Case study: Global data, farm size and food and nutrition security

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Abstract

Information about the global structure of agriculture and nutrient production and its diversity is essential to improve understanding of food production patterns, agricultural livelihoods, and food chains and their linkages to land use and their associated ecosystems services. We used existing spatially-explicit global datasets to estimate the production levels of crops, livestock, and aquaculture and fish products. We also estimated the production of vitamin A, vitamin B12, folate, iron, zinc, calcium, calories and protein. Furthermore, we estimated the relative contribution of farms of different sizes to the production of different agricultural commodities and associated nutrients, as well as how the diversity of food production, based on the number of different products grown per geographic pixel and distribution of products within this pixel (Shannon diversity index [H]), changes with different farm sizes. Globally, small and medium farms (≤50 ha) produce 51–77% of nearly all commodities and nutrients examined here. However, important regional differences exist. Large farms (>50 ha) dominate production in North America, South America, and Australia and New Zealand. By contrast, small farms (≤20 ha) produce more than 75% of most food commodities in sub-Saharan Africa, south-east Asia, south Asia and China. The majority of vegetables (81%), roots and tubers (72%), pulses (67%), fruits (66%), fish and livestock products (60%) and cereals (56%) are produced in diverse landscapes (H>1·5). Our results show that farm size and diversity of agricultural production vary substantially across regions and are key structural determinants of food and nutrient production that need to be considered in plans to meet social, economic and environmental targets. At the global level, both small and large farms have key roles in food and nutrition security. This analysis is crucial to design interventions that might be appropriately targeted to promote healthy diets and ecosystems in the face of population growth, urbanisation and climate change.

The study presented in this talk is the product of a truly trans-disciplinary collaboration between agricultural scientists and others. We worked with nutritionists, geographers, public health people, economists, livestock scientists and biodiversity specialists, and our aim was to try to map farm sizes around the world. This is a fundamental piece of information that is needed for a range of uses: for achieving the Sustainable Development Goals (SDGs) for example.

Until last year, we did not know what percentage of types of foodstuffs was really produced by smallholders in different countries. Yet that is a question we regularly get asked in various forms by donor agencies to guide their strategic

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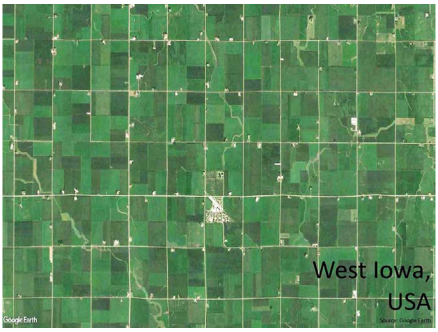
This paper has been prepared from a transcript and the Powerpoint slides of the presentation.



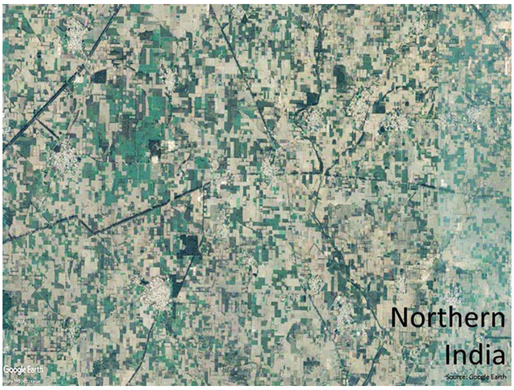


Figure 1. Satellite images of farmland in West Iowa (top left), France (top right), and northern India (left).

projects: for example, "What is the percentage of livestock coming from the smallholder sector?".

We started comparing farmland in different regions – for instance, in West Iowa, and in France and in northern India (Figure 1) – and asking ourselves: Is there any difference in the quality of the outputs from these different size farms? Do we get better ecosystem services? Do we get more nutrition coming out of fields like this? Do we get more risk, more resilience, etcetera? These are crucial questions if we really believe in the sustainability of our planet and in actually trying to create viable futures for smallholders in the developing world.

Since we began this study, the agenda has changed. Now we're talking about nutritional security. Kilojoules or calories produced per unit of land are simply not enough. Now we need to be very much more sophisticated in how we talk about the produce coming out of farming systems. Donors need this kind of information continually to make allocation decisions, and to understand how situations are changing in the smallholder sector. And for the SDGs we do not know enough about the sustainability of our planet if we do not understand the structure of agriculture.

The structure of production needs to be incorporated into global integrated assessment. It is not good enough at this stage to know that, for instance, the projections for China say it will be able to produce two-thirds more cereal. Instead, because of ethical considerations, what matters is who is going to produce this data, and what will be the impacts of the various schemes for producing the food – on the environment, or on livelihoods, on trade, etcetera?

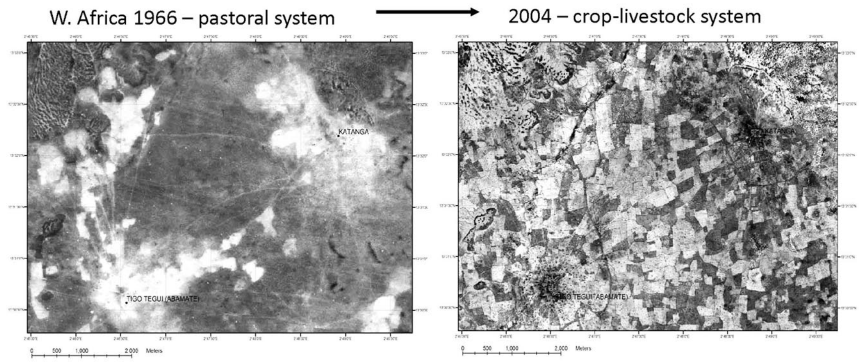


Figure 2. What role for smallholders in the future? Systems and livelihoods are in transition: the system is moving. *Source:* Herrero et al. 2012.

Obviously, there is also a big focus on linking agriculture with nutrition and health, which is strongly related to the current discourse around sustainable diets. Humanity really needs to try to eat better, so as to reduce the double burden of poor nutrition and the potential for very big health costs, especially as populations age.

However, the structure of production is constantly changing. All we can do is provide a snapshot at a particular moment, which is what my team has done. In reality there is monumental change happening in smallholder systems. Figure 2 illustrates a typical transformation seen in many African countries: changing from a pastoral region to one dominated by mixed crop–livestock systems in 40 years. This matters because, when we consider, for example, the roughly 20-year lag in technology-adoption in smallholder systems, it means that new technology is obsolete before it has been widely taken up – if the technology is being developed in the traditional way. So understanding systems-change is fundamental, and it is also fundamental for looking at the competitiveness of smallholder sectors.

Increasing importance for smallholder systems

In her Sir John Crawford Memorial Address yesterday, Dr Sibanda showed us that smallholder systems can become even more important as the agenda moves towards nutritional security. I agree with that. Nutritional diversity, including growing many things in little plots, can be very important. Nutritional diversity is key to sustainable nutritious diets, and sustainable profitable ecosystems. Although many diets meet the requirement for kilojoule or calorie availability, we are learning our micronutrient intake is dependent on the combinations of food we eat – and produce (Figure 3).

There is so much we do not know yet about nutrition. People tell me I am a romantic to value small systems, because farming is becoming consolidated into large farms, but I question whether that is the best way to go. Imagine a big pest in maize in the fields of Kansas; imagine how those farmers are going to manage risk. Do we know enough about use of resources, about emissions (Figure 4),

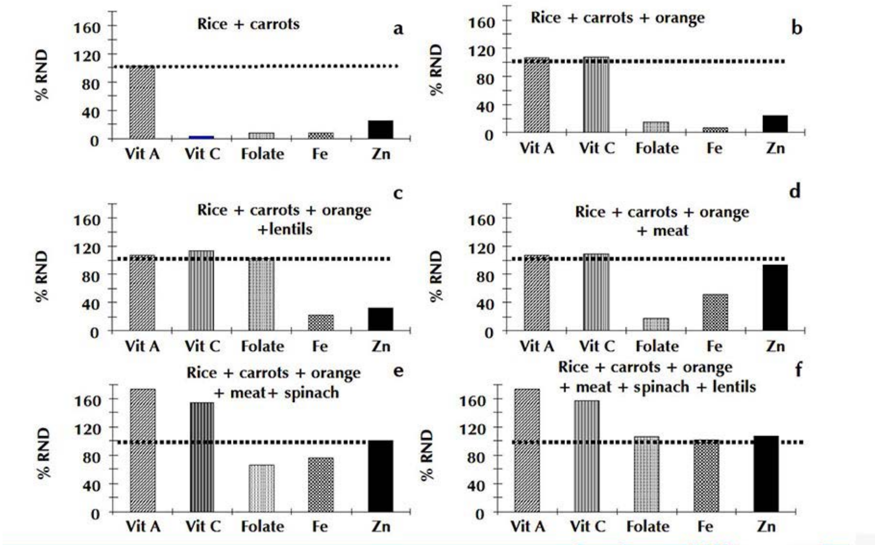


Figure 3. Nutritional diversity matters. *Source:* Oyarzun et al. 2001.

about income and employment opportunities for people? No, there are still too many questions.

Classifying farm sizes is an important initiative that can start opening this debate much more effectively. Also, from the sustainability perspective, what we grow will matter tremendously in these farms.

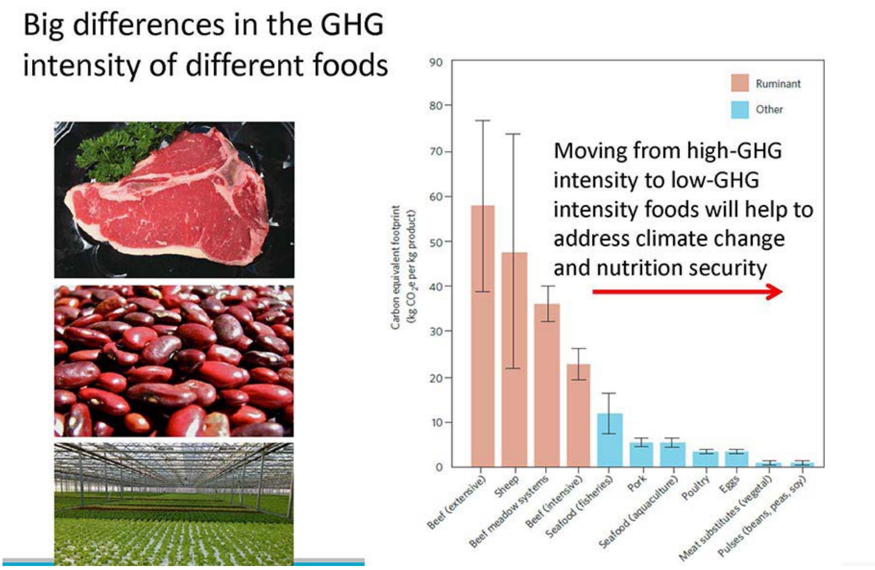


Figure 4. Foods differ in the greenhouse gases emitted during their production. *Source:* Ripple et al. 2014.

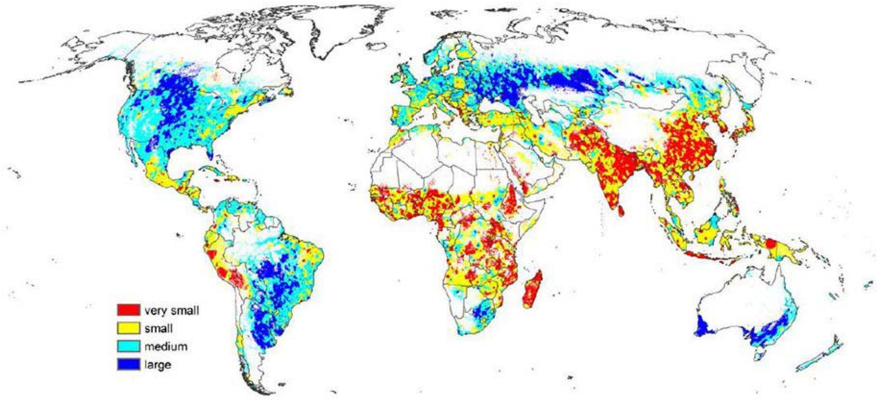


Figure 5. A global map of field size, derived by crowd sourcing and machine learning.
Source: Fritz et al. 2015.

Study methods

We started with a global map of field sizes (Figure 5) that we produced via a crowd-sourcing campaign that we then linked to satellite data (as in Figure 1). Then we applied machine-learning algorithms to estimate the plot sizes that were likely to be most important in these places. Then, using a range of optimisation techniques, we linked those to the farm-size distributions that are recorded in censuses from different countries, using 160 sets of census data. Figure 6 shows an example for Burkina Faso. As a last step we collected global spatial data on crops, livestock and fish: 42 crops from EarthStat, 7 livestock products (Herrero et al. 2013), 11 fish products (Watson 2017) – imagine all these layers on top of the data on farm sizes – and then we calculated the amounts of different nutrients that these crops and livestock products and fish could provide (Figure 7).

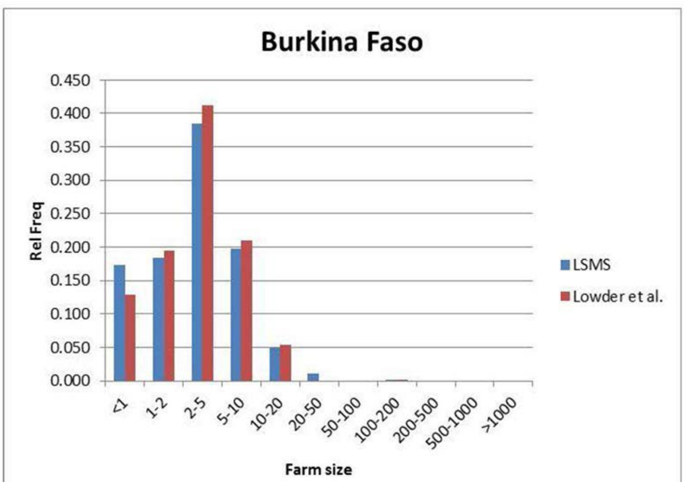


Figure 6. Farm size distributions, Burkina Faso.
Sources: Lowder et al. (2014), data from 1993; recent LSMS data, Frelat et al. (2016).

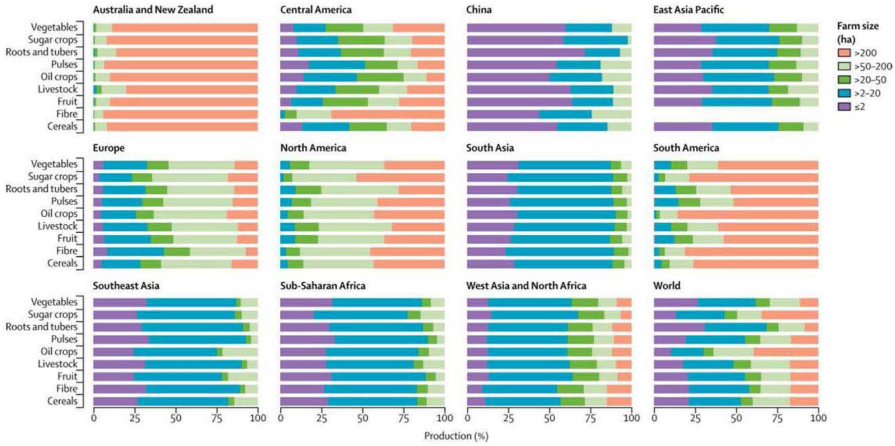


Figure 7. Small & medium farms produce 50–75% of the world's food. Horizontal axis = % of production; vertical axis = food type. Purple = farms <2 ha. Blue = farms 2–20 ha. *Source:* Herrero et al. 2017.

Figure 7 shows that, even if you take a global perspective, small and medium farms produce between 50 and 75 per cent of the world's food. This pattern is also similar for nutrients, apart from what is actually calories and also some of the oils that we tested (Figure 8).

We also looked at the diversity of agriculture, taking biodiversity indexes. In Figure 9, the deeper the purple the more diverse the production, with percentage of production on the horizontal axis from 0 to 100 left–right. The figure shows that more diverse landscapes are actually producing more food. You can see Europe has much more diverse production than the US. We also found that as farm size increases the agricultural diversity decreases.

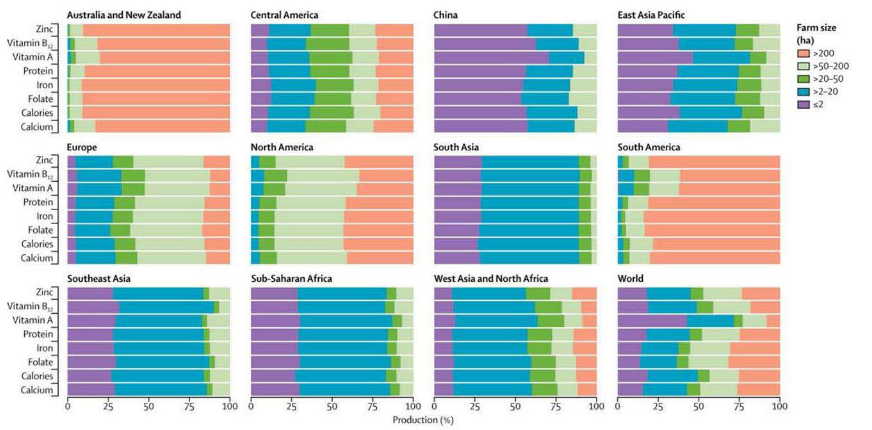


Figure 8. Nutrient production forms a similar pattern. Horizontal axis = % of production; vertical axis = nutrients. Purple = farms <2 ha. Blue = farms 2–20 ha. *Source:* Herrero et al. 2017.

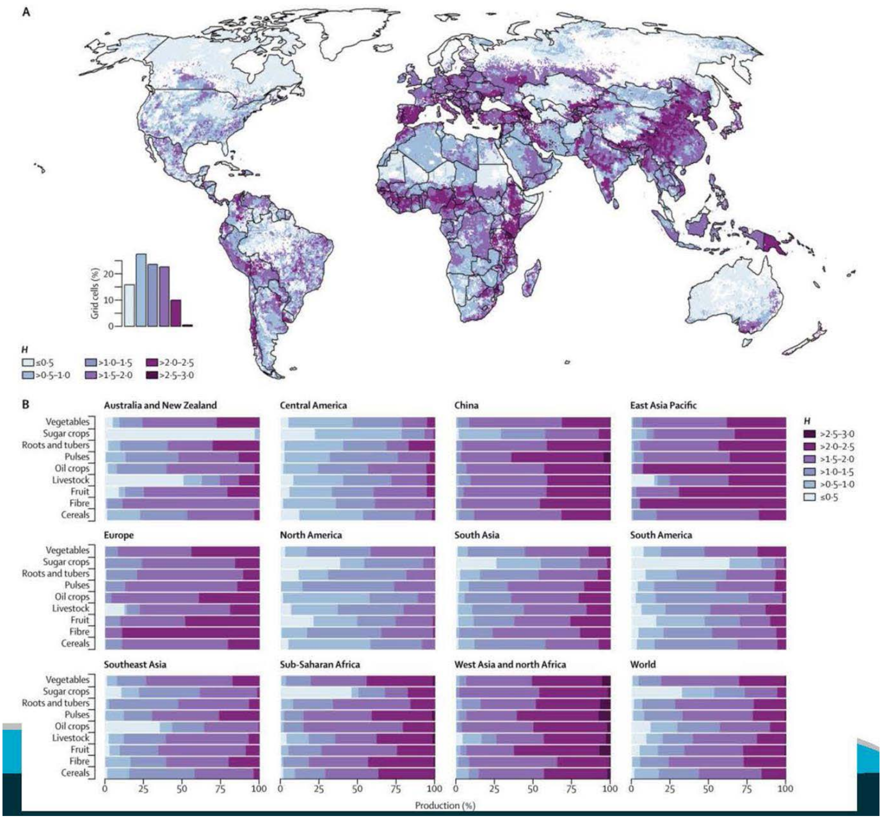


Figure 9. More diverse landscapes produce more food.
Horizontal axis = % of production; vertical axis = food type. *Source:* Herrero et al. 2017.

This is a crucial element, because we are trying to promote sustainable intensification. Sustainability is an aspect that is sometimes overlooked as food producers focus on a few cereals and a few crops that are easy to cultivate but that are actually diminishing our capacity to produce a wide variety of nutrients. Figure 10 shows nutrient production in relation to landcape diversity.

Uses of data, new research areas, and a recommendation

How can we promote sustainable intensification without losing diversity? The answer to that question needs to be central to how smallholder sectors are considered. The information we are collecting is the first that shows the relation between diverse landscapes and the production of a diversity of nutrients. Certainly, the patterns of these graphs differ greatly depending on where you are, but looking at the global picture we can see that we should try not to lose the great diversity associated with smallholdings, as Dr Sibanda beautifully presented with her account of her lived experience.

We released this data in April 2017, and we have seen an interesting response from the research community. The people working on the Global Burden of

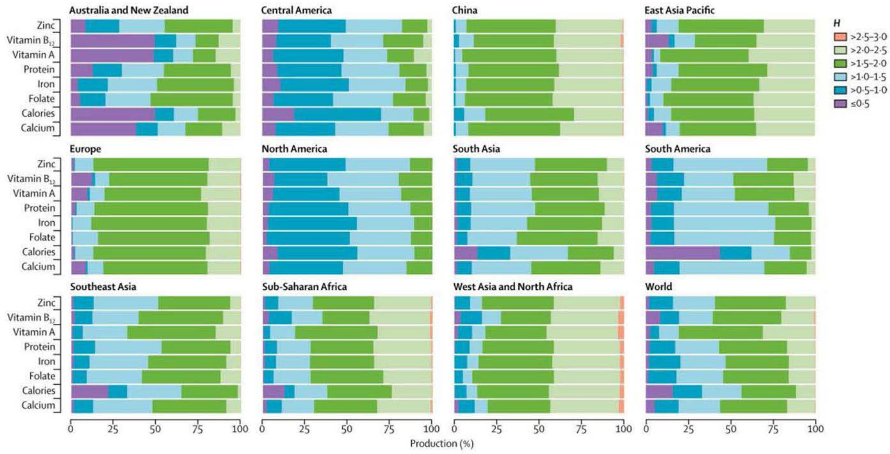


Figure 10. More diverse landscapes produce more nutrients.
Horizontal axis = % of production; vertical axis = nutrients.
Orange and green indicate larger amounts. *Source:* Herrero et al. 2017.

Disease took up the information on nutrients immediately, so as to link it to epidemiological data on stunting in children, for example, leading to potentially more trans-disciplinary work. The data has also been used in the Global Nutrition Report and by the EAT-Lancet Commission. Biodiversity research teams are interested to examine the data and see if places that are diverse in food production are better at maintaining ecosystem services and biodiversity, and if they are also better from a land perspective and so on. These are the kinds of new linkages that are going to be needed to meet, for example, the Sustainable Development Goals.

Finally, we should not let the default situation be that the market leads to consolidation of farms. There needs to be policy influence on the structure of farming. We need mechanisms through research and policy to actually understand and better shape the future in terms of farm structures, recognising that they seem to be central to how we will produce the necessary nutrients that we are going to need to feed the world.

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Mario Herrero is a Chief Research Scientist and Office of the Chief Executive Science Leader in CSIRO's Agriculture Flagship. He has more than 20 years experience working on strategic agricultural R4D projects in Africa, Latin America, Asia and Europe. Before coming to Australia in February 2013, he spent 12 years in Kenya, leading the Sustainable Livestock Futures and Climate Change programs and the Targeting Pro-Poor Interventions team at the International Livestock Research Institute. A known team-player, with an extensive network of partners and donors, he works in the areas of agriculture, food security and global change, targeting agricultural investments in the developing world, sustainable development pathways for smallholder systems, ex-ante impact assessment, climate change (impacts, adaptation and mitigation), development of scenarios of livelihoods and nutrition futures, multi-scale integrated assessment, and others. He has experience working at different scales, from the animal and farm level to the country, regional and global levels. He has coordinated several global and regional integrated assessments initiatives such as the African Livestock Futures Report for the Office of the UN Special Representative on Food Security, and the CGIAR global assessment of food production systems, ecosystems services and human well-being to 2030. He has also contributed to numerous international assessments such as the IPCC 4th and 5th Assessment Reports, 2010 World Development Report, the 2007/2008 Human Development Report and the 2007 Comprehensive Assessment of Water Management in Agriculture. He regularly participates in international committees such as IPCC's Working Group 3 (Mitigation) and the IPCC Task Force on Greenhouse Gas Emissions, and has served in several donor and science advisory committees on agriculture, livestock and the environment. He has published more than 300 fully refereed papers, book chapters and reports in his areas of expertise. He is currently on the editorial boards of *Agricultural Systems* (Elsevier), *Global Food Security* (Elsevier), *Agriculture and Food Security* (BioMed Central) and *Tropical Grasslands*, and has been a guest editor for the *Proceedings of the National Academy of Sciences* journal (*PNAS*). He has also supervised over 60 academic theses on different aspects of tropical agricultural production systems, and has recently become a Honorary Professor of Agriculture and Food Systems at the University of Queensland, Australia.