

Supplementary materials

1 Calculating the provincial per-capita food consumption

In 1998 and 2012, per-capita consumption of grain ration and grain-consuming and herbivorous livestock products among 31 provinces are calculated by the Eq. (1).

$$\text{Per-capita food consumption} = \text{Urban per capita consumption} \times \text{proportion of urban residents} + \text{Rural per capita consumption} \times \text{proportion of rural residents} \quad (1)$$

Where the consumption of grain-consuming livestock products is derived from pork, plus poultry and egg consumption, and the consumption of herbivorous livestock products is obtained by the sum of consumption of beef and mutton. It is worth noting that different foods contain different types of calories and protein which can provide different nutrients for people, but cannot be represented in the quantity. Therefore, the dimension of the food equivalent unit^[1] is used to convert different types of food consumption as ‘food equivalent’, and used to produce the total.

Animal and plant food equivalent are calculated as follow:

$$\text{FEU} = H/1585 + P/77 \quad (2)$$

$$\text{FEU}_a = H/6676 + P/21.6 \quad (3)$$

Where FEU, plant food equivalent; FEU_a, animal food equivalent; *H*, unit weight (100g) food calories; *P*, unit weight (100g) protein content of food.

According to ‘Ten percent law’ proposed by Lindeman^[2], animal and plant food equivalent conversion formula is:

$$\text{FEU}_a = 10\text{FEU} \quad (4)$$

Due to the limitations of data sources, to facilitate the calculation of several categories of food equivalent, provision^[3] for several kinds of food equivalent units was made as follows (Table S1):

Table S1 Approximate food equivalent unit (FEU) for several kinds food

Plant food	Animal food			
Grain ratio	Pork	Beef and mutton	Poultry	Eggs
1	8.1	10	9.7	6.5

2 Calculating consumption of feed grain and forage for livestock production

In the current agricultural system, producing 1 kg of pork, poultry and eggs consumes 3.5, 2.5 and 2 kg grain, respectively. Converted to food equivalent, producing 1 kg of FEUa pork, poultry and eggs need to consume 4.3, 2.6 and 3 kg of FEU, respectively. Consumption rates between pork, poultry and egg in 2012 are 52%, 27% and 21%, respectively, from which the approximate average grain consumption to produce 1 kg of FEUa grain-consuming animal products is 3.6 kg of FEU, and production of 1 kg (ie1 FEUa) herbivorous livestock products consumes 9 kg of FEU forage which contains at least 2.5 kg of FEU grain and 6.5 kg of FEU forage in the current agricultural system ([Table S2](#)).

However, in the grassland agricultural system, forage legume cannot only be used to feed cattle and sheep, but also as part of the consumption by grain-consuming livestock. Considering the above situations, the saving consumption rate of fodder grain by grain-consuming livestock and herbivorous livestock are set to 16.8% and 40%, the rate of growth to 7.2% and 15%. Then, in the grassland agriculture, producing 1 kg of FEUa of grain-consuming livestock will use 2.8 kg of FEU grain and 0.6 kg of FEU forage, while the production of 1 kg of FEUa herbivorous livestock products consumes only 7.8 kg of FEU containing 1.3 kg of FEU grain and 6.5 kg of FEU forage ([Table S2](#)).

Table S2 The consumption of grain feed and forage per animal product

Consume (kg of FEU)	Current agriculture system				Grassland agriculture system			
	Grain-consuming livestock		Herbivorous livestock		Grain-consuming livestock		Herbivorous livestock	
	Grain feed	Forage	Grain feed	Forage	Grain feed	Forage	Grain feed	Forage
	3.6	0	2.5	6.5	2.8	0.6	1.3	6.5

3 Prediction of the provincial per-capita food consumption in 2020

The trend analysis compares per-capita food consumption by fitting linear, exponential, quadratic and quadratic terms and other models. We could find that exponential model is the best fit for the amount of per-capita food consumption, while the linear model is the best for fitting to the consumption of grain-consuming livestock products, herbivorous livestock products and population. On the other hand, consumption of the gradual reduction in grain ratio was slow, especially for urban residents where per-capita grain ration consumption almost reached an equilibrium state. There is a big gap in the calories and protein consumption derived from livestock products compared with developed countries; the food consumption from livestock products should show a rapid growth trend^[3]. Based on the above two-aspect analysis, per-capita grain ration consumption with the exponential model and per-capita animal food consumption and population with linear model are projected as follows:

$$C_{\text{grain}} = a_1 + b_1 \ln t + \varepsilon_1 \quad ((t=1,2,3,\dots)) \quad (5)$$

$$C_{\text{grainfeed}} = a_2 + b_2 t + \varepsilon_2 \quad ((t=1,2,3,\dots)) \quad (6)$$

$$C_{\text{grassfeed}} = a_3 + b_3 t + \varepsilon_3 \quad ((t=1,2,3,\dots)) \quad (7)$$

$$\text{Population} = a_4 + b_4 t + \varepsilon_4 \quad ((t=1,2,3,\dots)) \quad (8)$$

Where C_{grain} , per-capita grain ration demand; $C_{\text{grainfeed}}$, the consumption demand of per-capita grain-consuming livestock products; Population, population amount on provincial scale; $C_{\text{grassfeed}}$, the consumption demand of per-capita herbivorous livestock products; a_1, a_2, a_3 , intercept terms; b_1, b_2, b_3 , time coefficients; t , time, and set 1998 as the base period ($t = 1$), and so on; $\varepsilon_1, \varepsilon_2, \varepsilon_3$, error terms.

It should be noted that the linear model can estimate the trend change in the short term, but this estimate may not be accurate in the medium to long term, because the long term trend may not be linear and may even be the opposite of short-term trends. Therefore, we exerted 124 times linear regression to project the consumptions of grain ration, grain-consuming and herbivorous livestock products and population among 31 provinces to estimate the parameters tested. If $P > 0.05$, the estimates are not reliable, we directly use the actual statistics in 2012 as a conservative estimation. If $P < 0.05$, estimated results is reliable and predict all variables to 2020 by using the model.

4 Food demand projection in 2020

Most parameter estimations of three categories of food per-capita consumption and population models were significant (Table S3), which indicated that the vast majority of parameter estimation was effective. The others of the estimated parameters (intercept terms and time coefficients) were significant at $P = 0.01$ levels, and the fitting degrees of them were good. Among them, only the time coefficients of the grain ration model in Shanghai and Tibet were not significant. The other 29 provinces estimated parameters (intercept term and time coefficients) were significant and that meant the model of per-capita grain ration demand was fit to be applied among these 29 provinces.

The time coefficients of the consumption demand for per-capita grain-consuming livestock products in Beijing, Shanghai, Zhejiang and Tibet was not significant, and fitting degrees of Tianjin, Shandong, Guizhou were poor ($0.375 \leq R^2 \leq 0.4$) although the time coefficients were still significant at $P = 0.05$ level. The estimated results of the remaining provinces were good and all parameter estimations was significant at level $P = 0.01$ (Table S3).

The time coefficients of the consumption demand of per capita herbivorous livestock products in Tianjin, Shanxi, Zhejiang, Shandong, Guangdong and Henan were not significant, and fitting degrees of Fujian, Hainan, Xinjiang were low ($0.228 \leq R^2 \leq 0.4$) although the parameter estimates were still significant at $P = 0.05$ level. The estimated results of the remaining provinces were good and all parameter estimations (intercept term and time coefficients) were significant at level $P = 0.01$ (Table S3).

Table S3 The results of the parameter estimations

Regions	Grain ration			Grain-consuming livestock products		
	R^2	a_1	b_1	R^2	a_2	b_2
Beijing	0.87	119.87**	-13.26**	0.08	31.04**	0.01
Tianjin	0.78	137.62**	-18.90**	0.39	25.61**	0.33*
Hebei	0.77	198.95**	-25.11**	0.85	11.61**	0.44**
Shanxi	0.69	207.52**	-26.50**	0.95	9.10**	0.51**
Inner Mongolia	0.90	196.39**	-24.96**	0.85	15.09**	0.76**
Liaoning	0.90	166.83**	-18.03**	0.81	20.13**	0.84**
Jilin	0.81	180.46**	-22.68**	0.87	15.83**	0.67**
Heilongjiang	0.93	194.07**	-31.22**	0.90	13.64**	0.76**
Shanghai	0.03	114.05**	-3.06	0.00	35.58**	-0.02
Jiangsu	0.80	216.80**	-35.77**	0.73	21.01**	0.51**
Zhejiang	0.93	183.44**	-28.03**	0.23	22.77**	0.2
Anhui	0.79	232.75**	-36.28**	0.90	15.49**	0.75**
Fujian	0.92	221.81**	-34.11**	0.55	25.32**	0.46**
Jiangxi	0.87	269.92**	-43.04**	0.95	14.79**	0.85**
Shandong	0.71	193.51**	-25.24**	0.38	18.28**	0.21*
Henan	0.60	231.96**	-31.75**	0.71	13.74**	0.40**
Hubei	0.78	214.60**	-28.16**	0.93	17.85**	0.80**
Hunan	0.90	255.28**	-38.39**	0.91	19.67**	0.91**

Guangdong	0.90	182.91**	-20.25**	0.56	34.71**	0.61**
Guangxi	0.92	209.73**	-27.75**	0.80	21.10**	0.81**
Hainan	0.54	206.70**	-32.42**	0.84	19.60**	1.03**
Chongqing	0.88	202.47**	-29.93**	0.78	26.44**	0.81**
Sichuan	0.78	221.23**	-30.01**	0.86	23.83**	0.89**
Guizhou	0.84	208.94**	-27.12**	0.39	22.45**	0.31*
Yunnan	0.90	227.70**	-32.73**	0.87	21.68**	0.63**
Xizang	0.15	214.57**	8.92	0.10	10.35**	0.15
Shanxi	0.81	195.93**	-25.58**	0.87	8.75**	0.44**
Gansu	0.54	231.61**	-21.38**	0.75	9.33**	0.52**
Qinghai	0.84	226.86**	-30.31**	0.82	11.32**	0.52**
Ningxia	0.89	218.69**	-29.48**	0.89	10.89**	0.51**
Xinjiang	0.86	202.41**	-12.92**	0.71	8.22**	0.51**

Regions	Herbivorous livestock products			Population		
	R^2	a_3	b_3	R^2	a_4	b_4
Beijing	0.75	4.25**	-0.08**	0.97	1131.34**	59.73**
Tianjin	0.13	2.97**	-0.02	0.88	861.99**	31.14**
Hebei	0.49	1.01**	0.02**	0.95	6503.69**	48.51**
Shanxi	0.11	0.94**	0.01	0.92	3147.68**	28.43**
Neimenggu	0.66	2.87**	0.17**	0.97	2334.35**	10.04**
Liaoning	0.6	1.46**	0.19**	0.95	4130.25**	16.91**
Jilin	0.45	1.42**	0.13**	0.77	2664.80**	6.25**
Heilongjiang	0.67	0.97**	0.17**	0.43	3765.20**	5.43**
Shanghai	0.64	4.65**	-0.10**	0.99	1384.14**	67.76**
Jiangsu	0.59	1.91**	0.04**	0.97	7159.30**	4971.44**
Zhejiang	0.02	2.12**	0.01	0.99	4394.51**	75.59**
Anhui	0.69	1.05**	0.05**	0.35	6202.30**	-11.98*
Fujian	0.4	1.99**	0.04*	0.96	3312.65**	29.74**
Jiangxi	0.83	0.83**	0.08**	0.94	4116.69**	25.51**
Shandong	0.01	1.37**	0.002	0.98	8796.64**	58.33**
Henan	0.07	1.42**	-0.02	0.00	9461.18**	-1.34
Hubei	0.8	1.03**	0.07**	0.20	5847.16**	-11.03
Hunan	0.81	1.08**	0.06**	0.00	6525.49**	-1.74
Guangdong	0.04	3.80**	-0.01	0.92	7436.73**	225.10**
Guangxi	0.77	1.30**	0.14**	0.00	4728.26**	0.54
Hainan	0.23	2.35**	0.42*	0.99	753.17**	9.10**
Chongqing	0.93	0.84**	0.20**	0.15	2961.15**	-9.04
Sichuan	0.86	0.85**	0.15**	0.56	8395.90**	-25.38**
Guizhou	0.86	0.88**	0.07**	0.34	3814.33**	-19.13*
Yunnan	0.65	1.20**	0.07**	0.99	4149.13**	35.43**
Xizang	0.58	7.28**	0.44**	1.00	248.57**	3.95**

Shanxi	0.81	0.61**	0.07**	0.96	3596.77**	10.90**
Gansu	0.6	0.91**	0.08**	0.57	2525.65**	2.66**
Qinghai	0.63	7.79**	0.05**	0.99	503.25**	4.71**
Ningxia	0.83	2.24**	0.19**	1.00	532.93**	7.7**
Xinjiang	0.33	5.75**	0.27*	0.97	1740.75**	34.04**

Note: **, $P < 0.01$; *, $P < 0.05$.

References

1. Ren J Z, Hou F J. Change traditional thinking about food grain production and use food equivalent in yield measurement. *Acta Prataculturae Sinica*, 1999, **8**(S1):55-75 (in Chinese)
2. Lindeman RL. The trophic-dynamic aspect of ecology. *Ecology*, 1942, **23**: 399–418
3. Lin H L, Li R C, Jin C Y, Wang C, Wei M H, Ren J Z. China's new problems of food security revealed by the Food Equivalent Unit. *Frontiers of Agricultural Science and Engineering*, 2014, **1**(1): 69–76