More animal farming increases animal welfare if soil animals have negative lives?

Summary

- I estimate the change in the welfare of animals affected by the production of beef, pork, chicken, turkey, dairy milk, fish, eggs, shrimp, peas, tofu, and soy milk. I analyse directly affected animals, and soil ants, termites, springtails, mites, and nematodes impacted by changes in land use.
- I suppose welfare per animal-year is proportional to the welfare range, the difference between the maximum and minimum welfare per unit time, and that this is a power law of the number of neurons. In particular, I use welfare ranges as a fraction of that of humans equal to "number of neurons as a fraction of that of humans"^"exponent of the number of neurons", with the exponent ranging from 0 to 2, as I did before. For an exponent of:
    - 0, all animals have the welfare range of humans.
    - 0.188:
        - The welfare ranges are pretty similar to the estimates in Bob Fischer's book about comparing animal welfare across species, which contains what Rethink Priorities (RP) stands behind now. An exponent of 0.188 explains 78.6 % of their variance.
        - The number of neurons has to become 209 k (= 10^(1/0.188)) times as large for the welfare range to become 10 times as large.
    - 0.5, corresponding to my best guesses for the welfare ranges, the number of neurons has to become 100 (= 10^(1/0.5)) times as large for the welfare range to become 10 times as large.
    - 1, the welfare ranges are proportional to the number of neurons.
    - 2, the number of neurons has to become 3.16 (= 10^(1/2)) times as large for the welfare range to become 10 times as large.
- I estimate food consumption decreases the living time of soil animals 410 k (shrimp) to 164 billion (beef) times as much as it increases the living time of the directly affected animals.
- I believe effects on soil animals are much larger than those on the directly affected animals. I am confident the exponent of the number of neurons is the parameter which affects the ratio between the effects on soil animals and directly affected animals the most by far, and effects on soil animals dominate at least for values of the exponent up to 1, which are the ones I consider plausible. I get the following increase in the welfare of soil ants, termites, springtails, mites, and nematodes as a fraction of the absolute value

of the change in the welfare of the directly affected animals. For an exponent of the number of neurons of (the lower and upper bound respect shrimp and dairy milk):
    - 0.19, 1.33 k to 1.76 billion.
    - 0.5, 223 to 11.6 M.
    - 1, 14.8 to 4.01 k.
- For all the animal-based foods I analysed besides shrimp, I estimate effects on soil animals would still be much larger than those on the target beneficiaries for a welfare per animal-year of exactly 0 for animals with fewer neurons than those considered in Bob's book, and an exponent of the number of neurons of 0.19 which explains very well its estimates. I calculate soil ants and termites have 2.91 and 1.16 times as many neurons as shrimp, so effects on them would still be relevant. I get the following absolute value of the change in the welfare of soil ants and termites as a fraction of the absolute value of the change in the welfare of the directly affected animals for an exponent of 0.19:
    - For the animal-based foods I analysed besides shrimp, 160 (fish) to 454 k (dairy milk).
    - For shrimp, 16.0 %.
- The logarithm of the increase in agricultural-land-years per food-kg explains over 90 % of the variance in the logarithm of the absolute value of the change in the welfare of the directly affected animals, and soil ants, termites, springtails, mites, and nematodes per food-kg for an exponent of the number of neurons up to 1.43. In other words, one can predict this absolute value of the change in welfare per food-kg from the increase in agricultural-land-years per food-kg alone for those exponents. This is because the effects on soil animals are much larger than those on the directly affected animals in this case, and the increase in the welfare of soil animals per unit area is similar.
- I conclude producing beef increases the welfare of the directly affected animals, and soil ants, termites, springtails, mites, and nematodes (considered all together) much more than the other foods for any exponent of the number of neurons.
- I continue to recommend changes in food consumption which increase agricultural land. I estimate the m^2-years of agricultural land per food-kg almost perfectly explain the increase in the welfare of the directly affected animals, and soil ants, termites, springtails, mites, and nematodes per food-kg for my preferred exponent of the number of neurons of 0.5 (see last 2 graphs). In particular, I recommend increasing the consumption of beef, which requires way more agricultural land than the other foods I analysed. Nevertheless, I recommend funding the Centre for Exploratory Altruism Research's (CEARCH's) High Impact Philanthropy Fund (HIPF) over that. I estimated buying beef is 3.72 % as cost-effective as funding HIPF.
- I recommend investigating whether soil ants and nematodes have positive or negative lives, starting with soil nematodes. I estimate effects on soil ants account for most of the effects on soil ants, termites, springtails, mites, and nematodes for all the foods I analysed for an exponent of the number of neurons of 1.40 or higher, and that effects on soil nematodes account for most of those effects for all the foods I analysed for an exponent of 1.21 or lower. I supposed soil nematodes have negative lives, but can easily see them having positive lives, and would conclude that increasing agricultural land is harmful (instead of beneficial) in this case.

Methods

I estimate the change in the welfare of animals affected by the production of beef, pork, chicken, turkey, dairy milk, fish, eggs, shrimp, peas, tofu, and soy milk. I analyse directly affected animals, and soil ants, termites, springtails, mites, and nematodes impacted by changes in land use.

I suppose welfare per animal-year is proportional to the welfare range, the difference between the maximum and minimum welfare per unit time, and that this is a power law of the number of neurons. In particular, I use welfare ranges as a fraction of that of humans equal to "number of neurons as a fraction of that of humans"^"exponent of the number of neurons", with the exponent ranging from 0 to 2, as I did before. For an exponent of:

- 0, all animals have the welfare range of humans.
- 0.188:
  - The welfare ranges are pretty similar to the estimates in Bob's book about comparing animal welfare across species, which contains what RP stands behind now. An exponent of 0.188 explains 78.6 % of their variance.
    - Bob, who led RP's moral weight project, said on July 28 that "What we [RP] stand behind now is really just what we published in the book [the one I linked to in the summary; here is a comparison between the book's and RP's initial estimates for the welfare ranges]".
  - The number of neurons has to become 209 k (= 10^(1/0.188)) times as large for the welfare range to become 10 times as large.
- 0.5, corresponding to my best guesses for the welfare ranges, the number of neurons has to become 100 (= 10^(1/0.5)) times as large for the welfare range to become 10 times as large.
- 1, the welfare ranges are proportional to the number of neurons.
- 2, the number of neurons has to become 3.16 (= 10^(1/2)) times as large for the welfare range to become 10 times as large.

RP's moral weight project included a report by Adam Shriver concluding "there is no straightforward empirical evidence or compelling conceptual arguments indicating that relative differences in neuron counts within or between species reliably predicts welfare relevant functional capacities". I guess there are other factors besides the number of neurons that influence the welfare range. However, an exponent of 0.188 explains 78.6 % of the variance of the estimates in Bob's book. So I prefer to rely on a simple formula to decrease noise, and easily obtain estimates for animals not covered in the book to explore implications for cause prioritisation. I get that exponent from the slope of a linear regression with null intercept of the logarithm of RP's preferred welfare range as a fraction of that of humans on the logarithm of the number of neurons as a fraction of that of humans

My formula for the welfare range as a fraction of that of humans implies a welfare range as a fraction of that of humans of 0 for organisms without neurons, which I think is an underestimate, as I am not certain they have a constant welfare per unit time as a result of not having neurons.

Furthermore, I speculate effects on microorganisms, which do not have neurons, are much larger than those on soil animals, although positively correlated.

I calculate the decrease in the welfare of the directly affected animals per food-kg by multiplying my past estimates by my updated welfare range of the directly affected animals as a fraction of that I used to obtain them.

I suppose the welfare per animal-year of soil ants/termites/springtails/mites/nematodes is -25 % that of fully happy soil ants/termites/springtails/mites/nematodes. I assume this holds for all biomes, but I guess there is variation in reality. Karolina Sarek, Joey Savoie, and David Moss estimated -42 % for the "wild bug" in 2018, which is more negative than what I assumed. My best guess is that soil animals have negative lives, but I am very uncertain.

I get the number of soil ants, termites, springtails, and mites per unit area for 10 biomes using the means in Table S4 of Rosenberg et al. (2023). I determine the number of soil nematodes per unit area by multiplying the number of soil arthropods from this table by 48.9, which is my estimate for the ratio between the number of soil nematodes and soil arthropods globally.

I set the animal-years of directly affected animals per food-kg of animal-based foods to estimates from Faunalytics for the United States (US) for the living time of farmed and wild animals, including farmed animals which die before slaughter, and 1 animal-day per wild feeder fish.

I rely on the m^2-years of agricultural land per food-kg from Poore and Nemecek (2018).

Here are my calculations.

Results

Number of soil animals affected

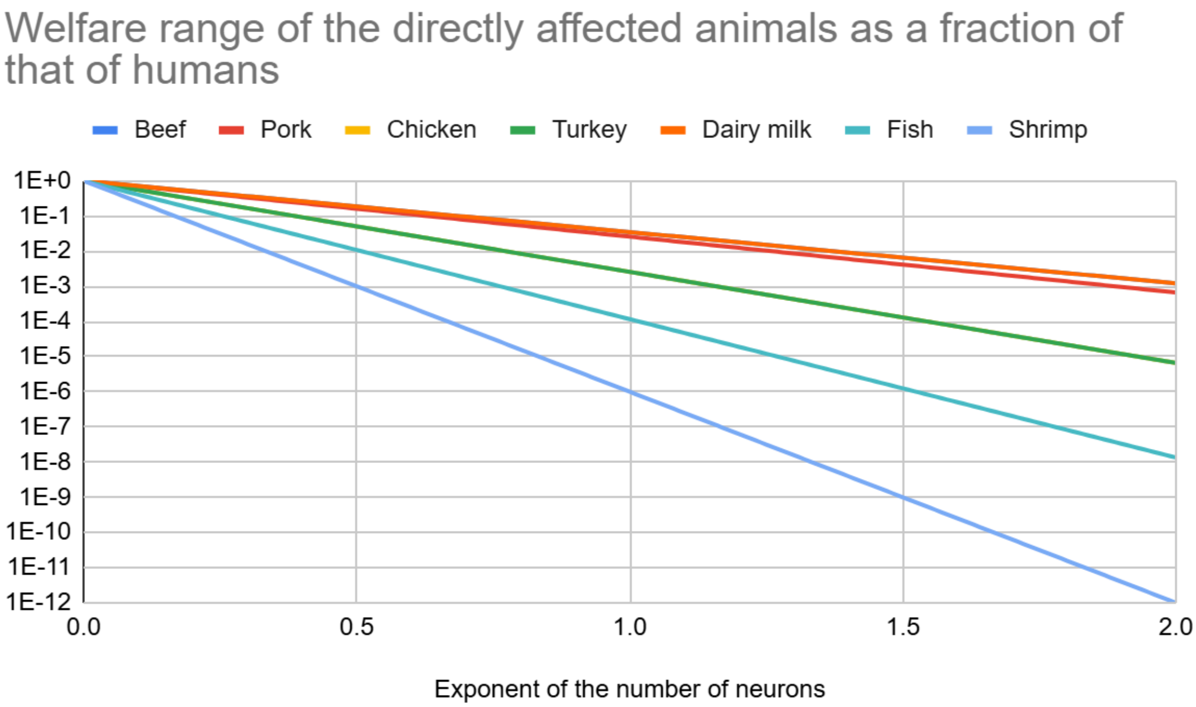
"E+" stands for "*10^". I estimate food consumption decreases the living time of soil animals 410 k (shrimp) to 164 billion (beef) times as much as it increases the living time of the directly affected animals.

Food	Increase in the living time of directly affected animals (animal-day	Initial number of soil animals per m² of the affected land	Final number of soil animals per m² of the affected land	Decrease in the number of soil animals per m²	Decrease in the living time of soil animals (animal-year/food-kg)	Decrease in the living time of soil animals as a fraction of the increase in

	/food-kg)					the living time of directly affected animals
Beef	3.09	5.11E+06	8.62E+05	4.25E+06	1.39E+09	1.64E+11
Pork	2.24	5.81E+06	1.36E+06	4.45E+06	7.73E+07	1.26E+10
Chicken	28.7	5.81E+06	1.36E+06	4.45E+06	5.44E+07	6.92E+08
Turkey	11.5	5.81E+06	1.36E+06	4.45E+06	5.44E+07	1.73E+09
Dairy milk	0.0378	6.38E+06	1.01E+06	5.37E+06	4.80E+07	4.64E+11
Fish	82.1	5.81E+06	1.36E+06	4.45E+06	3.74E+07	1.67E+08
Eggs	28.0	5.81E+06	1.36E+06	4.45E+06	2.79E+07	3.64E+08
Shrimp	9.92E+03	5.18E+06	1.36E+06	3.82E+06	1.11E+07	4.10E+05
Peas	0	7.06E+06	1.36E+06	5.70E+06	4.25E+07	
Tofu	0	5.81E+06	1.36E+06	4.45E+06	1.57E+07	
Soy milk	0	5.81E+06	1.36E+06	4.45E+06	2.94E+06	

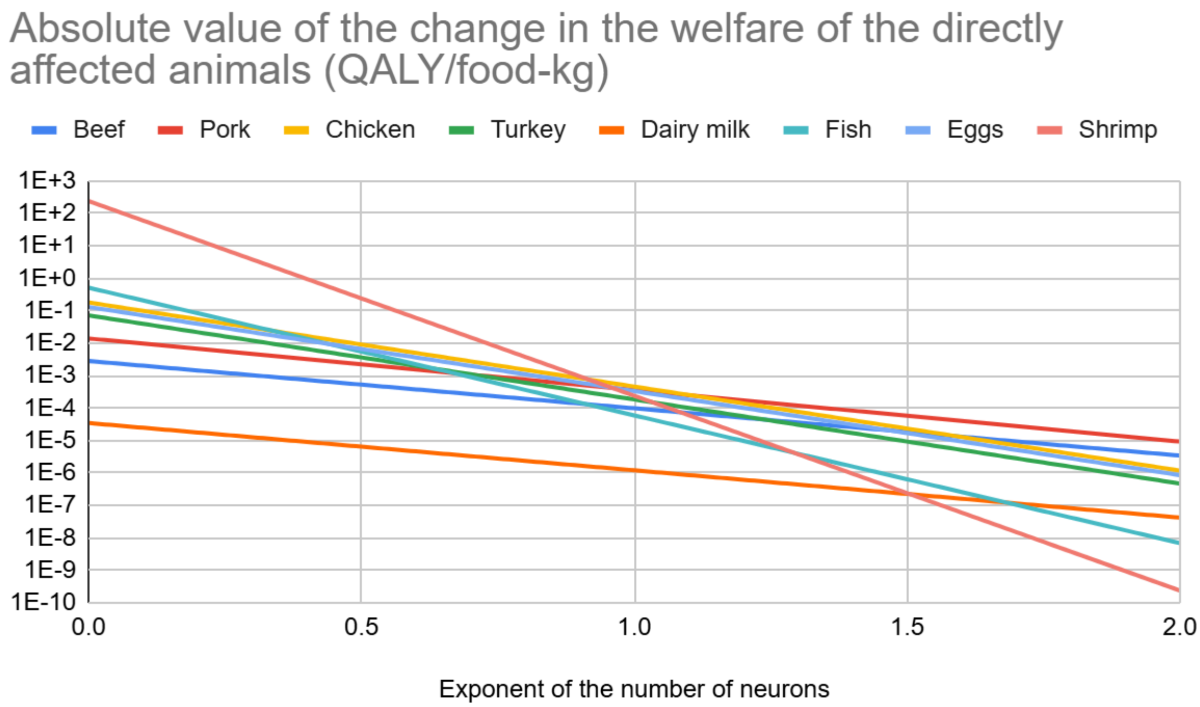
Welfare range of the directly affected animals as a fraction of that of humans

The welfare range of the directly affected animals decays faster (with the exponent of the number of neurons) for ones with fewer neurons. The slope of the straight lines below is the logarithm of the number of neurons as a fraction of that of humans.



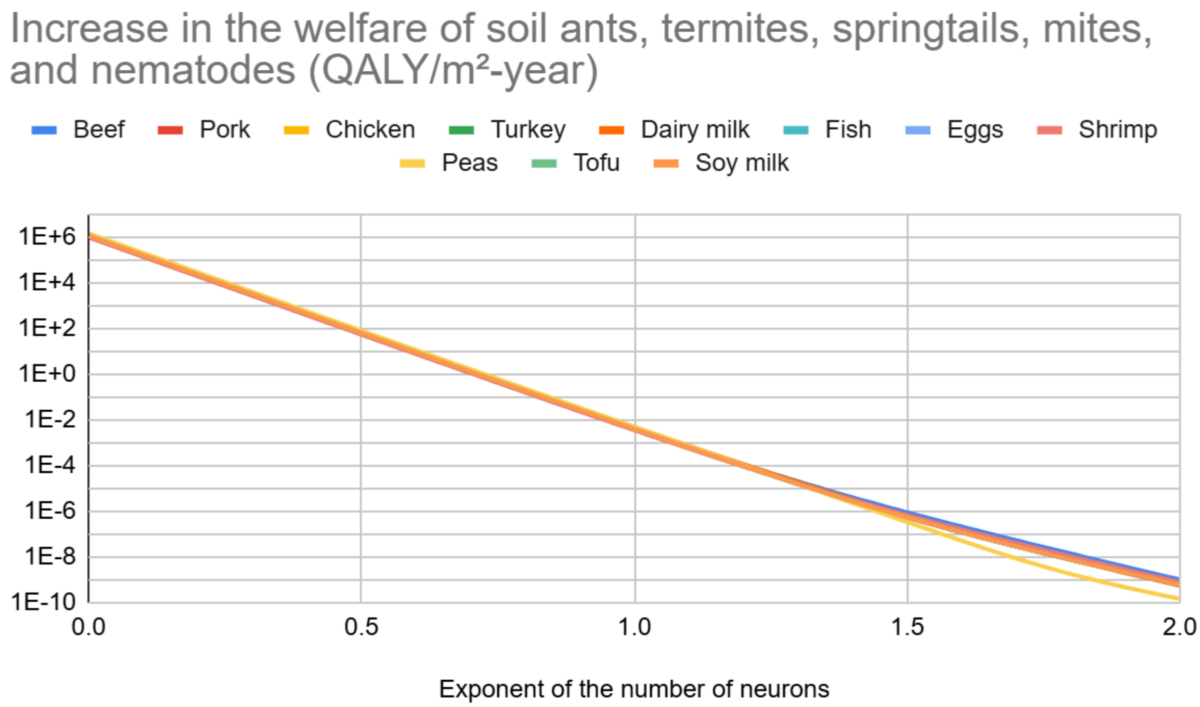
Absolute value of the change in the welfare of the directly affected animals

The lines for beef and dairy milk respect increases in welfare, and all the others represent decreases.



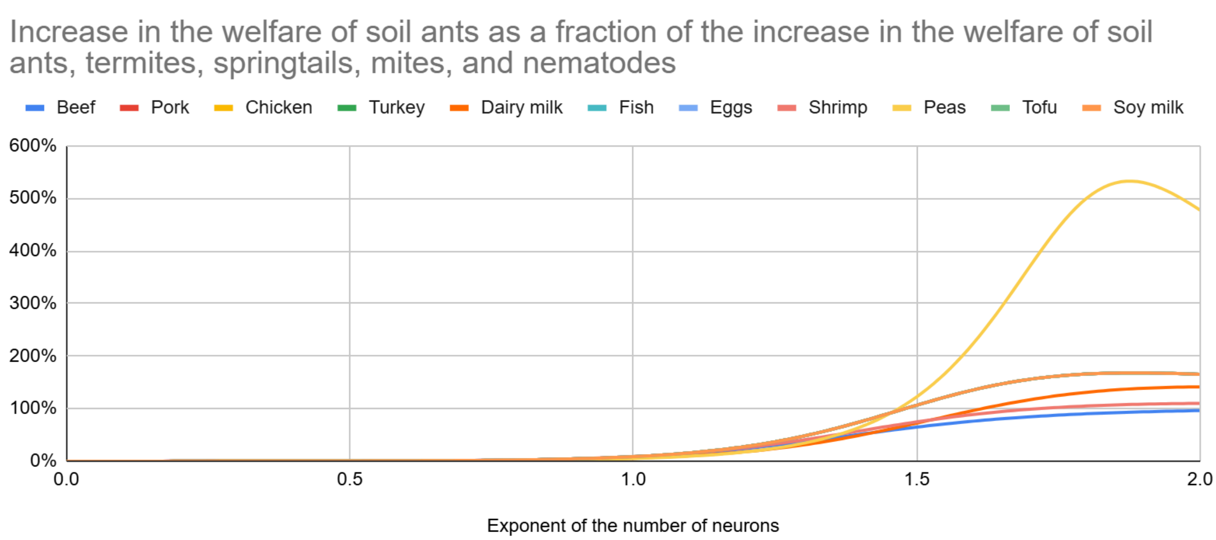
Increase in the welfare of soil ants, termites, springtails, mites, and nematodes

The increase in the welfare of soil soil ants, termites, springtails, mites, and nematodes per unit area is similar for all interventions because Gemini 2.5 guessed the additional agricultural land would replace biomes in approximately the same way. In reality, there is variation even within a single type of intervention.



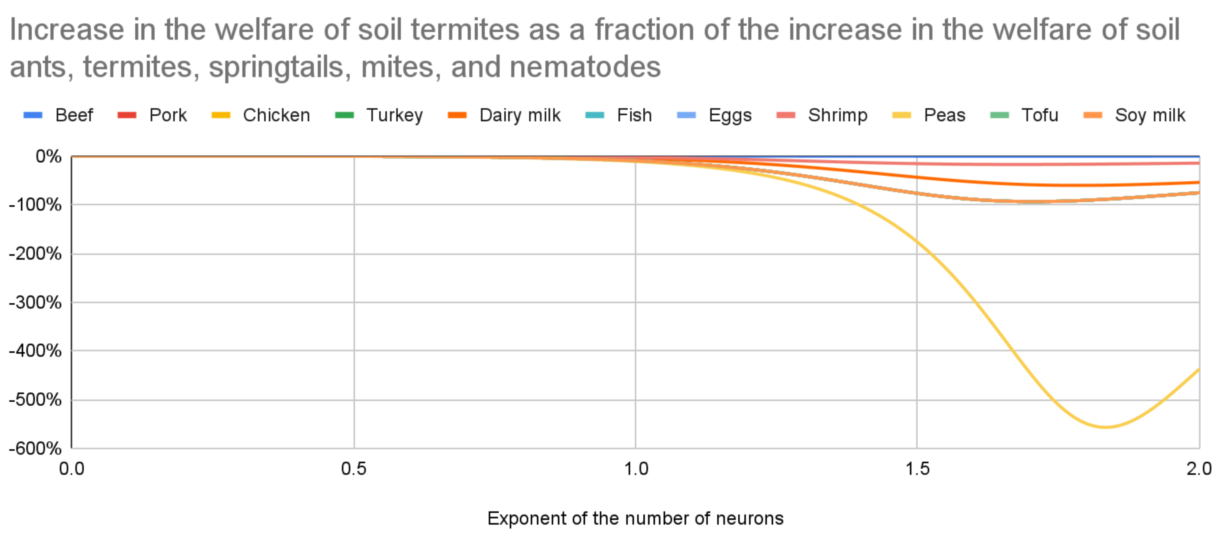
Increase in the welfare of soil ants as a fraction of the increase in the welfare of soil ants, termites, springtails, mites, and nematodes

The effect on soil ants is the major driver of the effects on soil ants, termites, springtails, mites, and nematodes for a high exponent of the number of neurons because they have the most neurons per individual among those animals.



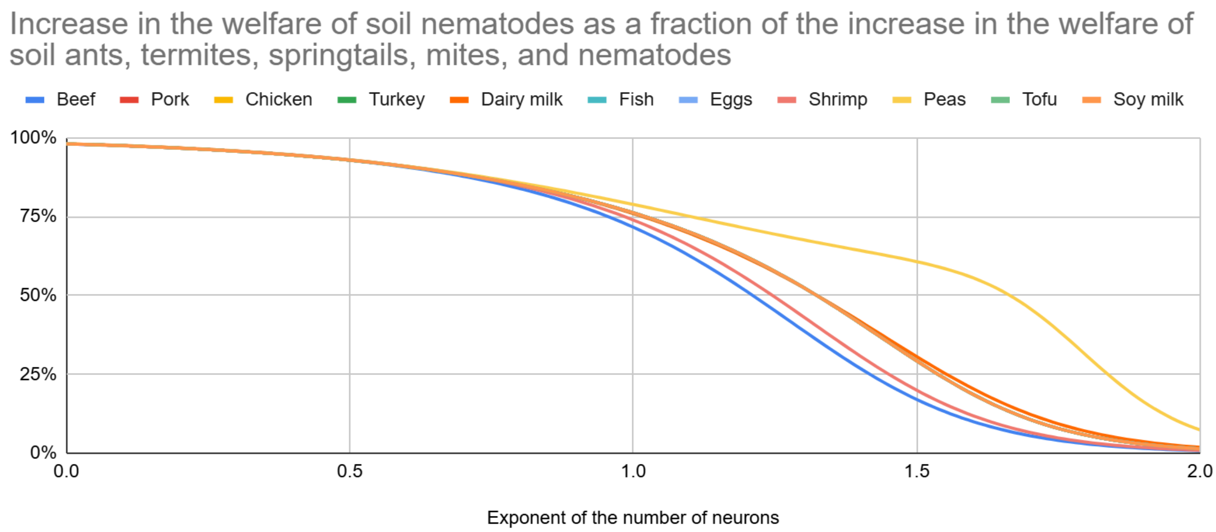
Increase in the welfare of soil termites as a fraction of the increase in the welfare of soil ants, termites, springtails, mites, and nematodes

I infer food production decreases the welfare of soil termites. However, crops and pastures have the least soil ants/springtails/mites/nematodes per unit area besides deserts, and xeric shrublands, which would very hardly be replaced by the additional agricultural land, and effects on soil termites account for a tiny fraction of the effects on soil ants, termites, springtails, mites, and nematodes for an exponent of the number of neurons lower than 1, which I endorse. So I conclude the welfare of those animals considered together would still decrease for land use changes different from the ones guessed by Gemini.



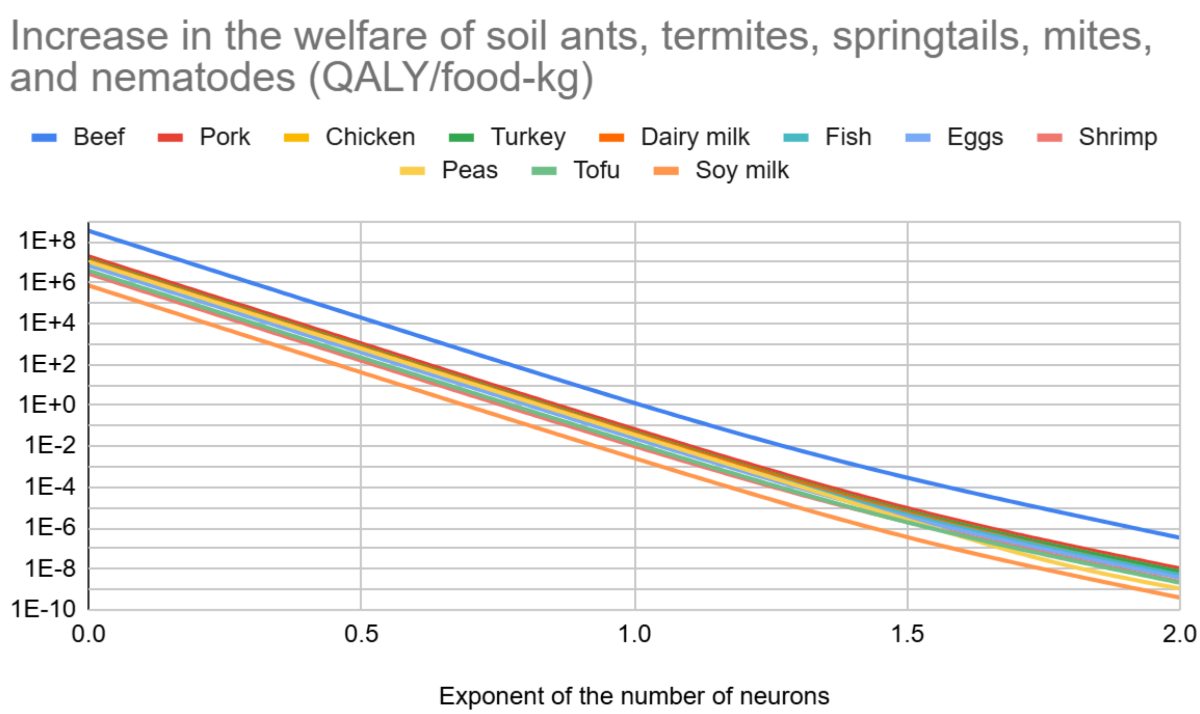
Increase in the welfare of soil nematodes as a fraction of the increase in the welfare of soil ants, termites, springtails, mites, and nematodes

The effect on soil nematodes is the major driver of the effects on soil ants, termites, springtails, mites, and nematodes for a low exponent of the number of neurons because they have the least neurons per individual among those animals.



Increase in the welfare of soil ants, termites, springtails, mites, and nematodes

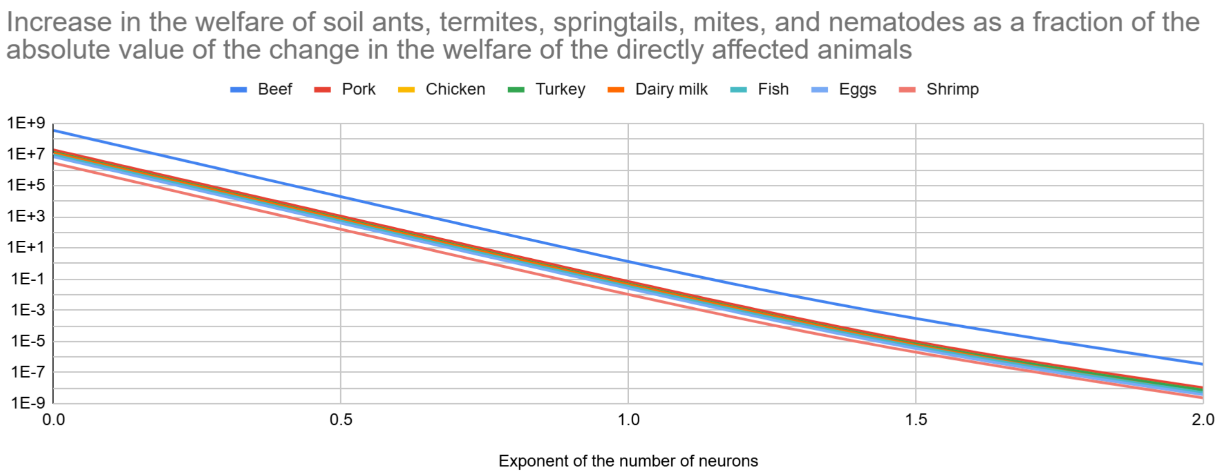
There is some variation in the increase in the welfare of soil ants, termites, springtails, mites, and nematodes per $ across foods. Yet, there is way more variation with the exponent of the number of neurons within a single food.



Increase in the welfare of soil ants, termites, springtails, mites, and nematodes as a fraction of the absolute value of the change in the welfare of the directly affected animals

I believe effects on soil animals are much larger than those on the directly affected animals. I am confident the exponent of the number of neurons is the parameter which affects the ratio between the effects on soil animals and directly affected animals the most by far, and effects on soil animals dominate at least for values of the exponent up to 1, which are the ones I consider plausible. I get the following increase in the welfare of soil ants, termites, springtails, mites, and nematodes as a fraction of the absolute value of the change in the welfare of the directly affected animals. For an exponent of the number of neurons of (the lower and upper bound respect shrimp and dairy milk):

- 0.19, 1.33 k to 1.76 billion.
- 0.5, 223 to 11.6 M.
- 1, 14.8 to 4.01 k.

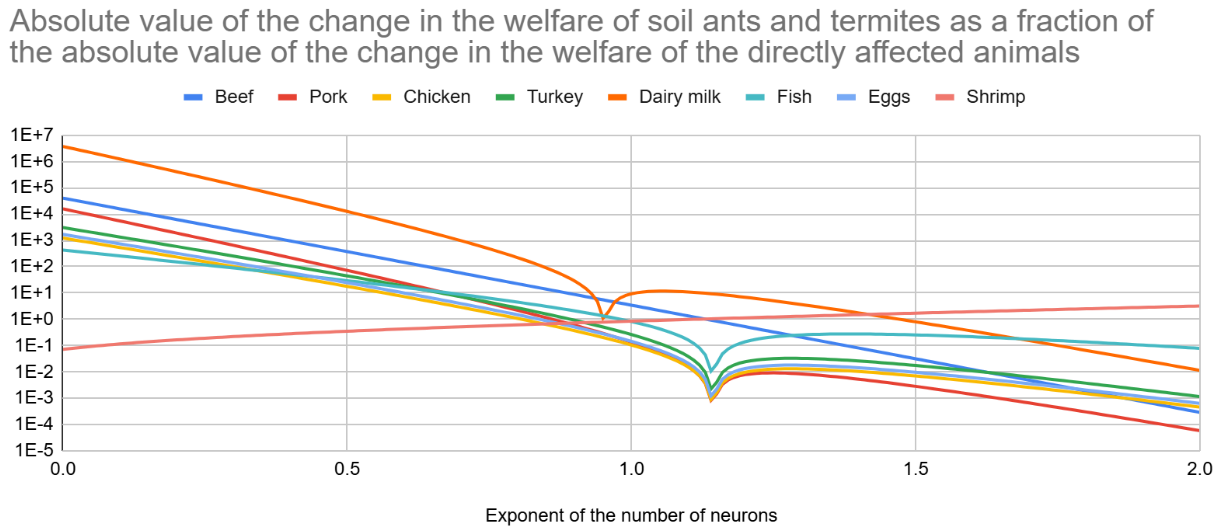


Absolute value of the change in the welfare of soil ants and termites as a fraction of the absolute value of the change in the welfare of the directly affected animals

For all the animal-based foods I analysed besides shrimp, I estimate effects on soil animals would still be much larger than those on the target beneficiaries for a welfare per animal-year of exactly 0 for animals with fewer neurons than those considered in Bob's book, and an exponent of the number of neurons of 0.19 which explains very well its estimates (an exponent of 0.188 explains 78.6 % of their variance). I calculate soil ants and termites have 2.91 (= 250*10^3/(86*10^3)) and 1.16 (= 100*10^3/(86*10^3)) times as many neurons as shrimp, so effects on them would still be relevant. I get the following absolute value of the change in the welfare of soil ants and termites as a fraction of the absolute value of the change in the welfare of the directly affected animals for an exponent of 0.19:

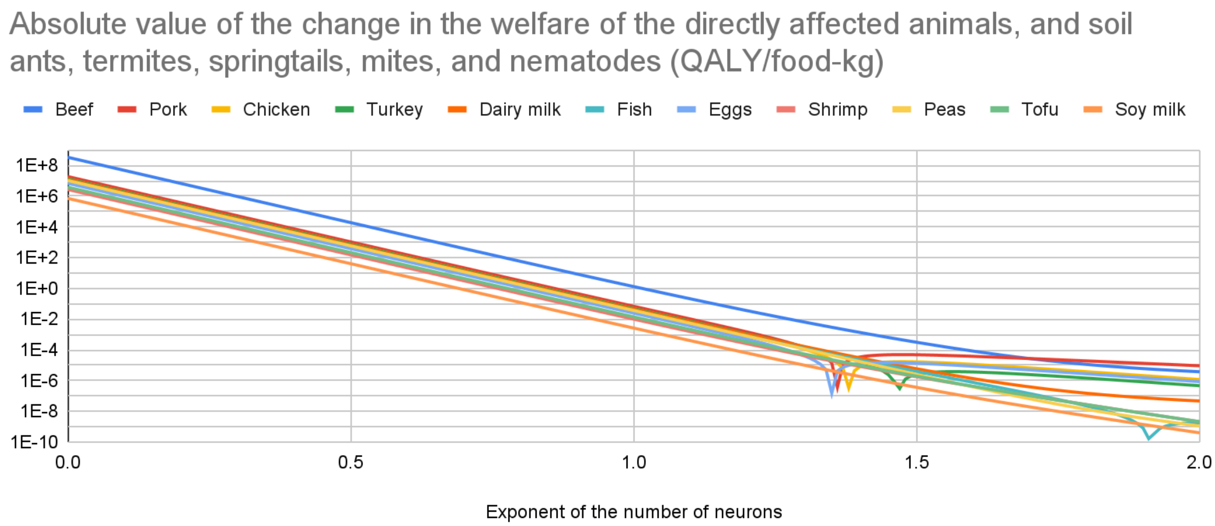
- For the animal-based foods I analysed besides shrimp, 160 (fish) to 454 k (dairy milk).
- For shrimp, 16.0 %.

The production of beef and shrimp increases the welfare of soil ants and termites for any exponent. The other animal-based foods decrease it before the sharp points below, and increase it afterwards.



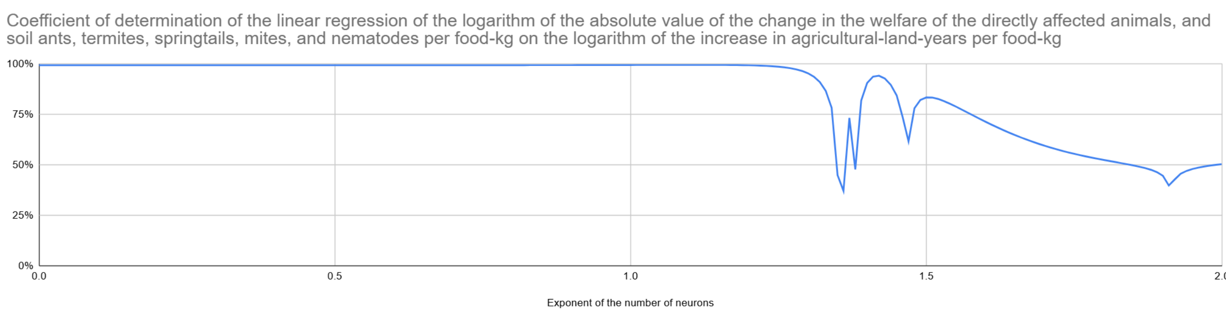
Increase in the welfare of the directly affected animals, and soil ants, termites, springtails, mites, and nematodes

I conclude producing beef increases the welfare of the directly affected animals, and soil ants, termites, springtails, mites, and nematodes (considered all together) much more than the other foods for any exponent of the number of neurons. The production of beef, dairy milk, peas, tofu, and soy milk increases their welfare for any exponent. The production of pork, chicken, turkey, fish, and eggs increases it before the sharp points below, and decreases it afterwards. The minimum exponent to decrease their welfare is 1.36 for pork, 1.39 for chicken, 1.47 for turkey, 1.92 for fish, 1.35 for eggs, and higher than 2 for shrimp.



Coefficient of determination of the linear regression of the logarithm of the absolute value of the change in the welfare of the directly affected animals, and soil ants, termites, springtails, mites, and nematodes per food-kg on the logarithm of the increase in agricultural-land-years per food-kg

The logarithm of the increase in agricultural-land-years per food-kg explains over 90 % of the variance in the logarithm of the absolute value of the change in the welfare of the directly affected animals, and soil ants, termites, springtails, mites, and nematodes per food-kg for an exponent of the number of neurons up to 1.43. In other words, one can predict this absolute value of the change in welfare per food-kg from the increase in agricultural-land-years per food-kg alone for those exponents. This is because the effects on soil animals are much larger than those on the directly affected animals in this case, and the increase in the welfare of soil animals per unit area is similar.



Results for my preferred welfare ranges

Below are the results for my preferred welfare ranges respecting an exponent of the number of neurons of 0.5. My exponent is significantly higher than the value of 0.188 which I estimate explains 78.6 % of the variance in RP's preferred estimates. So my exponent implies the welfare range increases much closer to linearly with the number of neurons, although still significantly sublinearly.

There is variation in land use changes within each type of food, and therefore increasing the production of specific subtypes of food matters. For example, increasing the production of some chicken may increase welfare more than increasing the production of random pork.

Intervention	Beef	Pork	Chicken	Turkey	Dairy milk	Fish	Eggs	Shrimp	Peas	Tofu	Soy milk
Increase in agricultural land (m²-year/food-kg)	326	17.4	12.2	12.2	8.95	8.41	6.27	2.91	7.46	3.52	0.660
Decrease in the living time of soil animals (animal-year/food-kg)	1.39E+09	7.73E+07	5.44E+07	5.44E+07	4.80E+07	3.74E+07	2.79E+07	1.11E+07	4.25E+07	1.57E+07	2.94E+06
Exponent of the number of neurons regarding my preferred welfare range	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500
Welfare range of the directly affected animals as a fraction of that of humans	0.187	0.161	0.0507	0.0507	0.187	0.0108	0.0507	0.00100			

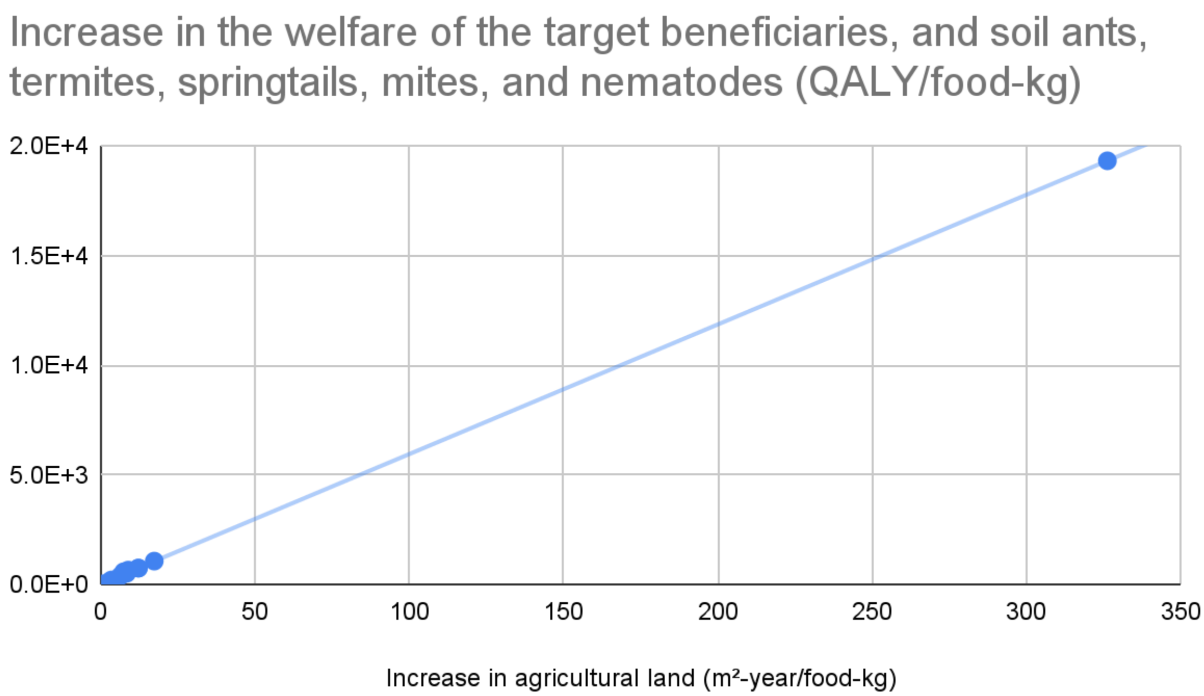
Welfare range of the directly affected animals as a fraction of that I have used in the past	36.3%	31.2%	15.3%	15.3%	36.3%	12.1%	15.3%	3.23%			
Decrease in the welfare of the directly affected animals (QALY/food-kg)	-5.26E-04	0.00223	0.00905	0.00362	-6.46E-06	0.00550	0.00657	0.238	0	0	0
Increase in the welfare of soil ants (QALY/m²-year)	0.201	0.201	0.201	0.201	0.157	0.201	0.201	0.178	0.143	0.201	0.201
Increase in the welfare of soil termites (QALY/m²-year)	-0.00461	-0.363	-0.363	-0.363	-0.238	-0.363	-0.363	-0.0940	-0.516	-0.363	-0.363
Increase in the welfare of soil springtails (QALY/m²-year)	1.06	2.10	2.10	2.10	2.36	2.10	2.10	0.768	3.35	2.10	2.10
Increase in the welfare of soil mites (QALY/m²-year)	2.97	2.48	2.48	2.48	2.96	2.48	2.48	2.893	2.65	2.48	2.48
Increase in the welfare	55.0	57.6	57.6	57.6	69.5	57.6	57.6	49.5	73.8	57.6	57.6

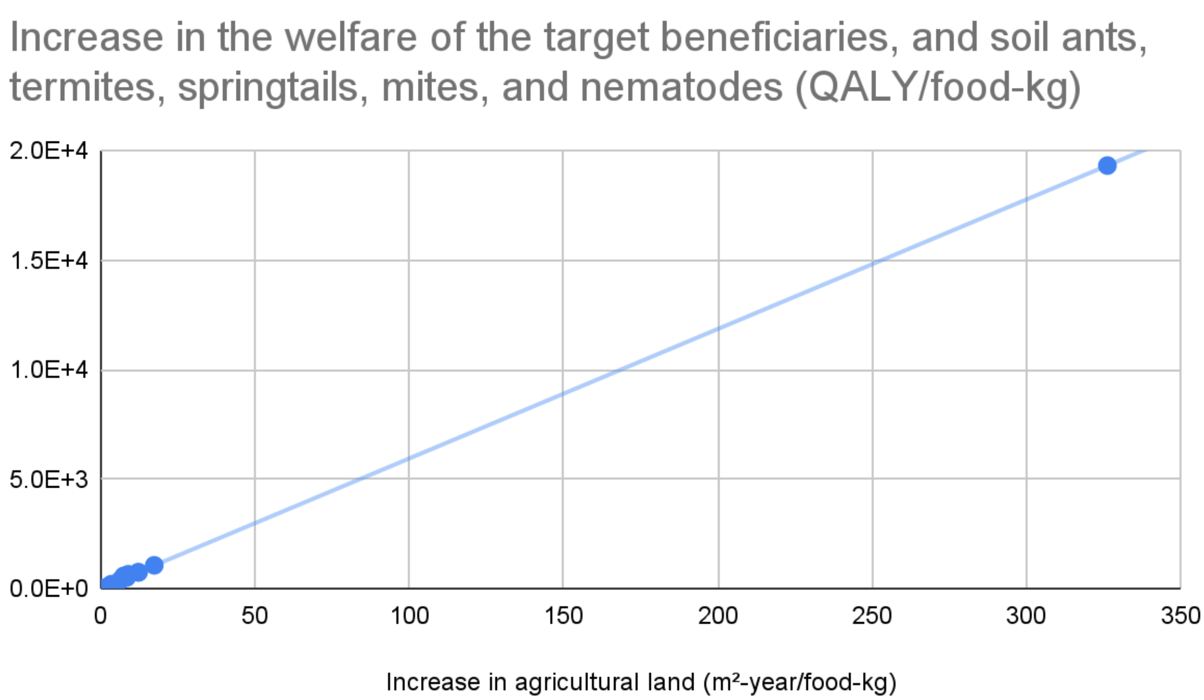
of soil nematodes (QALY/m²-year)											
Increase in the welfare of soil ants, termites, springtails, mites, and nematodes (QALY/m²-year)	59.2	62.0	62.0	62.0	74.7	62.0	62.0	53.2	79.4	62.0	62.0
Increase in the welfare of soil ants as a fraction of the increase in the welfare of soil ants, termites, springtails, mites, and nematodes	0.339 %	0.325 %	0.325 %	0.325 %	0.211 %	0.325 %	0.325 %	0.334 %	0.180 %	0.325 %	0.325 %
Increase in the welfare of soil termites as a fraction of the increase in the welfare of soil ants, termites, springtails, mites, and nematodes	-0.00778%	-0.585 %	-0.585 %	-0.585 %	-0.319 %	-0.585 %	-0.585 %	-0.177 %	-0.650 %	-0.585 %	-0.585 %
Increase in the welfare of soil springtails	1.80%	3.39%	3.39%	3.39%	3.16%	3.39%	3.39%	1.44%	4.21%	3.39%	3.39%

as a fraction of the increase in the welfare of soil ants, termites, springtails, mites, and nematodes											
Increase in the welfare of soil mites as a fraction of the increase in the welfare of soil ants, termites, springtails, mites, and nematodes	5.02%	3.99%	3.99%	3.99%	3.96%	3.99%	3.99%	5.44%	3.34%	3.99%	3.99%
Increase in the welfare of soil nematodes as a fraction of the increase in the welfare of soil ants, termites, springtails, mites, and nematodes	92.9%	92.9%	92.9%	92.9%	93.0%	92.9%	92.9%	93.0%	92.9%	92.9%	92.9%
Increase in the welfare of soil ants, termites, springtails, mites, and nematodes (QALY/food-kg)	1.93E+04	1.08E+03	758	758	668	522	389	155	592	218	40.9

Increase in the welfare of soil ants, termites, springtails, mites, and nematodes as a fraction of the absolute value of the change in the welfare of the directly affected animals	1.13E+05	2.78E+04	6.85E+03	1.71E+04	1.16E+07	1.13E+04	9.45E+03	223			
Increase in the welfare of the target beneficiaries, and soil ants, termites, springtails, mites, and nematodes (QALY/food-kg)	1.93E+04	1.08E+03	758	758	668	522	389	155	592	218	40.9
Increase in the welfare of the target beneficiaries, and soil ants, termites, springtails, mites, and nematodes as a fraction of that caused by eating beef	100%	5.57%	3.92%	3.92%	3.46%	2.70%	2.01%	0.800%	3.07%	1.13%	0.212%

For my preferred welfare ranges, the m^2-years of agricultural land per food-kg explain 100 % of the variance in the increase in the welfare of the directly affected animals, and soil ants, termites, springtails, mites, and nematodes per food-kg.





My recommendations

I continue to recommend changes in food consumption which increase agricultural land. I estimate the m^2-years of agricultural land per food-kg almost perfectly explain the increase in the welfare of the directly affected animals, and soil ants, termites, springtails, mites, and nematodes per food-kg for my preferred exponent of the number of neurons of 0.5 (see last 2 graphs). In particular, I recommend increasing the consumption of beef, which requires way more agricultural land than the other foods I analysed. Nevertheless, I recommend funding the Centre for Exploratory Altruism Research's (CEARCH's) High Impact Philanthropy Fund (HIPF) over that. I estimated buying beef is 3.72 % as cost-effective as funding HIPF.

I recommend investigating whether soil ants and nematodes have positive or negative lives, starting with soil nematodes. I estimate effects on soil ants account for most of the effects on soil ants, termites, springtails, mites, and nematodes for all the foods I analysed for an exponent of the number of neurons of 1.40 or higher, and that effects on soil nematodes account for most of those effects for all the foods I analysed for an exponent of 1.21 or lower. I supposed soil nematodes have negative lives, but can easily see them having positive lives, and would conclude that increasing agricultural land is harmful (instead of beneficial) in this case.