Environmental footprinting of New Zealand agricultural products and implications for food nutrition

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Agriculture and food have a major impact on the global environment, as shown in Figure 1. Food production contributes over one-quarter of the global greenhouse gas emissions, uses about half of the habitable land, and around 70% of all freshwater withdrawals, while contributing to over 75% of the pollution of our oceans and freshwaters. Therefore, when we discuss food and the efficiency of its production, it is essential that we consider the environmental impacts.

The commonly used approach to assess the environmental impacts of food is Life Cycle Assessment (LCA). With this approach, we attempt to account for all life stages of a food that contribute to environmental impacts. This goes beyond the farm, also considering processing, shipping, consumer use, and waste.

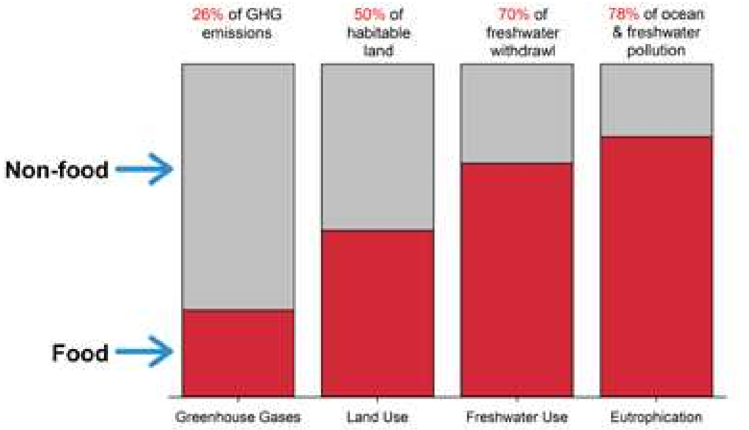

Figure 1. Summary of contribution of agriculture and food production to global greenhouse gas (GHG) emissions, land use, freshwater withdrawal and water pollution (Poore and Nemecek, 2018).

Implications of nutritional indicators

When we report values for an environmental impact, we must represent these in terms of a functional unit. But what is the function of a specific food? This question is extremely important, as most of the existing data is simply presented on a weight basis. A huge amount of work has been undertaken around the globe to calculate the carbon footprint of foods, but these results are almost always expressed per kilogram.

However, the value of food is more intricate than just its weight. The moisture content and the nutritional content of foods vary greatly. In most studies where carbon footprints are expressed per unit of mass, animal-sourced foods tend to have much larger footprints than fruit and vegetables. While the variability in footprints between different production systems is great, the general trend remains.

It is important that our analyses of environmental footprints go beyond simple comparisons with mass as the functional unit. Firstly, consider the food energy perspective. Figure 2 shows livestock products at the higher end and fruit and vegetables at the lower end on a mass basis. However, we see quite a different pattern when this data is expressed per calorie, with fruit and vegetables having the highest footprint per calorie.

We can also consider protein. The importance of protein as a component of the diet has been discussed by previous speakers, and Figure 3 shows a comparison between using a mass functional unit and using protein. In this instance, apples have a high impact per unit of protein, but low impact per unit mass. Clearly, the protein content of apples is not the quality that we look for in this food, and as such, comparing apples with livestock products on a protein basis is not necessarily reflective of

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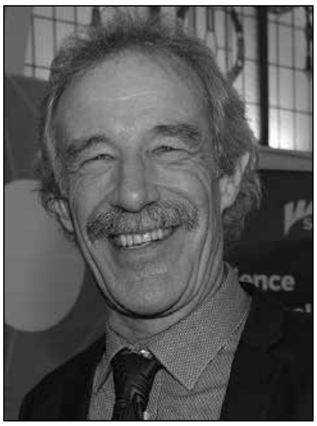

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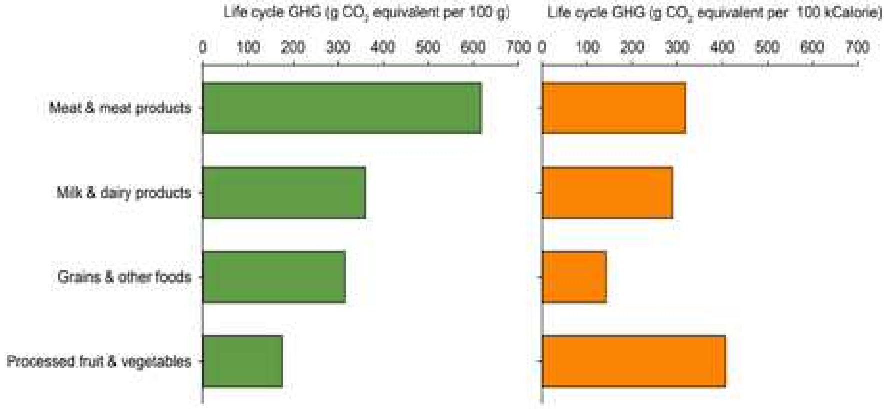
Dr Ledgard's research focus is the management of resource use and environmental impacts of pastoral farming systems. During the past decade this has involved application of Life Cycle Assessment across a range of New Zealand agricultural systems and products.

Figure 2. Summary of environmental assessment of the GHG emissions for different food groups from LCA research in France, expressed per 100 g or per kilocalorie (from Drewnowski *et al*., 2015).



the value of these foods. However, it emphasises the need to compare the environmental impact of foods on a fair basis, reflective of the function of that food.

What must also be considered is the method of production of food. For example, tomatoes grown in a heated greenhouse require high energy inputs for heating and light to meet out-of-season demand, resulting in a far higher carbon footprint than conventionally grown tomatoes (Figure 3).

Other speakers have emphasised that protein is not the whole picture, and that we need to be thinking about the essential amino acids also. A meta-analysis of different food types by Tessari *et al.* (2016) showed that livestock products have a high carbon footprint per unit mass. However, when the data is presented in terms of the mass required to meet the recommended daily intake of all essential amino acids, a different picture was presented (Figure 4). In this instance, rice and cauliflower have the highest footprints, further emphasising the importance of the value by which we compare food items.

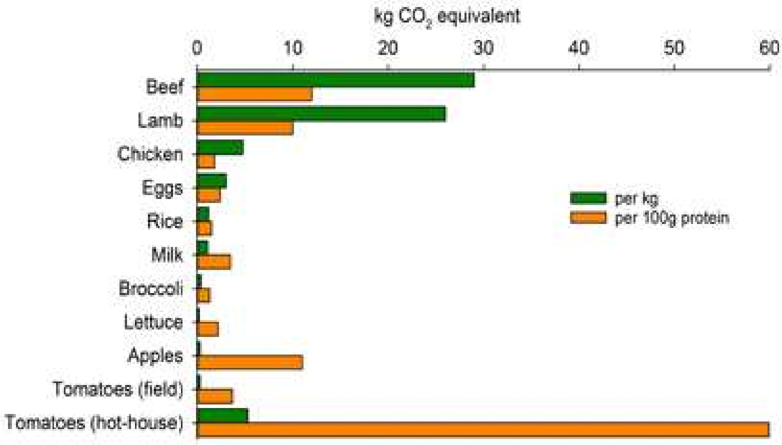


Figure 3. Summary of a meta-analysis of LCA studies on the carbon footprint of different foods expressed per kg or per 100 g protein (from Heller *et al*., 2013).

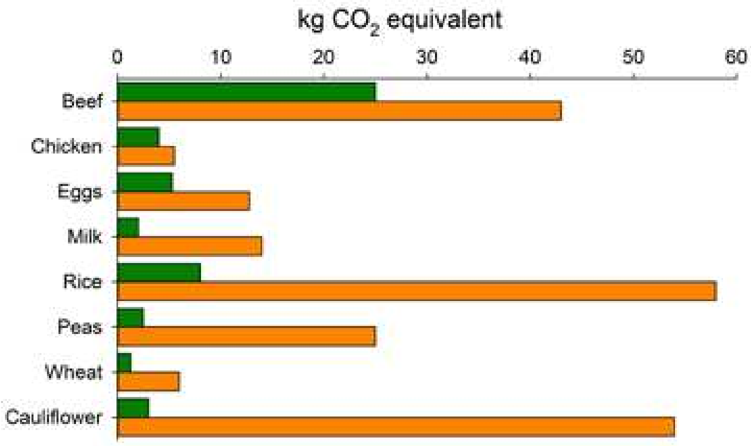


Figure 4. Summary of a meta-analysis of LCA studies on the carbon footprint of different foods expressed per kg or per amount of feed to provide the Recommended Daily Allowance of Essential Amino Acids (from Tessari *et al.*, 2016).

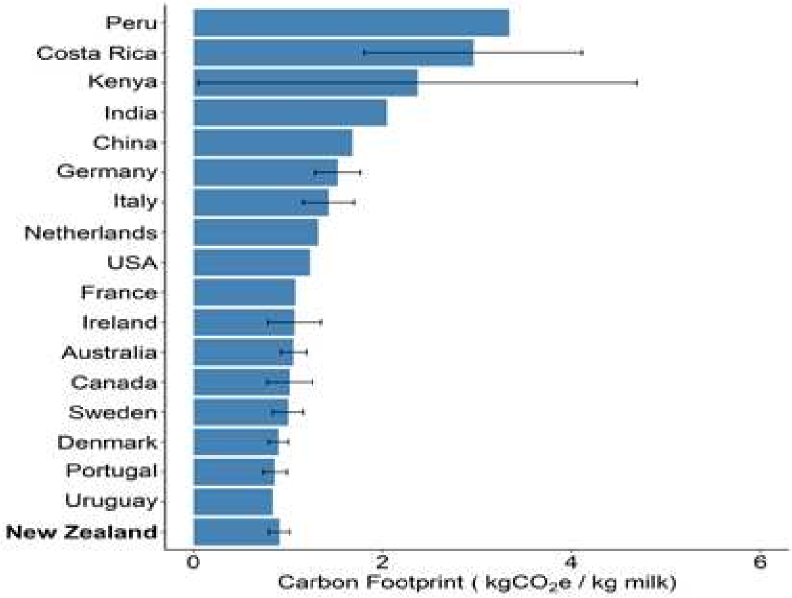
The question now becomes how to unify these approaches and find a best practice approach. A number of researchers have attempted to use multiple nutrients together as the functional unit (e.g. Fulgoni *et al*., 2009; Sonesson *et al*., 2019). In recent years, a further shift has been seen, comparing foods on a whole diet basis (e.g. McAuliffe *et al*., 2020). This recognises the need to have a balanced diet. However, there is very little agreement on the best method by which to do so.

To focus on New Zealand, we are fortunate that in the last year, there was a publication that brought together data on the carbon footprint of New Zealand diets (Barnsley *et al*., 2021). The average New Zealand diet was compared to a diet that followed the Ministry of Health dietary guidelines (Ministry of Health, 2020) that featured more vegetables and whole grains but still contained a mix of other components. The authors also considered a no-meat diet. The diet that shifted to the recommended dietary guidelines showed a 7–9% reduction in global warming contribution over the lifetime of an individual, while the no-meat diet showed a reduction of 12–15%. Importantly, the authors noted that the no-meat diet had inadequate iron, lower protein, and higher sugar content than the diet following the guidelines.

How do New Zealand products compare with those from overseas countries?

Research on New Zealand livestock products has shown the relatively low carbon footprint of our production systems. The results in Figure 5 show the on-farm carbon footprint of milk around the world. These results refer to the cradle-to-farm-gate stage and do not account for the full life cycle of the product, but research has shown that the on-farm stage is the dominant contributor for livestock products, including milk (e.g. Thoma *et al*., 2013). New Zealand milk production is at the bottom end of the range globally, as is our beef and sheep meat production (Figure 6). This reflects the fact

Figure 5. Summary of LCA studies of the carbon footprint of milk (cradle-to-farm-gate stage), with results adjusted as much as possible to reflect the same methodology (from Mazzetto *et al*., 2021a). Data includes direct land use change (from forest to pasture) for New Zealand, but this is excluded or not applicable in other studies.



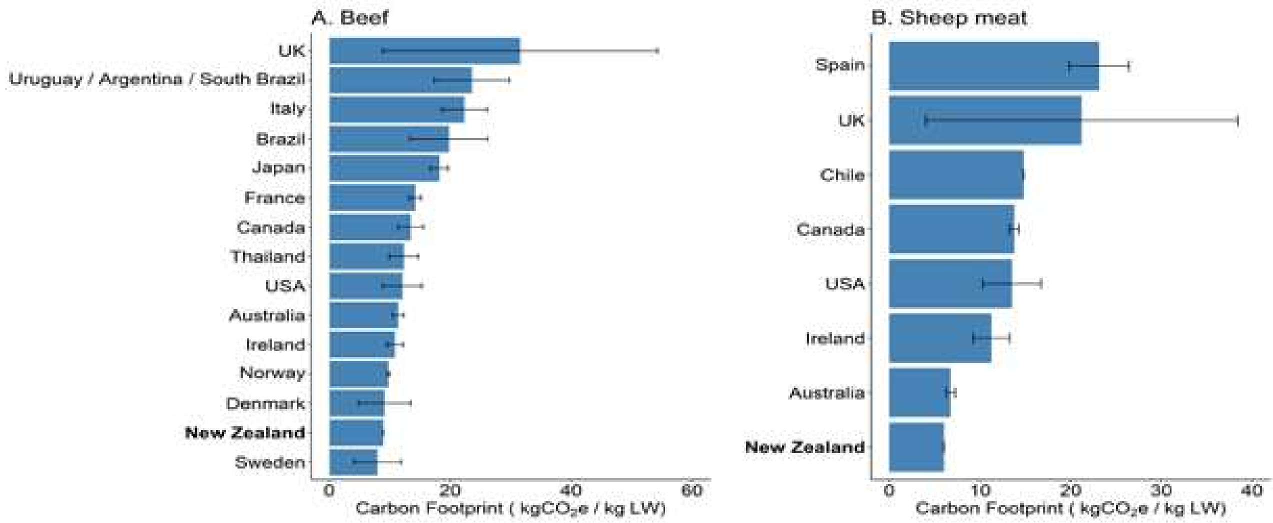


Figure 6. Summary of LCA studies of the carbon footprints of A. beef and B. sheep meat (cradle-to-farm-gate stage), with results adjusted as much as possible to reflect the same methodology (from Mazzetto *et al*., 2021b).

that our systems are based on a pasture diet with year-round grazing of very-high quality pasture compared to many northern hemisphere systems with animal housing (e.g. Ledgard, 2017; Lorenz *et al.*, 2019).

Looking to the future of New Zealand land use, I am certain that over the next fifty years we will see increased diversity. We already see this starting to happen with larger and more diverse quantities of crops, vegetables, and fruit varieties in particular. However, in thinking about these changes, we must consider land use suitability for these different applications. There is a limited land area in New Zealand that is highly suitable for crop production. Over the last few decades, we have occasionally tried to introduce wheat production in the Waikato region. However, on each occasion, these attempts have come to nothing due to disease problems. Other factors limit our ability to grow many crops in many parts of the country, including soil characteristics (heavy-textured, poor-draining soils), land slope, high rainfall, and humidity. In these situations, the production of animal feed and pasture can be an optimal use of the land for food production. However, there will always be a balance in the foods that we should produce, which will shift through time.

Environmental labelling of products

In the last 10 years, the European Commission have been putting a lot of focus into working on product environmental footprints (PEFs) for labelling food on supermarket shelves throughout Europe (European Commission PEF, 2021). This move relies on a lot of science, some of which New Zealand has been involved with. It is important that, rather than just reporting a single indicator for environmental performance, the multiple environmental impacts of a product are captured by these initiatives, and the PEF initiative covers up to 16 different resource use and environmental impact categories.

To focus on a few of these, fossil energy depletion is emerging as an important measure. New Zealand looks good on this basis due to our largely grazed animal production systems, compared to a system where crops are harvested and transported to the animals. Another measure is the pollution of fresh waters and the ocean. This may be something of an Achilles heel for New Zealand, but there are no published summaries of data for this measure in the same way as those we have seen for carbon footprinting. This is partly because there has been a lack of agreement on how to quantify water pollution impacts using LCA, but clearly this is an area that we need more focus on in the future

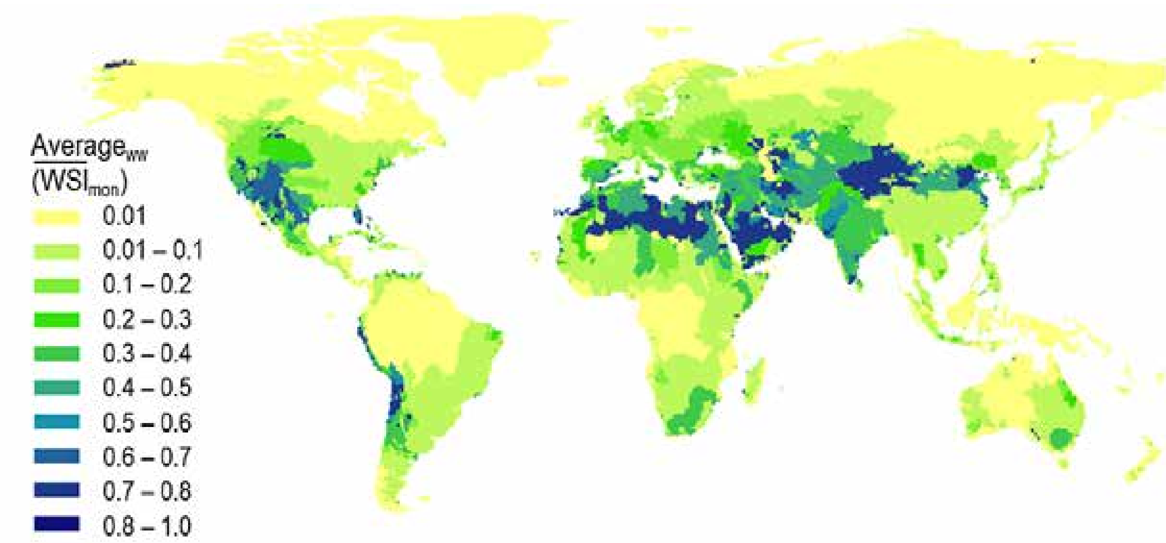


Figure 7. Global map of water stress index (WSI) representing the water withdrawal-to-availability ratio, which is used as a factor in calculation of a water scarcity footprint (from Pfister and Bayer, 2014).

to understand whether we are in fact worse than some of our overseas counterparts with housed livestock systems.

Perhaps more pertinent globally is the issue of a water scarcity footprint. While greenhouse gases are a global issue, since gases emitted have an equal impact regardless of where they are emitted, water dynamics are more localised. Billions of dollars are spent moving freshwater from areas of abundance to dry, arid areas such as in north-eastern China or California. When we consider freshwater use, we need to understand the demand for it relative to its local availability. In this instance, there is an internationally accepted approach called a water scarcity footprint. An element of this footprint is the water stress index (Figure 7).

To summarise, we will see more environmental labelling of foods in the future. This will feed back to us in terms of driving more efficient production in the future and the need to reduce greenhouse gas emissions in our production systems. However, it is important that New Zealand is involved at a global level in making the consumer aware of how to interpret these footprints. The per-kilogram footprints presented in many papers are not the whole picture; we should also consider the nutritional element of these footprints and the implications for diets that meet our nutrient requirements.

References

Barnsley, J.E., Chandrakumar, C., Gonzalez-Fischer, C., Eme, P.E., Bourke, B.E.P., Smith, N.W., *et al.* 2021. Lifetime climate impacts of diet transitions: A novel climate change accounting perspective. *Sustainability 13*. doi: 10.3390/su13105568

Drewnowski, A., Rehm, C.D., Martin, A., Verger, E.O., Voinnesson, M., and Imbert, P. 2015. Energy and nutrient density of foods in relation to their carbon footprint. *American Journal of Clinical Nutrition 101*: 184–191.

European Commission PEF 2021. Single market for green products: The Environmental Footprint pilots. European Commission https://ec.europa.eu/environment/eussd/smgp/ef_pilots.htm

Fulgoni, V.L., Keast, D.R., and Drewnowski, A. 2009. Development and validation of the nutrient-rich foods index: a tool to measure nutritional quality of foods. *Journal of Nutrition 139*: 1549–1554.

Heller, M.C., Keoleian, G.A., and Willett, W.C. 2013. Toward a life cycle-based, diet-level framework for food environmental impact and nutritional quality assessment: A critical review. *Environmental Science and Technology 47*: 12632–12647.

Ledgard, S.F. 2017. Assessing the environmental impact of sheep production. *In*: Achieving Sustainable Production of Sheep. Ed. J. Grayling. Burling Dodds Science Publishing. 24 p. http://dx.doi.org/10.19103/AS.2016.0019.20

Lorenz, H., Reinsch, T., Hess, S., and Taube, F. 2019. Is low-input dairy farming more climate friendly? A meta-analysis of the carbon footprints of different production systems. *Journal of Cleaner Production 211*: 161–170.

Mazzetto, A., Falconer. S., and Ledgard, S. 2021a. Mapping the carbon footprint of milk for dairy cows. Report for DairyNZ. RE450/2010/081. AgResearch, New Zealand. https://www.dairynz.co.nz/media/5794083/mapping-the-carbon-footprint-of-milk-for-dairy-cows-report-updated.pdf

Mazzetto, A., Falconer. S., and Ledgard, S. 2021b. Review of the carbon footprint of different food types as protein sources. Report for the Meat Industry Association and Beef+Lamb New Zealand. RE450/2010/097. AgResearch, New Zealand. 31 p.

McAuliffe, G.A., Takahashi, T., and Lee, M.R.F. 2020. Applications of nutritional functional units in commodity-level life cycle assessment (LCA) of agri-food systems. *International Journal of Life Cycle Assessment 25*: 208–221.

Ministry of Health 2020. *Eating and Activity Guidelines for New Zealand Adults: Updated 2020*. Wellington: Ministry of Health.

Pfister, S. and Bayer, P. 2014. Monthly water stress: spatially and temporally explicit consumptive water footprint of global crop production. *Journal of Cleaner Production 73*: 52–62.

Poore, J. and Nemecek, T. 2018. Reducing food's environmental impacts through producers and consumers. *Science 360*: 987–992. doi: 10.1126/science.aaq0216

Sonesson, U., Davis, J., Hallström, E., and Woodhouse, A. 2019. Dietary-dependent nutrient quality indexes as a complementary functional unit in LCA: a feasible option? *Journal of Cleaner Production 211*: 620–627.

Tessari, P., Lante, A., and Mosca, G. 2016. Essentail amino acids: master regulators of nutrition and environmental footprint? *Scientific Reports 6*: 26074. doi: 10.1038/sreps26074

Thoma, G., Popp, J., Nutter, D., Shonnard, D., Ulrich, R., Matlock, M., Kim, D.S., Neiderman, Z., Kemper, N., East, C., and Adom, F. 2013. Greenhouse gas emissions from milk production and consumption in the United States: A cradle-to-grave life cycle assessment circa 2008. *International Dairy Journal 31*: S3–S14.