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Reply to: Estimating low-opportunity-cost feed

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REPLYING TO Y. Gong and Y. Yang *Nature Food* https://doi.org/10.1038/s43016-025-01116-z (2025)

We are pleased that Gong and Yang[1] consider our work[2] an important contribution for alleviating the multiple environmental stresses caused by the global expansion of animal production and its associated increased demand for animal feed[3–5]. Our study[2] revealed that the pressures on land use and the environment can be reduced by about one-third in China when partially replacing commercial feed with low-opportunity-cost feeds (LCFs) in animal production. However, Gong and Yang[1] comment that this result may be overestimated because of the use of simple methods, overestimation of the use of food waste and fish meal as animal feed, use of relatively low feed conversion ratios (FCRs) and other possible alternatives for using LCFs. Here we reply to the criticisms and underscore the validity of our estimates.

In the past, LCFs were the main feed sources in animal production in China, but this has changed dramatically during the past decades[6]. As a consequence, the current potential of LCFs has not been studied in-depth in China, and thus there is relative scarcity of detailed data on LCFs and its use in animal feed in practice. Therefore, we have invested efforts in obtaining accurate data and information on LCFs, and adopted a simple but robust optimization method[7] to estimate animal feed formula in a transparent and consistent way, using data from 2009 to 2013 as baseline. We found that increased utilization of LCFs can potentially save 25–32% of the current feed-producing cropland area, and one-third of feed-related irrigation water, synthetic fertilizer use and associated greenhouse gas emissions in China. We emphasized the need for improved technology and coordination among stakeholders to achieve the potentials of increased LCF use in practice[2].

Gong and Yang[1] argue that we overestimated the potentials of using food waste and fish meal in animal feed, and that the FCRs in our scenarios were too low (suggesting the overestimation of land savings and associated environmental benefits). We agree that there are uncertainties in the amount of LCFs available and used in feed. The total amount of LCFs (including by-product from food processing, crop residues and food waste) was estimated at 1,131 Mt. Food waste accounted for about 5% and fish meal for about 1.5%. Owing data scarcity about the fractions of food waste used as feed in China for the reference years (2009–2013), we explored the literature. About 45% of the food waste generated in households in South Korea was recycled as animal feed in 2006, and in some districts as much as 80% (ref. 8). Based on these data as well as other literature[5], we used an upper limit of 39% for the use of food waste in the baseline 2009–2013. We therefore maintain that our estimates for the use of food waste in animal feed are appropriate for the baseline. We agree with Gong and Yang[1] that the use of food waste as animal feed in South Korea, Japan and China has decreased during the past decade following outbreaks of foot and mouth disease and African swine fever, and the subsequent policy changes. The future use of food waste as feed is thus uncertain. In our scenarios, we used optimistic (potential) estimates for the fraction of food waste used in feed (60–100%) based on the premise that new technology may reduce safety risks. We used lower estimates (25–50%) in additional sensitivity analyses, and the results indicate that the uncertainty has only a minor impact on the land-saving potential (see Supplementary Table 12 in ref. 2), mainly because food waste has a relatively small share in the total amount of LCFs. Evidently, there is a need to investigate the potentials of using food waste as feed in China and other developing economies further.

Gong and Yang[1] also argue that we overestimated the amount of fish meal available for animal feed, because of a wrong interpretation of 'pelagic fish' in the Food and Agriculture Organization (FAO) database and the neglect of fish meal by the aquaculture sector. We used data from the FAO[9]; pelagic fish in the FAO database includes various types of fish product (for example, fresh, cured, canned and fish meal). The amount of fish products used as feed was obtained from the Food Balance Sheet[9], where feed is defined as "the commodity in question available for feeding to the livestock and poultry" (aquaculture is not mentioned). Thus, we assumed that fish meal was used by livestock and poultry only. Following a further check of the pertinent literature, we agree with Gong and Yang[1] that we may have slightly overestimated the energy content of fish meal. Thus, we conducted additional sensitivity

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Table 1 | Impact of decreased fish meal use as animal feed on land savings

	Reduction of fish meal use as animal feed (%)	Land savings (% of total feed cropland area)		
		S1	S2	S3
Fang et al.[2]		25.4	26.8	31.9
Sensitivity analyses	−25	25.6	26.9	32.1
	−50	25.7	27.0	32.1

We reduced fish meal use in animal feed by 25% and 50% to assess how sensitive land savings are to these reductions in scenarios S1, S2 and S3, compared with the business-as-usual scenario.

analyses; halving the amount of fish meal in animal feed led to very minor changes in the total land-saving potential (Table 1).

Gong and Yang[1] also raise concerns about the relatively low FCRs for industrial pig and broiler farms in the scenarios with increased incorporation of LCFs in feed. We agree that with an increase of LCFs in animal diets the FCR may increase, as observed for pigs and chicken in traditional farms[2]. However, FCRs tend to decrease over time in industrial farms because of improved animal feeding, breeding and husbandry practices[6]. This trend of decreasing FCRs is likely to continue in the near future due to further improvements in animal feeding and precision amino acid supplementation[10]. Also, there is still a large variation in the current protein contents of the animal feed used by, for example, poultry farms in China; many farms feed crude protein levels in excess of recommended levels[11]. This is why the Chinese government recently promoted low-protein diets for industrial pig and chicken farms to reduce concentrate feed use[12]. We maintain that our FCRs in the scenarios for the near future are within reasonable ranges, and likely to be not too low because of over-simplifications in our model and misidentification of the amount of fish meal, as Gong and Yang[1] argue. We defined FCR as the amount of feed (dry matter) used per unit of animal products (milk, eggs and liveweight gain) in our model. If the FCRs of our scenarios were expressed as a function of the amount of meat produced, the values would be 3.7 kg kg^{-1}, which is in line with previous estimates for China[1,13,14]. And we maintain that the reported potential savings of commercial feeds and associated cropland areas, as well as the reduction of the environmental impacts, are as concluded.

Finally, we agree with Gong and Yang[1] that there are possible alternatives for using LCFs as animal feed, as also discussed in our paper[2]. However, a detailed evaluation of these alternatives was beyond the scope of our study, as we focused on the potential impacts of using LCFs as animal feed only, thereby exploring the transition from linear to more circular food systems[15]. Evidently, using LCFs for bioenergy or soil carbon sequestration will reduce their impacts as animal feed, but the latter is probably the preferred valorization pathway.

References

1. Gong, Y. & Yang, Y. Estimating low-opportunity-cost feed. *Nat. Food* https://doi.org/10.1038/s43016-025-01116-z (2025).
2. Fang, Q. et al. Low-opportunity-cost feed can reduce land-use-related environmental impacts by about one-third in China. *Nat. Food* **4**, 677–685 (2023).
3. Van Zanten, H. H. E. et al. Defining a land boundary for sustainable livestock consumption. *Glob. Change Biol.* **24**, 4185–4194 (2018).
4. Röös, E. et al. Greedy or needy? Land use and climate impacts of food in 2050 under different livestock futures. *Glob. Environ. Change* **47**, 1–12 (2017).
5. zu Ermgassen, E. K. H. J., Phalan, B., Green, R. E. & Balmford, A. Reducing the land use of EU pork production: where there's swill, there's a way. *Food Policy* **58**, 35–48 (2016).
6. Bai, Z. et al. China's livestock transition: driving forces, impacts, and consequences. *Sci. Adv.* **4**, eaar8534 (2018).
7. Hou, Y. et al. Feed use and nitrogen excretion of livestock in EU-27. *Agric. Ecosyst. Environ.* **218**, 232–244 (2016).
8. Kim, M. H. & Kim, J. W. Comparison through a LCA evaluation analysis of food waste disposal options from the perspective of global warming and resource recovery. *Sci. Total Environ.* **408**, 3998–4006 (2010).
9. *Food Balances (-2013, Old Methodology and Population)* (FAO, 2013); https://www.fao.org/faostat/en/#data/FBSH
10. Wu, G. & Li, P. The 'ideal protein' concept is not ideal in animal nutrition. *Exp. Biol. Med.* **247**, 1191–1201 (2022).
11. Tan, M. et al. Decision-making environment of low-protein animal feeding in dairy and poultry farms in China. *Nutr. Cycl. Agroecosyst.* **127**, 85–96 (2023).
12. *The Group Standard for Low-Protein Compound Feed for Pigs and Chickens was Released* (Ministry of Agriculture and Rural Affairs of the People's Republic of China, 2018); http://www.moa.gov.cn/xw/zwdt/201810/t20181026_6161577.htm
13. Sha, W. *Nutrient Cycling, Environment Losses and Sustainability Assessment of Livestock Production in Peri-Urban Area of Beijing* (in Chinese). PhD thesis (China Agricultural University, 2016).
14. Bai, Z. H. et al. Changes in pig production in China and their effects on nitrogen and phosphorus use and losses. *Environ. Sci. Technol.* **48**, 12742–12749 (2014).
15. Van Zanten, H. H. E. et al. Circularity in Europe strengthens the sustainability of the global food system. *Nat. Food* **4**, 320–330 (2023).

Author contributions

Q.F. drafted the article. All authors reviewed the draft and provided critical feedback and edits.

Competing interests

The authors declare no competing interests.

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