Life expectancy and planetary health in Addis Ababa can be enhanced through optimized consumption of plant and animal source foods

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Abstract:

In Ethiopia, children and adults face a double burden of malnutrition, with coexisting undernutrition, stunting, and non-communicable diseases. Here, we use a framework of comparative risk assessment, local dietary surveys, and relative risks from large observational studies to quantify the health and environmental impacts of meeting adult and child recommended daily protein intakes in urban Addis Ababa. We find that plant-based foods, especially legumes, would have the lowest environmental impact and substantially increase life expectancy in adults, whilst animal-sourced proteins could be beneficial for children. This context-specific approach – accounting for regional constraints and trade-offs – can aid policy makers in developing culturally appropriate, nutritionally adequate and sustainable dietary recommendations.

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Introduction

Many low-and-middle-income countries (LMICs) suffer a double burden of malnutrition. In Ethiopia, this burden is defined by simultaneously high child stunting prevalence (>30%) and women's overweight prevalence (>20%).[1] This high burden of malnutrition is partially due to suboptimal diets: protein deficiency accounts for 1.4% of disability-adjusted life years (DALYs)[2] and ~50% of women and children and >60% of men consume protein below the Estimated Average Requirement (EAR).[3]

Animal source foods with higher bioavailability of nutrients like heme iron, zinc, and vitamin B-12 may benefit child growth.[4] However, high intakes of for instance red and processed meats, are associated with greater risk of chronic diseases like obesity and cardiovascular disease.[5,6] Plant source foods are rich in the same nutrients (with variations in bioavailability and nutrient density)[7,8] but are associated with lower cardiovascular disease risk and smaller environmental impacts, specifically global greenhouse gas (GHGs) emissions and land use.[9] Current animal agriculture production is also a major contributor to global GHG emissions and accounts for ~70% of agricultural land use (30% of total land surface).[10] Increasing demand for animal foods in LMICs may put further strain on environmental resources: By 2050, LMICs are projected to account for 85% of world meat consumption and 70% of production.[11,12] In Ethiopia, beef consumption increased by 28% between 2005 to 2011 alone.[13] However, a complete substitution of animal with plant protein sources (e.g., from red meat to legumes) may not be universally possible, especially for vulnerable populations like pregnant women and young children with heightened nutritional demands.[8,9] Further, while increased protein supplies under current practices will tend to come at an environmental cost, shifting to climate-smart agricultural strategies could help restore land and water resources and reduce GHG emissions.

In 2019, based on modeling efforts, the EAT-Lancet Commission recommended adopting a global reference diet, consisting mainly of plant source foods, and minimal red or processed meat.[9,14-16] While useful for advocacy, global reference diets do not consider regional and local food systems variations and may have limited use in guiding national and regional food system policies and programs.[9] A recent study in India found that shifting current national food consumption patterns to diets meeting the dietary guidelines increased environmental footprint by only 3-5%.[17] To our knowledge, no such studies have been conducted in African LMICs. Given the double burden of malnutrition in Ethiopia and rising environmental resource strain related to demand for animal source foods, evidence is urgently needed on the health and environmental impacts of different dietary patterns. Therefore, we quantified the health and environmental impacts of meeting adult and child recommended daily protein intakes in Addis Ababa, Ethiopia using eight combination strategies of animal and plant source foods (Figure 1). We aimed to determine the optimal combination to improve child and adult health outcomes while also reducing the environmental footprint of meeting their nutritional needs. This assessment was conducted using an assumption of status quo food production efficiencies in Ethiopia for both animal and plant source foods.

Results

Characteristics of the survey population are reported in Supplementary Table 1. Among the 1,050 households enrolled in our nutrition survey, 31.3% of children, 65.9% of women, and

81.5% of men were consuming protein below recommended dietary allowance (RDA: 56.0 g/day for men, 46.0 g/day for women and 13.8 g/day for children[18]; Supplementary Table 3). Parameters used in quantifying the health outcomes of meeting the protein dietary reference intake are reported in Table 1. Average daily protein intake in the study population was 19.2 grams among children, 41.3 grams among women, and 38.9 grams among men. Among those who consumed protein below the RDA, average daily protein intakes were 10.3 grams among children, 30.8 grams among women, and 32.8 grams among men. Plant protein made up 75% of overall protein intake among children and 79% among adults in the current diet (Supplementary Table 1). Participants received 6.5% of their protein intake from chicken and eggs, 16.3% from milk and red meat, 50% from grains, and 28.3% from legumes. Seafood was consumed in negligible amounts (not reported).

Among the eight strategies to provide sufficient protein, the strategy of providing animal-source protein for children and plant-source protein for adults was estimated to have the largest absolute health gain: 2,117 annual deaths were delayed among the 3.6 million inhabitants of Addis Ababa, and life expectancy at birth was estimated to increase by 1.19 years (Table 2**a**, Figure 2**a**). Using legumes or a combination of all available plant foods would avert an estimated 2,085 annual deaths and increase life expectancy at birth by 1.16 years. By comparison, using the current composition of protein was associated with averting 1,604 annual deaths or increasing life expectancy by 0.89 years. The animal sourced food strategies were associated with a net increase of up to 120 annual deaths– a reduction in life expectancy at birth of 0.04-0.05 years (Table 2a). Results using the EAR threshold were overall similar: Using the EAR, the overall impacts per person (proportional reductions in stunting and mortality, increases in life expectancy, total deaths delayed) are lower because less protein is supplied per person. However, no changes are observed for the relative impact of each scenario, i.e. which is most environmentally efficient in improving life expectancy (Table 2a). Results using the EAR threshold are reported in Supplementary Table 1 and 2, but not reported on here.

Using legumes to provide sufficient protein had the lowest environmental impact with an increase of land and water use of 65% and a 2% increase in GHG emissions relative to the environmental impacts associated with the status quo diet consumed at the time of the survey (Table 3, Figure 2b). Environmental impacts are reported in their absolute unit increases in Supplementary Figure 1 and reported as percentage increases elsewhere to aid interpretability. The highest environmental impact was estimated for the milk and red meat strategy, with an increase of 190% in land and water use and 257% increase in GHG emissions. Impact on each environmental indicator varied by food group. For instance, using grains to increase protein would raise GHG emissions by 7% (0.03 kg/person-day), but increase green water consumption by 38% (593 liters/person-day) and land use by 21% (0.74 m^2/person-day). By comparison, the milk and red meat strategy would increase GHG emissions by 257% (1.23 kg/person-day), green water consumption by 38% (580 liters/person-day) and land use by 111% (3.83 m^2/person-day) (Table 3).

When all strategies were simply expressed in terms of health gains possible via doubling of environmental impacts, while disregarding the various advanced management approaches and technological innovations that could potentially improve environmental efficiencies, legumes had the largest health benefit by increasing life expectancy at birth by 4.63% (Figure 2c). Using animal-source protein for children and plant-source protein for adults and using a combination of plant-source foods were tied in showing the second largest increase in life expectancy at birth, namely 3.05-3.07% per doubling of environmental impacts. In contrast, animal source strategies – i.e., using red meat and dairy, chicken and eggs, or a combination of these –corresponded to a net 0.02-0.04% *decrease* in life expectancy at birth per 100% increase of environmental impact (Figure 2b).

Discussion

This optimization study evaluated the planetary health impact of meeting protein intake requirements using various food sources. Our results suggest an *average* potential 1.19 year or 1.8% increase in life expectancy at birth if the population of Addis Ababa consumed sufficient protein to meet the RDA for children, women, and men. This impact is similar to the increase in life expectancy expected if all obesity-related illness and mortality were eliminated from the target population (1.5 years for women and 1.9 years for men).[19] However, the type of protein source consumed can have substantially different effects on land and water use and GHG emissions. The combination of plant foods for adults and animal sources for children conferred the highest health gains over the status quo, closely followed by legumes, which imposed the smallest environmental strain. Protein from red meat and dairy was associated with the highest negative environmental impacts and had negligible impact on life expectancy.

Our findings are consistent with previous studies assessing the planetary health impacts of changing protein sources, which have recommended legumes and nuts as the primary protein source.[9] A global modeling study found similar environmental impacts from shifting national consumption patterns to replace 25-100% of animal sources with plant sources.[14] A recent projection study for India showed low intake of wheat, dairy, and poultry with an emphasis on legumes can reduce blue water footprints by 30%, GHG emissions by 12.9%, and save 6800 life-years per 100,000 adult population.[20] Using the environmental footprints of the status quo production patterns, our plant source food strategy showed much larger reductions in annual deaths for Addis Ababa at a higher environmental cost compared to the results in India. This is likely because we quantified the impact of increasing protein intake by food source, as compared to the substitution of current staple foods with more nutrient-rich plant- and animal-sourced foods done for India. Another recent study from India showed that changing domestic food production patterns towards low amounts of refined cereals, sugar, and plant oils could reduce regional cropland use by 50%, water demand by 65%, and combined resource inputs by 40%. Associated dietary shifts correlate with a decline in GHG emission of 34% and in total diet-related premature deaths of 14-30% (2.0-4.3 million people/year).[21]

Here, we examined the efficacy and environmental impacts of different diet patterns in urban Addis Ababa. However, strategies to increase protein intake in Ethiopia will depend on the local environmental context, and on national and local priorities. In areas experiencing water scarcity, priorities may favor a water-conserving strategy such as legume production. For instance, the western regions of Ethiopia receive moderate annual rainfall but have a dry winter, and the eastern regions are plagued by drought throughout the year. Thus, in the West a combination of plant foods may be more appropriate, whereas in the east a legume strategy may be the only viable option. Recommended strategies will also depend on dietary patterns across regions. The by-strategy comparison of stunting reductions shows that animal sources are more efficacious in reducing stunting per protein supplementation relative to plant sources, but that all nine strategies have modest impacts on stunting (0.42-2.0 percentage points). This finding fits with the observation that stunting prevalence is low in Addis Ababa (19%) relative to the national average (39%). The combined strategy may also be more culturally appropriate, being similar to the Christian Orthodox fasting pattern, where adults consume a vegetarian diet 250 days per year but children retain access to eggs and dairy. These results highlight that in diverse agro-climatic countries like Ethiopia a combination of optimization strategies may be more likely to achieve optimal health and environmental impact.

Relatedly, we calculated the environmental impacts that would result from extending current agricultural practices to meet the protein RDA in Addis Ababa. This would generally lead to an increase in land and water use and GHG emissions. Putting our various strategies for improving urban diets into a national (land, water) and global (emissions) context, we found that all strategies exceed national per-capita constraints on irrigation water, exceed or potentially exceed constraints on green water and land use, but would stay below per-capita GHG emission constraints apart from livestock-based strategies (Figure 3). These findings suggest that higher domestic agricultural productivity is needed to meet population protein needs sustainably within the country. Increased use of chemical fertilizers, pesticides, and machinery might help increase agricultural productivity in the short- to mid-term. Yet, such practices can increase production costs for farmers, which small-holders likely could not afford without government help, and would also likely exacerbate environmental degradation. In the long run, innovations in livestock management such as using seaweed as a food additive to reduce enteric fermentation may improve the dynamics between protein production and environmental impact.[22] In Ethiopia, reducing tillage, intercropping, and agroforestry approaches may reduce land and water use from plant food production and help offset resulting GHG emissions.[23-25] In other LMICs, silvopastural approaches or using higher quality crop residues as feed for ruminant meat and dairy can increase milk yields, sequester carbon, and reduce erosion. [21,26,27] While more quantitative research is needed to estimate the pros and cons of such alternative approaches for Ethiopia, these options hold promise for finding positive ways to deliver increased protein consumption while minimizing harm to environmental resources, or even improving them.

While legume production had the smallest environmental impact, providing some animal source foods alongside legumes offered additional health benefits in Addis Ababa. In addition to providing micronutrients important for child health, sustainable animal husbandry can help cycle nutrients within the ecosystem, reduce fertilizer use, diversify farmers' income, and serve as a financial buffer during droughts or floods.[28] Other studies have shown that limiting meat consumption is more environmentally favorable than eliminating it entirely.[16] Therefore, to optimize health and environmental impacts, Ethiopia could adopt strategies that encourage increased animal source consumption among children and increased plant source consumption among adults. We caution against extrapolating our findings to other African countries because the environmental impact of different food production strategies varies from place to place. Rather, context-specific local models are needed to aid policy makers in adapting the EAT-Lancet Commission reference diet to define local variants that are culturally appropriate, nutritionally adequate, and respect regional environmental constraints and planetary bounds. Lastly, dietary improvements are costly, and the average household may not be able to afford the EAT-Lancet recommendations, nor the locally adapted planetary guidelines.[29,30]

Several limitations are of note. First, as there are currently no cohort studies of protein intake and adult mortality in LMICs (as is the case for many other exposure-outcome relationships[9]), we derived the *relative* reduction in adult mortality using evidence from the only available prospective study in the United States. These estimates may not be directly applicable to Ethiopia. However, the population from which the effect estimate was derived had at least one unhealthy condition, which also constitutes a large proportion of the Addis Ababa population. Second, we derived estimates of the effect of higher protein intake on child stunting from an analysis that did not adjust for total calories, possibly leading to overestimation.[8] Third, although caloric intakes for children in our sample were similar to those reported for Addis Ababa from a nationally representative survey, mean adult intakes were lower by 300 kcal for women and 450 kcal for men.[3] This may reflect social desirability bias of women exaggerating their children's food intake, which would imply lower actual protein intakes and potentially underestimating the health and environmental gains from meeting the protein gap among children. Therefore, our estimates of health gains and environmental costs should be interpreted relative to other strategies, not as absolute gains. Further, we rely on a single measure of diet to estimate usual intake over the past seven days during January-February of 2018. We are therefore unable to capture the longer-term seasonal fluctuations of urban dietary patterns and impacts on reported intakes of protein foods.[31] Finally, we focused only on low protein intake compared with the RDA and did not model the health impact of other nutrients within a protein-rich diet.

Despite these limitations, our study has several major strengths. First, we collected local dietary data using a random sample of the target population to account for demographic, cultural, and socioeconomic patterns that influence the local food system. We further disaggregated our optimization by women, men, and children to reflect differential effects of plant- versus animal-source foods. We incorporated age-sex-specific mortality patterns for Ethiopia by using demographic life tables. Additionally, we used data on land and water use and GHG emissions derived from methodologically coherent global datasets, facilitating a comparison of our findings with other world regions. We modelled impacts on mortality exclusively. Yet, protein deficiency also reduces quality of life, for instance by increasing susceptibility to infection or reducing work capacity through muscle wasting and thus earning potential. In more severe cases, reduced quality of life can take the form of conditions like edema and kwashiorkor. Thus, estimating benefits of increased protein intake on mortality is a conservative case. Lastly, we used a single consistent allocation method for land and water resource use and GHG emissions of animal source foods to calculate their environmental impacts.

The findings presented here demonstrate the need for regional, tailored approaches to LMIC diet and food systems research – and policy development. Our approach of looking at trade-offs and applying rigorous methods to make local assessments of dietary options could be used to inform national nutrition guidelines. If food production is insufficient and threatened by climate change, population growth and environmental degradation, then governments, donors, and communities should consider possible alternative foods or production options. Future research should assess the feasibility and affordability of local dietary strategies like the ones examined here across the different Ethiopian contexts, while also investigating the impact of adopting more environmentally sustainable production strategies.

Methods

We evaluated the health impact of supplying protein to meet the Recommended Dietary Allowance (RDA) level using various sources of plant and animal protein foods.[18] For each strategy, we also calculated the combined environmental impact of land and freshwater use together with GHG emissions associated with meeting the RDA for protein for the study population. Finally, we compared and ranked the eight strategies in terms of health impact per environmental impact.

Protein food strategies

Each protein strategy was composed of a basket of foods (e.g. chicken and eggs or chickpeas, beans, groundnuts, lentils, and peas) consumed in the same proportions as consumed in the study population to preserve demonstrated local food preferences. Protein strategies were decided based on local expert and actual intakes from systematic surveys of more than 1,000 households that used a full food frequency questionnaire to capture what foods were consumed in the population. Our eight strategies were 1) all available protein foods, 2) chicken and eggs, 3) milk and meat, 4) all available animal source foods 5) grains, 6) legumes, 7) all available plant sources, and 8) a combination of animal source foods for children and plant source foods for adults. For each strategy, we calculated the average number of servings that would be needed by each person to meet the RDA for protein (Table 1). We focused on protein intake given the high potential for large impacts on planetary health relative to other macronutrients, micronutrients and minerals.

Nutritional and health outcome data

Participants and data:

Between January and March 2018, we selected a multi-stage random sample of 1,050 households from five sub-cities of urban Addis Ababa, Ethiopia. Inclusion criteria were that households had 1) a woman of reproductive age (18-49) and 2) at least one child between six and 59 months of age. In households where a male aged 18-49 years was available, he was also enrolled. To measure estimated dietary intakes, we used a locally adapted semi-quantitative food frequency questionnaire (FFQ)[32] We administered the FFQ to 1,050 children (aged six months to five years), 1,050 women and 635 men (aged 18 to 49 years) for a total sample size of 2,735 across 1,050 households. The survey was not stratified by age. Therefore, we applied the overall estimates of protein intake for ages 18-49. Female adult participants filled a household demographic survey, whereas weight and height were measured in all participants. Informed consent was collected from all participants and the survey protocol was approved by the Institutional Review Board of the Harvard T.H. Chan School of Public Health and by Addis Continental Institute of Public Health (IRB17-1825).

Health and nutritional data

We calculated total protein consumed from foods in each protein strategy using 1) FFQ food intake data, 2) protein contents from the Ethiopian food composition table (FCT), and 3) portion sizes obtained from previous nutrition surveys in Addis Ababa.[33] We used the Tanzanian FCT where Ethiopian estimates were missing, and used estimates adjusted for moisture and waste.[34] By comparing total protein intake with RDA, we estimated the prevalence of suboptimal protein intake.[18]

We used a pooled analysis of two large prospective cohort studies conducted in the United States to derive effect estimates for *relative* reductions in adult mortality by replacing carbohydrates with animal or plant protein.[5] *Relative* reductions in childhood stunting (defined as a height-for-age z-score more than two standard deviations below the WHO Child Growth Standards median) per unit increase in protein intake were obtained from a prospective analysis of 130,000 children in 49 LMICs, including 28 in sub-Saharan Africa.[8] Finally, *relative* reductions in child mortality from reducing stunting was derived from a pooled analysis of ten prospective studies involving 530,000 children in LMICs.[35] Mortality rates by age and sex for Ethiopia were derived from the 2015-2020 estimates from the United Nations Population Division.[36] We removed deaths for infants under six months of age, as we assumed these infants to be mostly breastfeeding and therefore not consuming protein foods (Supplementary Text 1.1).[36,37] The population of Addis Ababa was obtained from the most recent national census of 2007.[38] Annual number of deaths in Addis Ababa were estimated by applying Ethiopian age-sex-specific death rates to the population.[36,38]

Environmental data

We assessed the environmental impacts of increasing protein source food production for the population of Addis Ababa, Ethiopia, by calculating associated blue water (irrigation) and green water (rain) consumption, GHG emissions, and total land use for each specific food (Supplementary Table 3). We adopted blue and green water needs in liters per kg of food product from the Water Footprint Network Database.[39] Using the Cool Farm Tool emission calculator, we estimated total GHG emissions in kg CO_2 eq/t, excluding potential emissions from fertilizer use and transport.[40] To calculate total land use we adopted average annual crop yield data.[41]

Estimates on land and water use and GHG emissions from animal-source foods were based on weighted average national livestock data[42], and included information on animal-specific feed intakes, feed crop and forage yields, associated total GHG emissions, and irrigation and drinking water needs.[43,44,45] No water and land resources were allocated to supplying crop residues used as feed. All livestock emissions were allocated evenly across total live weight and additional products (milk/eggs), i.e., one kilogram of meat shows the same resource use efficiency as one kilogram of milk or eggs. Resource use and GHG emissions per crop or livestock unit were then converted to their respective footprint per kilogram of edible protein. We assessed environmental impacts relative to the current environmental impact of producing the foods currently consumed by the sample population. Our analysis relies on national averages which may mask substantial variation in land and water use across the country. If more productive agricultural practices were adopted, environmental impacts could potentially be much lower.

Statistical analysis

The proportional reduction in mortality, or the Population Attributable Fraction (PAF), for each strategy was estimated separately for children, men, and women using the following relationship:

$$\text{PAF} = \frac{P_i(RR_i - 1)}{1 + P_i(RR_i - 1)}$$

Where *i* represents the proportion of children, men, or women that are either below (or above in case of higher intake of animal source foods in adults) the RDA for protein based on the estimated protein intakes from our nutritional survey. The RR_i is the relative risk of death associated with protein intakes below (or above) the RDA. For children, the proportional reduction in mortality from protein intake was mediated through stunting (Supplementary Text 1.2). The number of annual deaths delayed was calculated as the product of the attributable fraction (PAF) and the annual number of deaths in Addis Ababa. For each protein strategy, we used PAFs for each age-sex group and the 2015-2020 life tables for Ethiopia to calculate absolute and percentage increases in life expectancy at birth.[36]

To estimate associated environmental impacts, we assessed the changes anticipated vis-a-vis demand for green and blue water resources, GHG emissions, and land use per unit of protein. This involved calculating both the average percentage change in each case, compared with current levels, as well as total proportional increase in land and water use needed to meet the protein RDA under each strategy. Lastly, we report percent increase in life expectancy at birth per percentage increase in environmental impacts use to enable comparisons.

Statistical analyses were conducted using Stata 16 (StataCorp LP).

Data availability statement

The datasets generated during and/or analyzed during the current study are not publicly available due to limits on data sharing agreement by partners in Ethiopia, in compliance with institutional regulations. The data are available on reasonable request.

Code availability statement

All computer code used to generate results that are reported in the paper and central to its main claims is available upon request, to editors and reviewers.

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Author contributions statement:

MB, GD, AB, CC, SM, and WF designed the research study; AT, YB, and WF conducted field research and oversaw implementation; MB, GD, RZ, and KD analyzed the data; MB wrote the paper; MB and WF have primary responsibility for final content. AB conducted the literature review. LB and SM critically revised the manuscript for important intellectual content. All authors have read and approved the final manuscript and are accountable for all aspects of the work.

Declaration of interests

The authors declare no competing interests. The funder of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report. All authors had full access to all the data in the study and the corresponding author had final responsibility for the decision to submit for publication.

Supplementary information:

Supplementary Text 1: Methodological detail

Supplementary Table 1: Characteristics of the study population in Addis Ababa, Ethiopia.

Supplementary Table 2: Estimated health impacts using the estimated average requirement (EAR)

Supplementary Table 3: Ethiopian environmental impact footprints

Figure 1 legend: Conceptual framework for analysis. A plus or minus sign indicate positive or negative effects, respectively.

Table 1: Parameters used in quantifying the health outcomes of meeting the protein dietary reference intake in Addis Ababa, Ethiopia

Strategy Type	Strategy[a]	Serving Size of Food (g)[b]	Average Protein Content of Food (g/100g)[c]	Average Number of Servings Consumed[d]			Average Protein Content of Foods (g/Serving)			Number of Additional Servings Required to meet the Protein Recommended Dietary Allowance [e]			Percentage Point Reduction in Stunting per Food Serving [f]	RR for Adult Mortality per Percent Kcal [g]
				Children	Women	Men	Children	Women	Men	Children	Women	Men		
Combination of Food Groups	**Current Protein Composition**	42-214	12	2.9	3.2	3.0	4.8	10.2	10.3	0.74	1.49	2.25	-1.3*	..
Animal Source Foods	**Chicken and Eggs**	42-200	18	0.2	0.2	0.2	3.9	10.6	10.0	0.91	1.44	2.32	-2.3	1.003
	Milk and Red Meat	52-239	15	0.6	0.5	0.4	4.2	10.8	12.1	0.84	1.40	1.91	-2.3	1.003
	Combination	42-239	16.6	0.8	0.6	0.6	4.1	10.8	11.6	0.86	1.41	2.01	-2.3	1.003
Plant Source Foods	**Grains**	159-281	5	1.4	1.6	1.5	5.1	10.3	10.3	0.68	1.48	2.26	-1.5	0.965
	Legumes	50-200	9	0.7	1.0	0.9	4.8	9.7	9.6	0.73	1.57	2.41	-0.6	0.965
	Combination	50-281	7	2.1	2.6	2.5	5.0	10.0	10.0	0.70	1.51	2.31	-1.0 *	0.965

a: Detailed list of food items and ratio of consumption by age and sex for each food group is available upon request; b: Range of serving size of foods in each strategy according to the Ethiopian Food Composition table. Child portion size assumed as a quarter adult portion size; c: Unweighted average of protein concentration from Food Composition Table. Calculation is available upon request; d: Weighted average of number of servings of each food consumed with weights being the frequency of consumption relative to other foods in each strategy (using nutritional intake data from local survey), e: Calculated as the difference in recommended daily protein intake and average protein intake among those not meeting the protein RDA, divided by average protein per serving; f: As percentage point reduction in stunting prevalence per serving of food (based on estimates from Headey et al.[8] and Pimpin et al. (unpublished)); g: Relative risk (RR) due to receiving the proposed program per 1% substitution of energy.[5]

Table 2a: Estimated annual reductions in adult and child mortality and child stunting and years of life gained for eight dietary strategies to meet the protein recommended dietary allowance (RDA) among children (six months to five years of age) and adults (20-60 years) in Addis Ababa, Ethiopia

Strategy type	Strategy	Proportional Reduction in Mortality (%)			Number of Annual Deaths Delayed			Percentage point reduction in stunting per child meeting the RDA	Years of Life Expectancy Gained per Person Born	Percentage Increase Life Expectancy at Birth
		Children N=1,050	Women N=1,050	Men N=635	Children N=1,050	Women N=1,050	Men N=635			
Combination of food groups	**Current protein composition**	1.5	9.1	19.5	23	407	1,174	1.1	0.89	1.35
Animal source foods	**Chicken and eggs**	2.8	-1.0	-2.0	44	-43	-118	2.1	-0.04	-0.07
	Milk and red meat	2.6	-1.0	-2.0	41	-43	-118	1.9	-0.05	-0.07
	Combination	2.7	-1.0	-2.0	41	-43	-118	2.0	-0.05	-0.07
Plant source foods	**Grains**	1.4	11.8	25.7	22	530	1,546	1.0	1.17	1.77
	Legumes	0.6	11.8	25.7	9	530	1,546	0.4	1.16	1.75
	Combination	1.2	11.8	25.7	18	530	1,546	0.9	1.17	1.77
Animal source foods for children, plant source foods for adults		2.7	11.8	25.7	41	530	1,546	2.0	1.19	1.80

Table 3: Population-weighted daily per capita environmental impacts of selected dietary strategies to meet the protein recommended dietary allowance (RDA) in Addis Ababa, Ethiopia

Strategy type	Strategy	Increase in Blue Water Use [l/cap/day]	Percentage Increase in Blue Water Use	Increase in Green Water Use [l/cap/day]	Percentage Increase in Green Water Use	Increase in Land Use (m^2/cap/d)	Percentage Increase in Land Use	Increase in GHG Emissions (kg/cap/day)	Percentage increase in GHG Emissions	Total Percentage increase in Selected Environ-mental Impacts
Combination of all food groups	**Current protein composition**	12	18	632	41	1.41	41	0.22	45	145
Animal source foods	**Chicken and eggs**	18	26	2592	168	6.17	179	0.11	22	395
	Milk and red meat	28	42	580	38	3.83	111	1.23	257	447
	Combination	25	38	1083	70	4.41	128	0.95	198	434
Plant source foods	**Grains**	13	20	593	38	0.74	21	0.03	7	86
	Legumes	2	2	372	24	0.40	11	0.01	2	40
	Combination	4	6	513	33	0.62	18	0.02	5	63
Animal source foods for children, plant source foods for adults		4	7	518	34	0.65	19	0.03	7	66

Figure 2a legend: ASF = Animal source foods. PSF = Plant source foods. Results reflect intakes of children between six months and five years, and adults between 20 and 60 years in Addis Ababa.

Figure 2b legend: ASF = Animal source foods. PSF = Plant source foods. Results reflect intakes of children between six months and five years, and adults between 20 and 60 years in Addis Ababa.

Figure 2c legend: ASF = Animal source foods. PSF = Plant source foods. Results reflect intakes of children between six months and five years, and adults between 20 and 60 years in Addis Ababa.

Figure 3 legend: Light red cells suggest production exceeds supply boundaries; light orange cells are between current national average intake and supply boundary (i.e., food waste reductions could make this work); dark green are below supply boundary.