Sourcing protein for planetary health

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1 Introduction

It is hard to overstate the importance of the study of planetary health, given the overlapping crises of biodiversity loss, land and water use, and climate change, amongst other global challenges. Central to our health, and the health of the environment, is food and the way we produce it. This is a huge subject, encompassing areas as diverse as population growth, inequality of food availability in different parts of the world (obesity and malnutrition), soil erosion and habitat loss, nutritional education, local culinary traditions, government policy, the lobbying and marketing power of 'big business', and waste management. This study will therefore limit itself to looking at protein in human diets, how we obtain it, and the implications for sustainability.

2 Planetary health impact of protein production

The visualisation in Figure 1 was produced by Ranganathan et al for the World Research Institute, which collects and presents data to support sustainable policymaking by governments, businesses, institutions and civil society groups [1]. It shows a comparison of the environmental impact in three different dimensions for common foodstuffs, including wheat, rice, pulses, fish, poultry and meat. The data is presented as global mean values, therefore we can expect it to hide local variation, but the disproportionate environmental impact of beef production is striking.

Looking more closely at beef production, de Olivera Silva et al [2] model the resulting emissions in Brazil, taking into account pasture management, soil carbon and deforestation, and predict that increased beef production could counter-intuitively *lower* emissions because of the economic incentive for better management of land. However this scenario depends on successful control of deforestation, which has been lacking in the past, and also overlooks other incentives for better pasture management, such as government subsidies to promote carbon capture.

Having considered the environmental impact of beef protein, we should also consider its impact on human health. Wyness [3] recommends the eating of red meat in a balanced diet, but also sets out the UK Department of Health finding that there is a probable

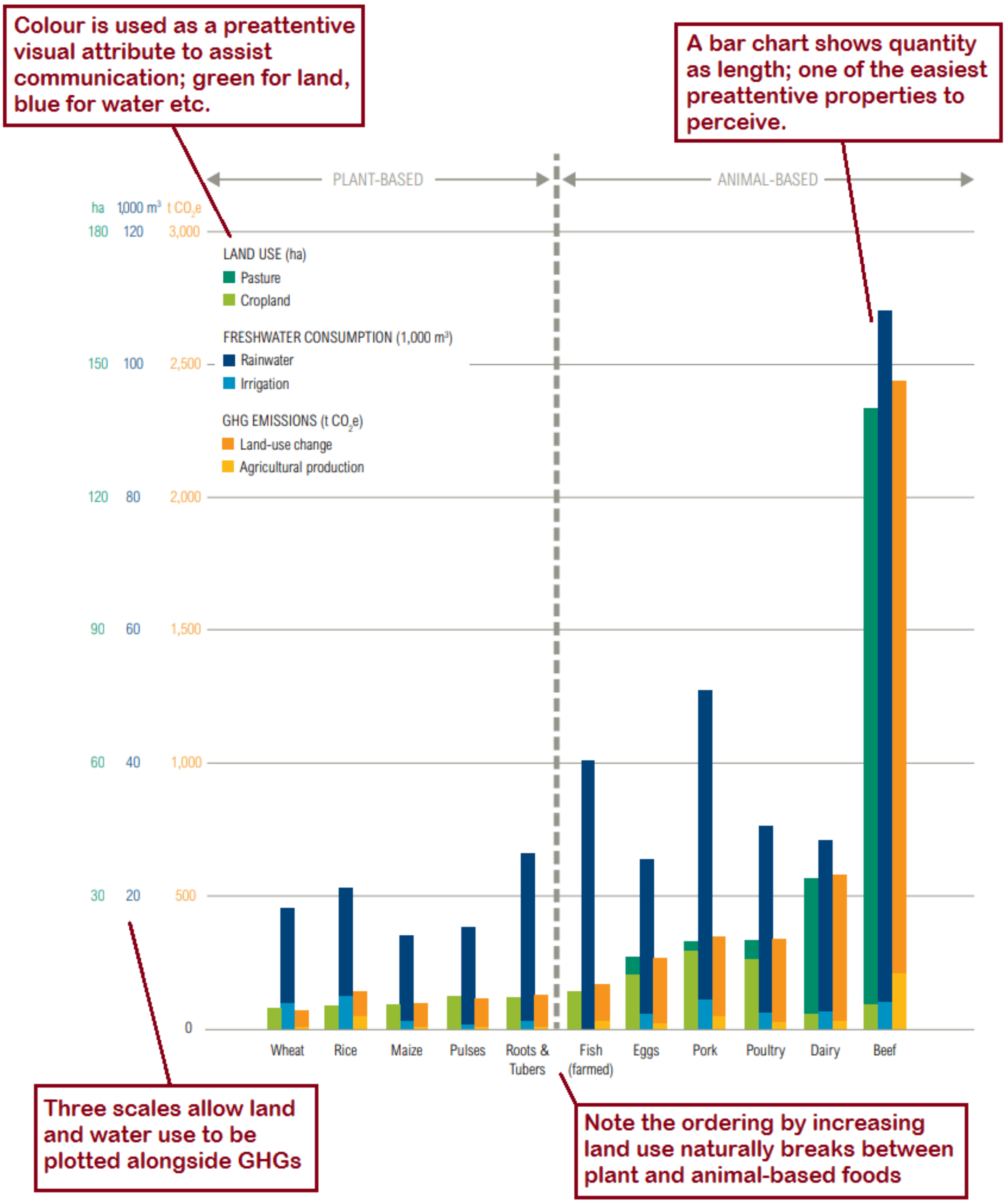

Figure 1: Land use, water use, and greenhouse gas (GHG) emissions per ton of protein consumed, a comparison of a range of animal and plant-based foods (shown as global means) [1], with annotations. Note that beef as a source of protein uses double the water required by the next most impactful foodstuff; approximately four times the land use by the same measure; and produces more greenhouse gases than all the other sources combined. Data has been collated from more than one source.

link between eating a lot of red and processed meat and colorectal cancer. She reports that those eating more than 90g/day are recommended to reduce consumption to an average of 70g/day (current UK intake is 86g/day for men; 56g/day for women). Willet et al for the EAT-Lancet Commission [4] found links between red meat consumption and overall mortality, cardiovascular disease, stroke, and Type 2 diabetes in a meta-analysis of studies.

Thus it seems clear that there are persuasive arguments to reduce beef consumption, both for individual health and the health of the planet. However to move away from what is a rich source of dietary protein, alternative sources must be found. To be an adequate replacement these sources must be nutritious, healthy and have a small environmental impact, as well as other desirable qualities such as low cost, ease of production, suitability for a wide range of diets, and social acceptability.

3 Alternative protein sources

Three alternative sources of protein that we will investigate are: insects, single cell proteins (SCP), and cultured (or lab-grown) meat. Plant-based alternatives to meat (eg. soya, tofu, Quorn) are well-established and will not be considered here.

3.1 Insect protein

Insects are eaten in many regions of the world; van Huis [5] states that more than 2000 species are consumed in tropical countries. He lists the reasons that indicate insect production is more sustainable than livestock production as:

> "lower greenhouse gas and ammonia emissions, less land area needed, more efficient feed conversion, and potential to be grown on organic by-products"

Additionally he notes that it is likely that insect production will require less water, although a full life cycle analysis is needed to confirm this.

Lähteenmäki-Uutel et al [6] list a variety of species as approved for human consumption: grubs, termites, beetles, ants and bees (in the Indigenous Australian diet); bees, silkworms, termites and ants (in Chinese medicine and food); wasps and silkmoths (Japan); crickets (Thailand); moths, beetles, wasps and termites (Nigeria). They review the regulatory environment for insects as a foodstuff in global markets and note that every country differs in which insects are permitted for food, which is holding back the commercialisation of this protein source.

3.2 Single cell proteins

Nangul and Bhatia [7] describe single cell proteins (also known as microbial proteins) as those that are extracted from cultures of algae, bacteria, yeasts or fungi (pure or mixed). SCP are attractive because they can be grown on agricultural waste with low land and water requirements, independently of local climate. They have a high protein content (45-85% dry cell weight) and reproduce rapidly. However some sources of SCP can contain toxins, and the potential for allergic reactions has yet to be considered. Taking the concept further, Sillman et al [8] have shown that hydrogen-oxidising bacteria together with direct air capture of carbon dioxide and (renewable) electricity can produce SCP for consumption. The closed-system bioreactors needed for this novel form of protein production have a low land requirement and can even be sited underground, although the process is energy intensive so land is required for electricity generation. A comparison with protein production from soybeans in the US showed that the arable crop required ten times more land and water than SCP, although the energy costs were lower. The authors conclude that there is more to be done in terms of food safety, scaling up production, and a fuller environmental assessment before this protein source can be commercialised.

3.3 Cultured meat

Hong et al [9], in their review of the issues and technical advances in this field, describe cultured meat as an emerging technology. The technique involves the *in vitro* growth of animal muscle cells into an edible product; thus it is not entirely independent of the need to keep livestock. In comparing cultured meat with traditionally farmed meat, they state that it has lower requirements for land and water, produces fewer GHGs, has a short production time, high yield, and fewer food safety concerns. However it currently has a higher production cost.
Surprisingly, an Australian company, Vow, working with Ernst Wolvetang at the University of Queensland has created cultured meat using mammoth DNA [10]. The muscle protein was reconstructed using a small amount of elephant DNA, grown and cooked into a meatball, to raise awareness of the possibilities of this technology.

3.4 Acceptability

Although the scientific evidence has been clear for some time, that a typical diet in Europe or the USA is not healthy for individuals or the environment, both governments and consumers have shown resistance to change. A few of the possible reasons might be: not trusting new food sources for safety or taste; enjoying their current diets; cost; resistance to government advice; the influence of marketing and supermarkets; and wanting to support traditional livelihoods. Ranganathan et al develop a framework to address the problem of acceptability; see Figure 2.
Additionally some of these alternative protein sources would be unacceptable to certain population groups; eg. vegetarians and vegans would be unlikely to accept insect protein or cultured meat; Hindus would avoid cultured beef for religious reasons; and the kosher or halal status of alternatives needs to be decided.
Differing reactions to these protein sources are already apparent: Italy has banned cultured meat [11], but insect protein seems established in Australia beyond the Indigeneous diet - see the commercial enterprise Circle Harvest (`https://circleharvest.com.au/`), which sells snacks and other foods made from crickets, mealworms and ants, produced in their technologically advanced insect protein farm. Traditionally

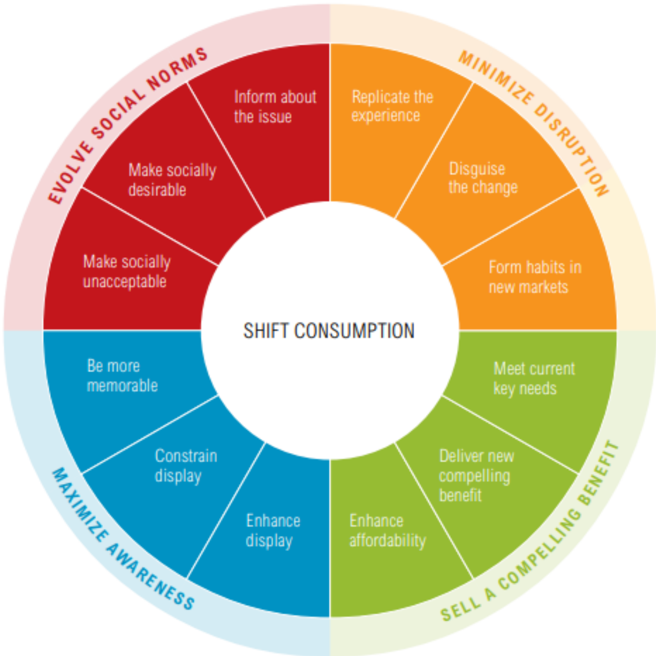

Figure 2: The Shift Wheel [1] depicts a framework to improve acceptability of alternative foodstuffs, under the categories of evolving social norms, minimising disruption, maximising awareness and selling a compelling benefit. Note that for any dietary shift to occur, it requires a willingness of policymakers and producers to pursue it.

SCP have been widely consumed in fermented food and cultured dairy products [7], so may be more acceptable.
Overall, the Good Food Institute [12] report that record investment went into alternative proteins in 2020, showing an accelerating trend in acceptability (Figure 3).

4 Impacts and uncertainties

Many sources report the health benefits of reducing red meat consumption. Ranganathan et al consider possible scenarios to move towards a more sustainable food system, one of which is named Ambitious Beef Reduction [1]. This involves regions where beef consumption is above the world average of 3.2g/protein per capita (predominantly Brazil, Canada, USA), reducing their consumption to the world average. Applying this scenario to US data (2009, per capita), their model showed significant reductions in agricultural land use (0.96 - 0.64ha) and GHGs (16.6 - 11.1 tons CO_2e). Although the planetary health benefit is large, beef producers (especially small farms) would need support to transition away from some beef production, possibly with government grants to encourage rewilding and carbon capture.
There are also uncertainties around a dietary shift of this kind. How viable are alternative proteins to produce at scale and reasonable cost, and to ensure benefits are enjoyed

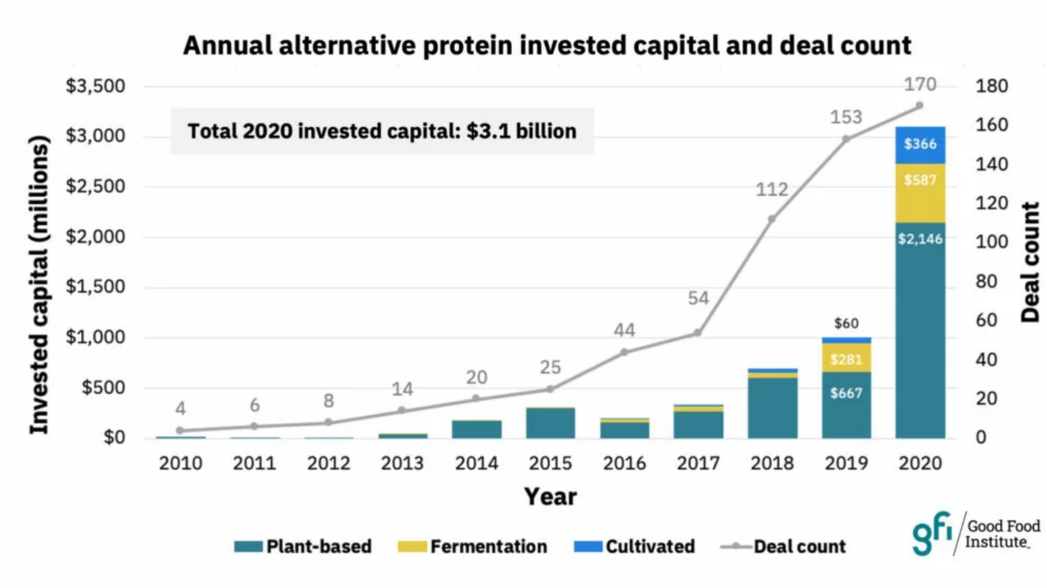

Figure 3: The size of global markets for alternative protein represented by capital invested between 2010 and 2020 indicate a rapidly growing trend [12]. As defined by the Good Food Institute, alternative protein refers to plant-based, cultured and SCP (described as fermentation) protein, but not insects.

equitably amongst regions and individuals? How will governments and consumers react? What impact will climate change have on both traditional and alternative sources of protein over the coming decades? What new ethical issues may be raised? Further work is needed.

5 Conclusion

In this short study we have of necessity neglected many aspects of this issue, and also the complex interrelatedness of food and other systems. Similarly it has not been possible to investigate the differences between countries and regions, or the protein needs of particular groups (eg. children, pregnant women, older people). In conclusion there are promising sources of alternative protein that require research, investment, policy-making or marketing input that would trigger positive change for planetary health.

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