

Text

S1 The dietary energy requirements calculation

Table

S1 List of nutritive factor and waste and food waste/lost rate in Europe.

S2 Fruit yield in Germany on pure orchard land, orchard and grass mix, orchard and farming land mix, and on vineyard

S3 Basal Metabolic Rates Slope (S) and Constant (C) by Sex and by Age Group

S4 Estimated total energy expenditure (TEE) for infants, children and adolescents

S5 Complied body weight data in Germany by sex and by age groups

S6 Population depending on sex and age in Germany in 2011

S7 Coefficients a_i and b_i between HDI and consumption of total food, animal products, sweeteners, vegetable oils and vegetables

S8 Comparison of population, agricultural land area between three regions

Figure

S1 Share of organically farmed area in the utilized farming are in Germany from 1994 to 2018 and its linear fitting curve from 1994 to 2050

S2 Vegetal and animal calorie potential in Ilm-Kreis

S3 Vegetal and animal calorie potential in Dithmarschen

S4. Prediction of total food demand, vegetal food demand and animal food demand in county Dithmarschen from year 2018 to 2050

S5. Prediction of total food demand, vegetal food demand and animal food demand in county Ilm-Kreis from year 2018 to 2050

S6 Polygons categorized by gridded blocks in Ludwigsburg

Text

Text S1: The dietary energy requirements calculation

The dietary energy requirements for adults above 20 and elderly are calculated by multiplying the population data according to age and sex groups by their respective BMR, PAL and country correction factor (Equation 1 and 2). BMR is derived from the average per capita daily food requirement for the population from 1950 to 2010 for a five years resolution by country, age, sex group, body weight [1]. Due to the fact that no standardized global data on PAL for countries is available, three PAL scenarios (light, moderate, and heavy) are considered to account for uncertainty. The average PAL values of non-overweighted adult in United States are taken as the moderate PAL [1,2]. Minimum dietary energy requirements are estimated by using a PAL value of 1.55, which also represents the lower bound for food requirements (light PAL). PAL values larger than 2.4 are difficult to maintain permanently. Thus, this value is considered as the upper bound (heavy PAL). Because of the limited physical activity of the elderly, for age groups older than 80 years the PAL values are kept constant, at 1.28 for males and 1.19 for females for all PAL scenarios, based on observed PAL values for elderly in the United States [1].

$$DER = BMR \times PAL \quad (1)$$

$$BMR(country, age, sex) = C(age, sex) + S(age, sex) \times BW(country, age, sex) \quad (2)$$

where BMR is a linear function of body weight (BW), and where constant (C) and slope (S) depend on age and sex groups (see Table S3 in supplementary data).

The age cohort of infants, children, and adolescents is further divided into four groups (0–4, 5–9, 10–14, and 15–19 years) based on the age groups for which population data is available. The energy requirements for infants, children, and adolescents is assumed by multiplying the population data according to age and sex groups by their respective average daily energy requirement for different PALs obtained from FAO/WHO/UNU [2] (see Table S4 in supplementary data).

In the next step, the extra energy required for a 40-week pregnancy and a 6-month lactation period is calculated (Equation 3). A woman requires an additional food of 280 kcal/day and 590 kcal/day of food on average during her pregnancy and lactation period, respectively [2]. The number of pregnant women (N_{preg}) in a region is estimated by

$$N_{preg} = \frac{BR \times P \times GP}{365.25} \quad (3)$$

where BR denotes crude birth rate [3]; P represents population in a year (365.25 days); and GP is a mean gestation period of 280 days from Naegele's rule.

Finally, the total dietary energy demand of the region is the summed value of the adults by Equation 1 and 2, of the infants, children, and adolescents by Table S4, and additional energy for pregnancy by Equation 3.

Table

Table S1: List of nutritive factor and waste and food waste/lost rate in Europe. The nutritive factors are obtained from FAO (2001) [4]. The food waste/lost rate during agriculture, postharvest, processing and distribution is obtained from Figure S1 to S5 from FAO (2011) [5].

Crop product	Nutritive factor (nf) [kcal/100 g]	Food waste during agriculture, postharvest, processing and distribution
Winter/Spring cereals	334	12.3%
Maize	356	12.3%
Winter rapeseed (oil)	884	16.4%
Sugar beet	70	42.7%
Potato	67	42.7%
Fruit (other)	45	33.2%
Wine (vineyard)	68	33.2%
Meat products	-	12.0%

Table S2: Fruit yield in Germany on pure orchard land, orchard and grass mix, orchard and farming land mix, and on vineyard.

Crop type	Plant density [tree/ha]	Fruit production yield [t/ha]
Fruit orchard	5,000 – 10,000 [6] (p 280)	23.9 [7]
Fruit orchard in grassland	300 [6] (p 280)	0.96
Fruit orchard in farming land	300 [6] (p 280)	0.96
Grapevine	-	8.61 (wine) [8]

Table S3: Basal Metabolic Rates Slope (S) and Constant (C) by Sex and by Age Group and – AG1 (20–29 years), AG2 (30–59 years), AG3 (60–79 years) and AG4 (80+ years) [1] with the Three PAL Values in USA

Age [years]	Sex	S [kcal/kg]	C [kcal]	Light PAL	Moderate PAL	Heavy PAL
AG1	Male	15.057	692.2	1.55	1.75	2.4
AG2	Male	11.472	873.1	1.55	1.74	2.4
AG3	Male	11.711	587.7	1.55	1.62	2.4
AG4	Male	11.711	587.7	1.28	1.28	1.28
AG1	Female	14.818	486.6	1.55	1.79	2.4
AG2	Female	8.126	845.6	1.55	1.83	2.4
AG3	Female	9.082	658.5	1.55	1.62	2.4
AG4	Female	9.082	658.5	1.19	1.19	1.19

Table S4: Estimated total energy expenditure (TEE) for infants, children and adolescents using FAO tables [2] in kcal/cap/day.

Sex	Age	Light PAL	Moderate PAL	Heavy PAL
Male	0-4	1086	1086	1086
Male	5-9	1517.5	1731	1945
Male	10-14	2205	2594	2979
Male	15-19	2845	3340	3850
Female	0-4	910	910	910
Female	5-9	1419	1618	1821
Female	10-14	1918	2259	2600
Female	15-19	2125	2500	2875

Table S5: Compiled body weight data in Germany in kg by sex– male (M) and female (F), and by age groups– AG1 (20–29 years), AG2 (30–59 years), AG3 (60–79 years) and AG4 (80+ years) [9]

Country	Sex	AG1	AG2	AG3	AG4
Germany	F	64	68	71	67
Germany	M	79	85	84	79

Table S6: Population depending on sex and age in Germany in 2011 [10].

Age	Total		Sex	
			Male	Female
	Population	Relative percentage	Relative percentage	Relative percentage
Under 5	3338895	4.2	2.2	2.0
5 - 9	3525830	4.4	2.3	2.1
10 - 14	3940566	4.9	2.5	2.4
15 - 19	4013880	5	2.6	2.4
20 - 29	9708172	12.1	6.1	6.0
30–59	34471416	42.9	21.5	21.4
60–79	17007688	21.3	10.0	11.3
80+	4213248	5.3	1.7	3.6

Table S7: Coefficients a_i and b_i between HDI and consumption of total food (a), animal products (b), sweeteners (c), vegetable oils (d) and vegetables (e).

Food category	c_i	d_i
a	0.39	0.15
b	1.81	-1.67
c	1.75	-1.86
d	0.93	-1.33
e	1.25	-2.24

Table S8. Comparison of population, agricultural land area and climate between three regions

Country	Unit	Ludwigsburg	Ilm-Kreis	Dithmarschen
Agricultural land area	[ha]	50,302	74,451	124,108
Food potential density	[million kcal/ha]	7.4	4.7	5.6
Yearly average temperature (2020)	[°C]	10.1	9	9.5
Precipitation (2020)	[mm/a]	729	570	794
Population density	[person/km ²]	2,200	139	93

Figure

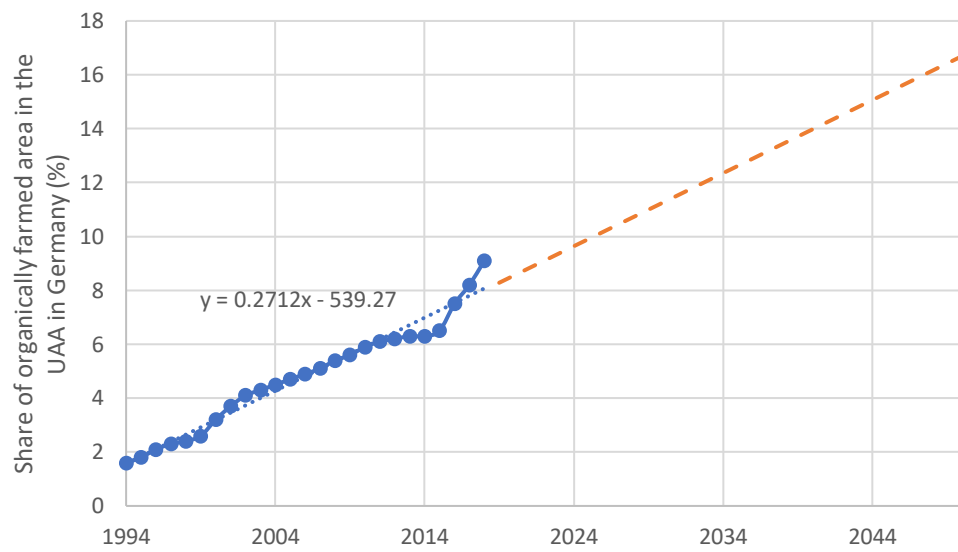


Figure S1. Share of organically farmed area in the utilized farming are in Germany (%) from 1994 to 2018 and its linear fitting curve from 1994 to 2050 [11].

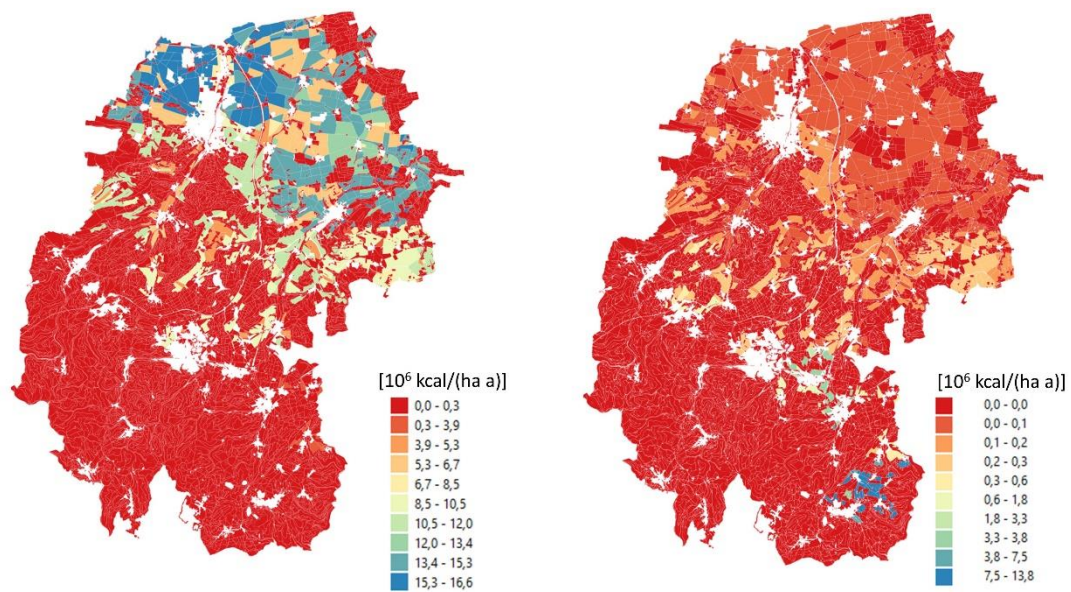


Figure S2. Vegetal (left) and animal calorie potential (right) in Ilm-Kreis

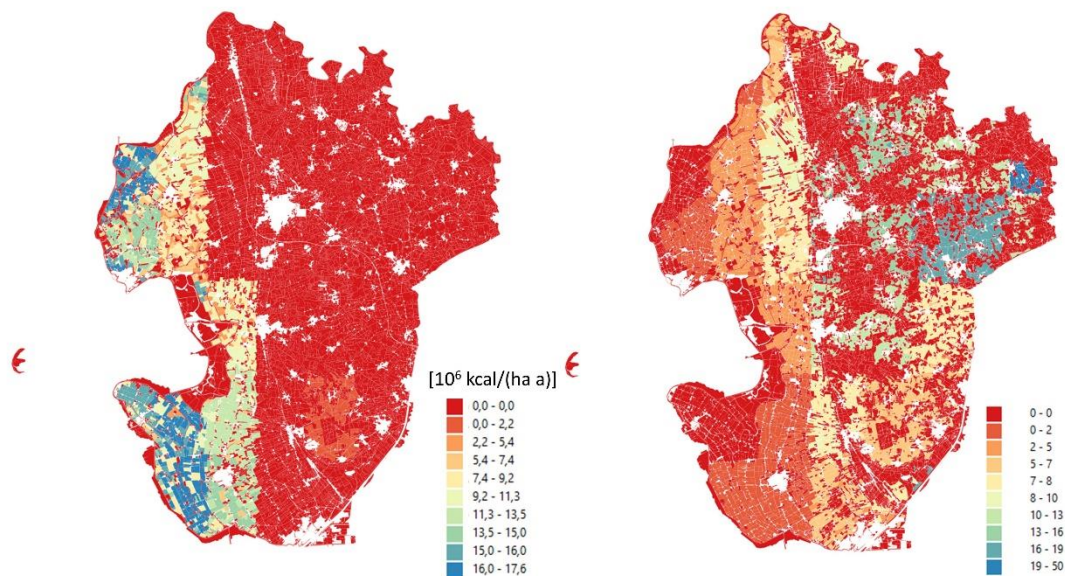


Figure S3. Vegetal (left) and animal calorie potential (right) in Dithmarschen

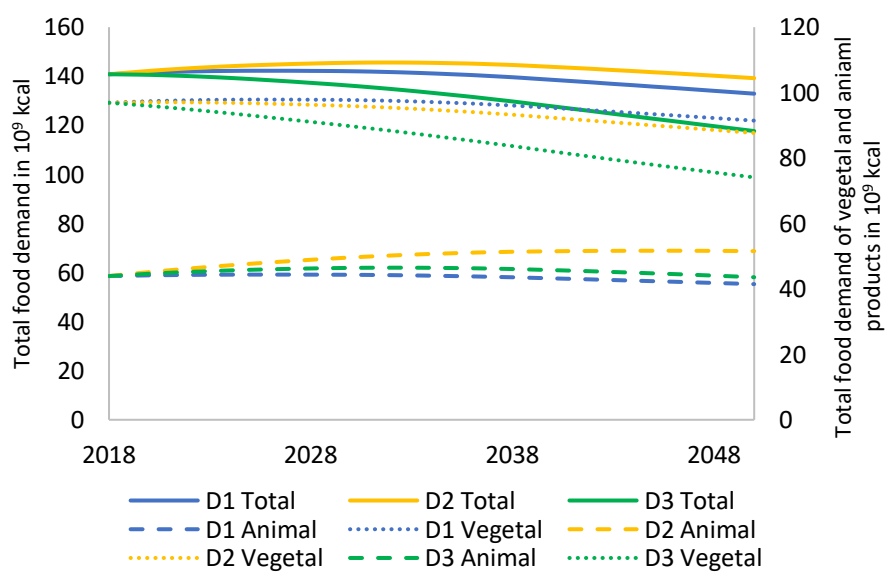


Figure S4. Prediction of total food demand (solid line), vegetal food demand (dot line) and animal food demand (dash line) in county Dithmarschen from year 2018 to 2050

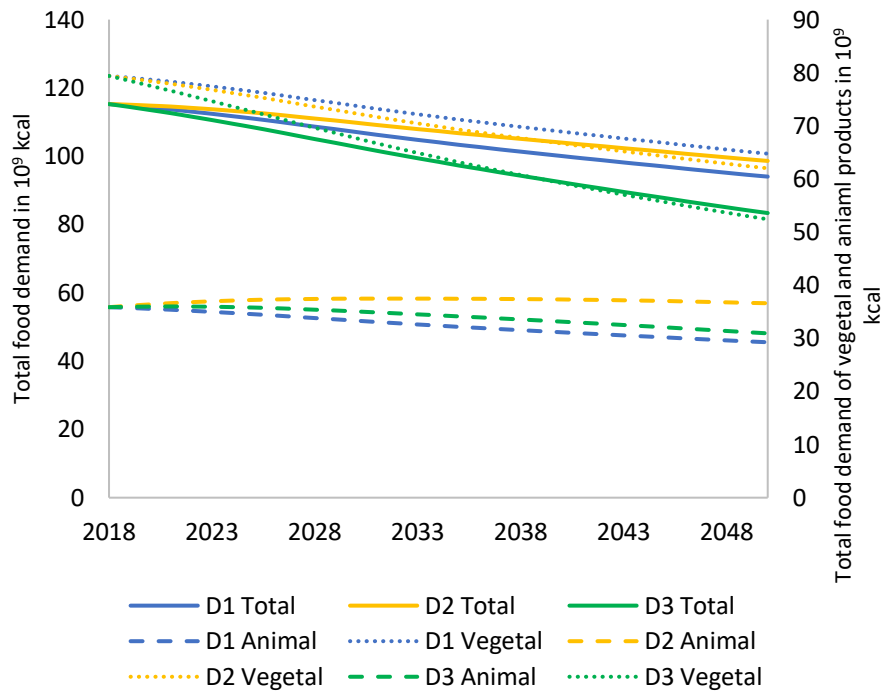


Figure S5. Prediction of total food demand (solid line), vegetal food demand (dot line) and animal food demand (dash line) in county Ilm-Kreis from year 2018 to 2050

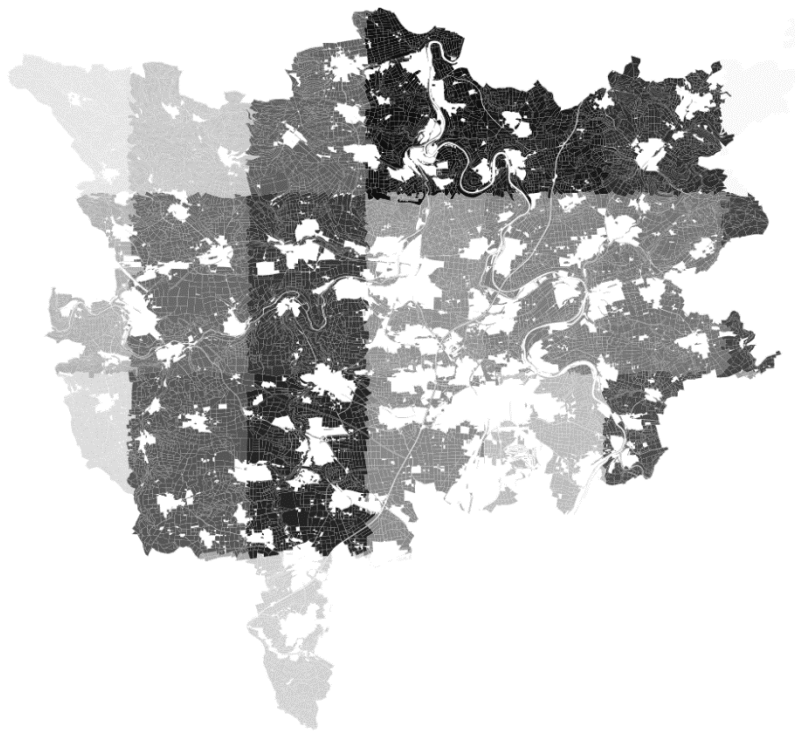


Figure S6. Polygons categorized by gridded blocks in Ludwigsbürg

Reference

1. Hiç, C.; Pradhan, P.; Rybski, D.; Kropp, J.P. Food Surplus and Its Climate Burdens. *Environ. Sci. Technol.* **2016**, *50*, 4269–4277, doi:10.1021/acs.est.5b05088.
2. University, U.N.; Organization, W.H. *Human Energy Requirements: Report of a Joint FAO/WHO/UNU Expert Consultation: Rome, 17-24 October 2001*; FAO, 2004, ISBN 9251052123.

3. The World Bank. *Birth rate, crude (per 1,000 people)*, 2020.
4. FAO, F. *Food balance sheets: A handbook*; FAO Rome, 2001.
5. Gustavsson, J.; Cederberg, C.; Sonesson, U.; van Otterdijk, R.; Meybeck, A. *Global food losses and food waste*.
6. Martin, K.; Hans, H.; Hermann, H. *Energie aus Biomasse: Grundlagen, Techniken und Verfahren*; Springer Verlag, Germany, 2001.
7. Statistisches Bundesamt. Areas and quantities harvested (production for the market) of fruit. Available online: <https://www.destatis.de/EN/Themes/Economic-Sectors-Enterprises/Agriculture-Forestry-Fisheries/Fruit-Vegetables-Horticulture/Tables/2-4-areas-quantities-harvested.html> (accessed on 12 January 2021).
8. Statistisches Bundesamt. Wine - Areas under cultivation, yields per hectare, quantities harvested. Available online: <https://www.destatis.de/EN/Themes/Economic-Sectors-Enterprises/Agriculture-Forestry-Fisheries/Wine/Tables/must-areas-under-cultivation-yields-hectare-quantities-harvested.html> (accessed on Jan 12. 2021).
9. Statistisches Bundesamt. *Mikrozensus - Fragen zur Gesundheit*, 2005, 2009, 2013, 2017.
10. Statistisches Bundesamt. Population depending on sex and age (five years age groups): Census from the adjusted stock of registers. Available online: <https://ergebnisse.zensus2011.de/> (accessed on Jan 13. 2021).
11. Eurostat. Share of organic crop area out of the total utilised agricultural area (UAA). Available online: <https://ec.europa.eu/eurostat/databrowser/> (accessed on 20 January 2021).