Eating Fewer Animal Products also Saves Animal Species

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John M Halley, *grew up on a farm in a farming community in Ireland. He graduated as an electronics engineer from University College Dublin in 1983, then earned his MSc and PhD degrees from University College London in 1989. He travelled extensively in China, took a job in England, then Scotland, and finally settled in Greece, where he is currently associate professor of ecology at the University of Ioannina. Animals and the environment have always interested Halley, but his areas of scientific expertise are in the application of mathematics and statistics to biodiversity, climate change, and extinction.*

Introduction – Human Impact

Humans use more resources than any other species. By 1986 humans were already either consuming, diverting or otherwise interfering with 40% of the total annual biomass produced on land every year on earth (Vitousek, *et al.* 368-373 “Human Appropriation”). In the seas, we “only” appropriate 8% of aquatic productivity (Pauly and Christensen 255-257). Humanity also intervenes dangerously in major biogeochemical cycles. For example, 39% of nitrogen entering the global ecosystem every year is introduced by human beings, mostly as fertilizers (Falkowski, *et al.* 291-296). People appropriate more than half of the planet’s usable, flowing freshwater. For example, 98% of US rivers are impeded, mostly by dams (Vitousek, “Human Domination” 494-499). During growing seasons, many of the great river systems of the world, such as the Indus, actually run dry before they find the sea. This is caused by our massive use of the water, mostly for irrigation. Human emissions have inflated the atmospheric carbon dioxide reservoir by 35%, up from 280ppm in 1800 to 379ppm in 2005 (Le Treut, *et al.* 100). Such excessive emissions have serious consequences, including climate change. It is no longer statistically credible to attribute the global warming we have observed since 1850 to natural causes (Halley 2492-2502).

Another measure of our enormous and dangerous impact is the sheer biomass of humanity and that of domesticated animals. For example, the biomass of Great Britain’s 800 million chickens is now over *100 times* greater than the total biomass of their wild birds. A 1999 study estimated that the biomass of wild birds in Great Britain had fallen from 14,200 tonnes in 1968 to 12,742 tonnes in 1988, a decrease of 10% (Dolton and de M. Brooke 274).). Given the continuing trend in wild bird biomass, this number should have fallen to 11,468 tonnes by 2008. In contrast, there are now more than 800 million chickens in the UK. If each living chicken weighs 1.5kg then the total biomass is 1.2 million tonnes. The ratio of these two masses is 104.64 - chickens in the UK weigh 105 times more than the total biomass of all Britain’s wild birds. Similar ratios prevail in other industrialized countries.

In 1979, the biomass of humans – when there were only 4.4 billion of us – was *three times* that of *all* the planet’s wild mammals, which of course includes such massive animals as whales, elephants, buffalo, and bears (Atjay, Ketner, and Duvigneaud 129-181). Since the late sixties, the rate of human population growth has decreased, and by the middle of the 21st century, our population should start to decline (Cohen 25-39). Unfortunately, this good news is offset by new and disturbing trends, most notably, increased per-capita consumption, especially of animal products. Since our increased demand for animal products will be met primarily by factory farming, this will be a catastrophe for animal welfare. It also portends a major acceleration of species extinction.

As humans continue to multiply and consume, everyone else’s space is reduced. Currently, the main factors driving species extinction are overhunting, species introduction, climate change, and habitat loss. Of these, the most important is habitat loss, especially through conversion of wildlands to agriculture (though in the future climate change is likely to become the lead cause of habitat loss) (Pimm 117-119 “Biodiversity and Climate Change).

Although it is impossible to be precise about annual extinctions caused by habitat loss, a conservative estimate for the Amazon alone (where most habitat loss is caused by conversion of forests to grasslands for raising animals) is 3,000 species per year. Current rates of extinction are hundreds or even thousands of times greater than pre-human extinction rates (Pimm et al 347 "Future of biodiversity").

Species extinction rates are estimated by species-area curves, which show how species numbers (on islands, for example) vary in relation to square feet of habitat (Brooks, Pimm, and Oyugi 1140-1150). Similar rules apply for "islands" of various types – not just for those surrounded by water, but for any isolated habitat fragments, including those that have been divided and isolated by human development. Each "island" can support a limited biodiversity, and as the island's size decreases, so does the number of species that can coexist. So, if we convert most of a rainforest to cultivation, we will not only lose the species that once dwelled where we have created fields, but also many of the remaining species, because they cannot be sustained in such diminished areas, and therefore go extinct. Thus, people's preference for meat-eating, because this preference drives others to clear rainforests in order to graze cattle, leads directly to the extinction of species (and also, of course, to the death of most of the wild animals in the affected areas).

The purpose of this anaylsis is to explore how human dietary preferences affect this picture using quantitative methods. In order to explore the relationship between human dietary choice and species extinction, I first calculate the annual food-energy distribution for a sample of people in Europe (the "standard" diet). I then estimate the required area of cultivation required for such a diet, and compare this land area to that required to support a vegetarian or vegan diet. Finally, I discuss the advantage of a meat-free diet with regard to habitat loss and species extinction.

Quantitative analysis is limited. In addition to the technical difficulties described later (see 'Limitations') this approach compresses all the individual stories of humans and other animals into featureless numbers. When it comes to changing our lives or our lifestyle, the quantitative approach alone is entirely inadequate. Nonetheless, a mathematical approach can play an important role because in Western cultures, numbers tend to "pack a punch." For example, the fact that the mass of (factory-farmed) chickens exceeds all natural birds one hundred times over is a powerful testament to the imbalance we have created. In this spirit, this article uses numbers to quantify the cost (in biodiversity) of our dietary choice. Combined with other information, this mathematical analysis provides incentive for informed, concerned citizens to think more carefully about what they choose to eat.

Quantifying the Impact of Diet Conversion

In terms of reduced environmental impact, various forms of vegetarianism, and veganism, compare favorably with meat-eating. For example, the environmental impact of humans using soy protein is somewhere between 4.4 and 100 times less than that of humans using animal protein (Reijnders and Soret 664S-668S). More recently, scientists have started to analyze the US diet in terms of global warming, noting that the average American diet throws 1.5 tonnes more CO_2 into the atmosphere, per person per year, than does a vegan diet (Eshel and Martin). This is equivalent to the difference between driving a high efficiency car and an SUV.

The Food and Agriculture Organization's 2006 landmark report, *Livestock's Long Shadow*, highlights the environmental impact of an animal-intensive diet *(Steinfeld, et al.)*. This report notes that 18% of our annual greenhouse-gas emissions stem from animal production. Other authors, such as Goodland and Anhang, argue that more than half of our greenhouses gases (51%) stem from animal farming (Goodland and Anhang 10-19). An interesting aspect of Goodland and Anhang's analysis is that they include the direct respiration of livestock in their figures. As explained by Barnosky, natural respiration would also have occurred in the vast natural herds of megafauna (such as mammoths and mastodons, who were probably exterminated by humans), but such great beasts existed in considerably smaller numbers than current domestic herds, which are maintained above natural carrying capacity by petrochemicals (Barnosky 11543-11548).

Given that our diet affects the environment, I incorporated methods by which students of Applied Ecology can calculate the environmental impact of their personal dietary choices, using the methods in Brewer & McCann's *Laboratory and Field Manual of Ecology* (Brewer and McCann). To discover their dietary "ecological footprint," each student keeps a three-day record of their consumption of common food categories. With the help of a handy-reference table, students look up the calorific value of food types. Using this, they calculate the calorific value of foods they consume over a three-day period, and by extrapolation, they estimate their annual caloric consumption. On the basis of well-known agronomic relations, students also calculate the area of cultivation that is required to support each food category consumed. For example a square metre can supply 1000 kcal per year in the form of oranges, but only 40 kcal in the form of cheese.

Based on information gathered from this exercise (between 2007-09), I have assembled a database, from which I have randomly extracted the results for 25 students in order to estimate average consumption (Fig. 1).

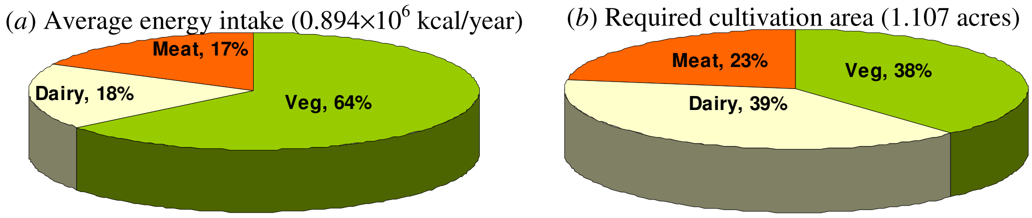

Figure 1. Share of energy intake derived from meat, vegetables, and other animal products (dairy and eggs) (a) compared with corresponding areas needed to support the components of this diet (b) for a random sampling of Greek students in Applied Ecology at Ioannina. (Greek people tend to eat a high proportion of fish relative to Americans, but their consumption of fish is still not very high, and since footprint calculations regarding fish and seas are somewhat different, fish is not included in this figure. This omission reduces the apparent consumption of animal products slightly.)

With an overall caloric intake of 0.894 million kcal/year, students typically receive 64% of their caloric intake from vegetable sources, 17% from meat sources, and 18% from dairy products or eggs. This is a typical pattern in Western countries, a pattern which differs substantively from other areas of the world, in which vegetables generally supply 90% of caloric intake. When we examine land area required to support common food categories for Western consumers, we find that, on average, a total of 1.107 acres are required. We also find proportions: 38% for vegetables versus 23% for meat sources, and 39% for other animal products. Animal products require considerably more land per kilocalorie because the land must support not only the humans but also the animals.

On the basis of patterns of consumption recorded by students, I constructed two dietary options: the *Partial Vegetarian*, and the *Partial Vegan*. The first is likely to represent someone on their way to becoming a full vegetarian, who foregoes a fixed proportion of meat intake, and makes up for lost caloric energy by consuming more vegetables *and* more dairy products. The *Partial Vegan* is likely to represent someone on their way to becoming a full-fledged vegan, who eschews a fixed percentage of meat *and* dairy, increasing only vegetable consumption to meet energy requirements.

I calculated the required area of cultivation for each of these proposed diets. The result is shown in the Figure 2. This figure assumes that each kcal of meat removed from the partial vegetarian's diet will be replaced with vegetables *and* non-meat animal products, in a ratio of 18:64 (as is the case with students, shown in Fig. 1). In this scenario, 22% of replacement foods come from dairy and eggs, while 78% come from vegetable products. If consumers fill the meat-gap with a *greater* proportion of dairy and eggs (rather than vegetables), *there will be no reduction in land area required – and it might even increase*. While vegetarianism usually requires less land than a meat-based diet, this reduction is rooted in the shift to vegetables. In contrast, vegetarians who increase their consumption of dairy and egg products, similarly increase their "ecological footprint" because dairy and egg products require farmed animals, which requires much more grain as calories are cycled through cattle and chickens. Therefore, simply removing meat leads to a 6.2% reduction of land use (at best) if dairy and egg consumption expands with a reduction in meat. In contrast, this same improvement occurs with just a 15% commitment to a vegan diet. However, some authors (Haddad and Tanzman 626S) argue that most vegetarians typically turn to vegetable alternatives, substituting less than 15% of lost flesh calories with dairy and eggs. Such a vegetarian would require only 0.918 agricultural acres, offering a 17% reduction over the standard meat-dairy-and-eggs diet. Vegetarians who employed a 90:10 replacement ratio (favouring vegetable-derived products) would need only 0.787 acres, representing a 29% land area reduction in comparison with the standard diet.

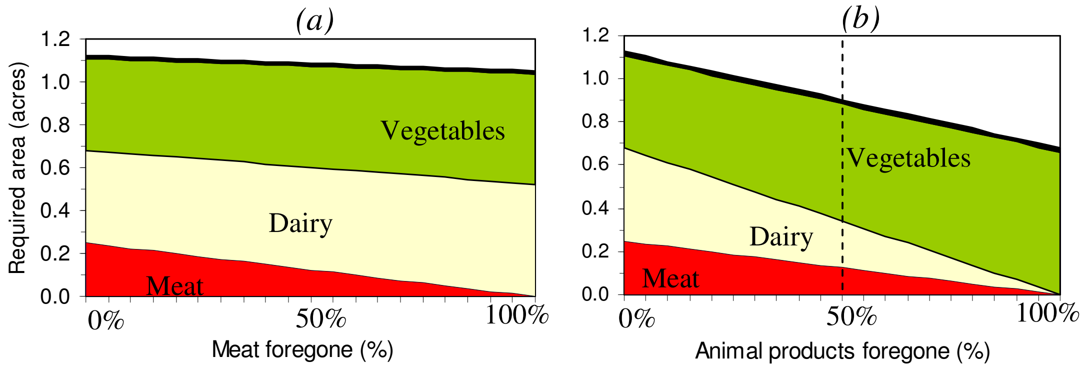

Figure 2. This graph shows the amount of land required to support a partial vegetarian (a) and a partial vegan (b) diet, respectively. The partial vegetarian (a) reduces meat consumption, and replaces this with vegetable *and* dairy consumption. The partial vegan (b) replaces animal products "across the board" with vegetable products. The horizontal axis represents the degree of replacement; the total vegetarian and the total vegan are therefore represented on the far right of each graph. Accordingly, a 50% vegan is indicated by the dotted line on graph (b). A 50% vegan has cut consumption of animal products by half, replacing half of their animal calories (meat, milk, and eggs) with vegetable calories. The upper heavy line defines the drop in total land area required as consumers shift from meat to dairy and vegetables (vegetarian, graph a) or from meat and dairy to vegetables (vegan, graph b). For example, the 50% vegan (dotted line, right panel) will require a total of 0.885 acres to produce the food he or she consumes (0.125 for meat consumption, 0.216 for other animal products consumed, and the remaining 0.544 acres for vegetables). For the purposes of this graph, each person is assumed to have a caloric requirement of 0.894×10^6 kcal/year (as is the case for my Greek students), and a ratio of 18:64 is assumed for meat replacement with vegetables *and* non-meat animal products.

Figure 2 shows that reducing the amount of meat in one's diet, without reducing other animal products, leads to marginal reductions in the land area required (left panel). Thus switching to a vegetarian diet has little effect on our ecological footprint. In contrast, reducing our intake of animal products overall greatly reduces land use, and therefore is highly beneficial to the environment (right panel). The vegan diet requires just 0.662 acres of cultivated land, compared to 1.107 acres for the standard Western diet, rich in animal products.

Discussion

The most important insight provided by this statistical analysis is that a reduction in our intake of animal products is rewarded with major environmental improvements. Another important insight is that merely removing meat alone achieves very little – the whole spectrum of animal products must be reduced if we are to reduce our ecological footprint. This is not surprising because raising farmed animals requires much more land than does raising vegetables, and farmed animals are required if we are to have eggs and dairy products.

Figure 3 provides a more detailed view of the environmental cost of various foods. A barchart shows the land needed to produce the main components of the standard Western (Greek) diet, with the exception of fish. Note that Figure 3 demonstrates that the energy cost of a square metre of land is considerably higher for animal products than for vegetable foods. For example, an acre of land planted with potatoes could support eight times the number of people supported by a square meter of land devoted to animal products, excluding milk. Potatoes can support 3.81 times as many people as can milk products. Note that cheese has a strikingly low caloric yield in relation to land use. Cheese requires a very large area of land in exchange for very few consumable calories.

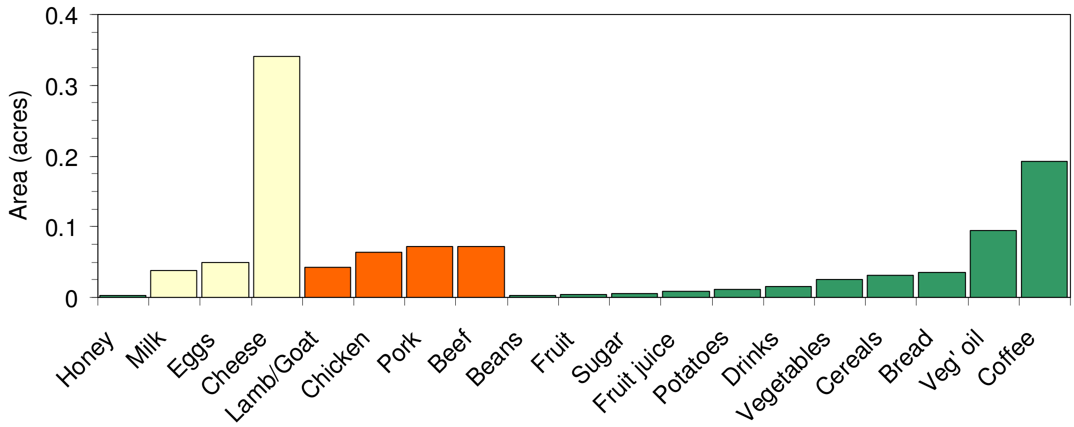

Figure 3. Land area required for the principal components of the standard Greek diet (except fish) as represented by students (as noted above). The sum of the heights of all bars totaled adds up to 1.107 acres, the average area required to support student diets, as reported in questionnaires. Note: "Drinks" include wine, beer, and soft drinks, but not milk or coffee.

Why is there only a 40% overall gain if we remove *all* animal products from our diet? It is because, in contrast to the analysis of others (such as Reijnders and Soret), I am comparing complete diets rather than focusing on a single element (such as protein). This means that vegan and vegetarian diets are assessed based on the current spectrum of consumption for each sector, and are being compared with a meat-based diet that already includes 64% vegetable products. Thus, there is only about 36% increase in vegetable consumption that is possible. Furthermore, high-yield vegetable products, like potatoes and beans, are seldom prominent in the standard vegan or vegetarian diet, while comparatively lower-yield products are more common (especially in Greece), such as vegetable oils. Additionally, other low-yield vegetable products that are commonly consumed, such as coffee, require very large areas of land.

Environmental and animal activist agendas do not always coincide. This is most notable when we compare yields *within* the meat sector. For example, in this analysis we find that students eat nearly four times as much poultry as goat or lamb, but this contributes only twice as much land-use. But chicken farming entails far greater animal welfare problems because of the intense abuse entailed in our factory farming system. So environmentalists may sometimes say "eat more chicken" while animal advocates say "especially avoid eating chicken." Nonetheless, as environmental factors beyond land use are considered (such as the affects of nitrogen from chicken manure) (Steinfeld, *et al.* xx-xxiii), this conflict is likely to disappear.

If 300 million people (approximately equal to the population of the USA) were to become even 50% vegan, the environmental results would be significant, saving approximately 0.223 acres per person. The total area saved would be over 270,000 km^2. This is larger than the area (about 23,000km^2) of the Amazon currently lost annually due to deforestation. This not only exploits farmed animals, but also causes the extinction of 3000 species per year. Clearly there is much more that environmentalists and animal advocates can agree on with regard to diet. Whether we care about the planet, species, or individual animals, we need to move toward consuming more vegetable products, and away from meat, dairy, and eggs.

Limitations

I have analyzed the relation between diet, basic nutritional energetics and land use. This analysis is only one small part of the larger environmental picture with regard to diet.

Modern animal agriculture is linked to a truly staggering number of environmental problems: natural-habitat destruction, greenhouse gas emissions, soil degradation, aquifer depletion, and various kinds of pollution – including the creation of dead-zones in the oceans (Steinfeld, *et al.* xx-xxiii). Industrialized animal production (factory farming) also entails increased animal abuse, massive social costs (many small farmers are replaced by a few intensive units, and many unemployed people living on social welfare), an increase in zoonotic illnesses (like bird and swine flue), and the misuse (and consequent ineffectiveness) of antibiotics (Steinfeld, et al. 254, 70, 69, 142). While all of these issues demand equal time and consideration, the above analysis serves to show the direct link between environmental and animal welfare agendas through the prism of personal dietary preferences.

It is also important to note that nutritional energetics (calories in versus calories out) is only one part of any dietary assessment, which must ultimately assess the qualities of certain foods, such as protein and fibre content. There is a rich and growing body of literature that examines the challenges and benefits of a vegetable-based diet compared to a diet rooted in animal products (Am. Diet Assoc 1266-1282; Campbell and Campbell 225-241; Eshel and Martin 1-17).

A land-based assessment also ignored the energy input required for agricultural production, cooking, storage, and processing various food types. Again, as discussed by Eshel and Martin, evidence suggests that these factors, when considered, also point to the environmental efficacy of the vegetarian/vegan food option (Eshel and Martin).

Conclusions

Because of the enormous mass of humanity currently on the planet, even small changes in human lifestyles can have enormous environmental impacts. One such impact can be brought about if we consume fewer animal products. A diet rich in animal products leads to an environmentally devastating chain of events: conversion of natural environments to farmland, displacement and death of wild animals living in these regions, and reduced wild populations in remaining wildlands (which leaves these populations more prone to extinction). Thus, the consumption of animal products leads to habitat destruction and species extinction. Humans can help end this disastrous spiral by consuming less meat, dairy, and eggs.

From an environmental point of view, if one is concerned about deforestation and species loss, we ought to reduce our consumption seriously, not only of meat but of all animal products. Merely moving towards a diet rich in non-meat animal products (dairy and eggs) achieves virtually nothing. Thus the environmentalist is led to a conclusion similar to the animal activist: removing meat from one's diet is not enough; it is much better to be quarter-vegan than 100% vegetarian.

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Appendix: Methods of calculation.

The energy intake of most Western consumers is composed of a vegetable component V, a dairy and egg component D and a meat component M. The sum of these must meet the required energy E.

$$E = M + D + V$$

Changing to a vegetarian diet can be done by reducing the meat component and increasing the other two sectors, leading to new proportions:

$$E = \alpha M + \beta(D + V)$$

Since we need the total energy to remain the same, we can estimate the required β , the increase of dairy and vegetable foods:

$$\beta = \frac{E - \alpha M}{D + V}$$

The total ‘footprint’ for a consumer, the area of cultivation required, is the sum of the areas required for each food type. For example, suppose the total area needed to support a standard diet (1.107 acres) consists of components meat, dairy and vegetable portions A_M, A_D and A_V. Provided that the only changes made are *between* sectors, but not *within* sectors, the land areas needed will change proportionately.

For the above three sectors, the total area needed is:

$$A_1 = \alpha A_M + \beta(A_D + A_V)$$

Thus, the area required to support a partial vegetarian will be:

$$A_1 = \alpha A_M + \frac{E_0 - \alpha M}{D + V}(A_D + A_V)$$

Similarly, the area required by a partial vegan will be:

$$A_2 = \alpha(A_M + A_D) + \frac{E_0 - \alpha(M + D)}{V_0} A_V$$

In this analysis, we can see that to describe the change of areas needed for cultivation, as we change the ratios between sectors in the diet, we only need a single parameter α to describe the process. Thus, there is a direct and simple link between the degree of reduction of animal products in our diet and the area saved.