Sustainable nutrition

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Received: 31 May 2017
Accepted: 29 November 2017

doi: 10.1079/PAVSNNR201712056

The electronic version of this article is the definitive one. It is located here: http://www.cabi.org/cabreviews

Abstract

A new paradigm – 'sustainable nutrition' – has emerged where distinct streams of scientific discourse are beginning to overlap: in global change, environmental science, agriculture, food security, nutrition, sustainable development and public health. A broadening of perspective has accompanied this new way of thinking, which holistically considers overall food system performance, as measured by economic, environmental, societal, nutrition and health outcomes. This systems approach includes analysis of entire food supply chains: beginning with the production of essential agricultural inputs, animal and crop farm operations, fisheries and aquaculture, processing, storage, distribution, preparation, consumption and ending with waste disposal. The burgeoning scientific literature on this topic is reviewed here, which points to four actions that are needed to achieve sustainable nutrition: (1) carefully define terminology and agree upon quantifiable measures, metrics and methods of assessing the status of sustainable nutrition; (2) bridge the gap between the ability to characterize national-scale food system performance and the diet and health of individuals, by gender, age and socio-economic status; (3) better coordinate and resource the efforts now underway at local and regional levels that attempt to enhance sustainable nutrition; and (4) facilitate consensus-building across the full spectrum of food system stakeholders on the trans-sectoral, ethically based policies and other interventions that are needed across entire food supply chains in order to attain sustainable nutrition.

Keywords: sustainability, food security, nutrition security, climate change, resilience, food safety, food loss and waste

Review Methodology: A set of baseline background references was initially gathered from one of the author's recent peer-reviewed articles [1]. This list was then supplemented by November 2017 Google Scholar queries for papers published since 2013 that matched the following keyword searches: 'sustainable diet', 'sustainable nutrition' and 'sustainable nutrition security'. Removal of duplicates from these four lists of papers produced a consolidated set of 105 unique references judged to be relevant to this topic.

Review

In recent years, the companion themes of 'sustainable nutrition' and 'sustainable diets' have emerged where distinct streams of scientific literature have widened and begun to overlap, in the areas of global change, environmental science, agriculture, food security, sustainable development, nutrition and public health. A broadening of perspective has accompanied this new trend, a way of thinking that now considers overall economic, environmental, societal, nutrition and public health outcomes of food system performance in a holistic manner [2]. This systems approach includes analysis of all stages of food supply chains, including the production of essential agricultural inputs (e.g. seed, fertilizer and crop protection products), animal and crop farm operations, and all of the many steps involved in human utilization of food: processing, storage, distribution, preparation, consumption and waste disposal [3].

The topic of 'sustainable diets' first took prominence on the global stage at a major international conference co-organized by FAO and Bioversity in Rome in 2010 [4].

In plenary, the gathered experts endorsed the following definition:

> *Sustainable Diets are those diets with low environmental impacts which contribute to food and nutrition security and to healthy life for present and future generations. Sustainable diets are protective and respectful of biodiversity and ecosystems, culturally acceptable, accessible, economically fair and affordable; nutritionally adequate, safe and healthy; while optimizing natural and human resources.*

According to a key 2014 paper by Tilman and Clark [5], if more sustainable diets were widely adopted, they could offer substantial health benefits, reduce greenhouse gas (GHG) emissions, land clearing and resultant species extinctions. Even more recently (in 2017), Pamela Mason and Tim Lang co-authored a book analysing the many additional complex factors that are involved in the pursuit of sustainable nutrition: dietary quality, health, environment, social values, economy and governance [6]. A common theme in much of the recent literature is the sharpening realization of the challenge that food systems face to deliver sustainable nutrition, due to multiple colliding constraints: including human population pressure, resource scarcity, ecosystem degradation and climate change [7]. The literature includes a stark assessment that today's global food system is unsustainable, whether defined in narrow environmental terms or more broadly to include socio-economic dimensions [8]. This dire assertion is difficult to refute. Nearly 800 million people globally are still without sufficient calories [9], and at least two billion lack sufficient nutrients [10]. The repercussions of these vitamin and mineral deficiencies are both serious and long-lasting to human health [11]. Food supplies that provide ample or even excessive calories but are deficient in key nutrients compromise nutritional status ('hidden hunger') and contribute to the added burden of non-communicable disease [12]. An especially troubling feature in low- and middle-income countries is the so-called 'nutrition transition' to more processed foods, which can be associated with a loss of nutritional balance and some of the same diet-related conditions that already plague many higher income countries (obesity, heart disease, diabetes, etc.) [13].

Perhaps most significantly from a long-term perspective and as already noted briefly above, food systems are negatively impacted by climate change. The Fifth Assessment Report of the United Nations Intergovernmental Panel on Climate Change (IPCC) highlighted the effects of water scarcity and higher temperatures on crop yields, and the higher food prices and diminished food security that are likely to result [14]. Unfortunately, the causality of these effects is in both directions. Certain food system practices damage the environment and are a major source of the very GHGs that contribute to global warming [15]. Globalization is another mega-trend with potentially profound nutritional implications [16]. In an increasingly inter-connected world, the lack of sustainable nutrition security in one region can have widespread political and economic ramifications, potentially leading to global impacts [15].

Measuring Sustainable Nutrition

One of the major challenges to the members of the scientific community who are attempting to study and eventually enhance the ability of food systems to deliver sustainable nutrition is the need to agree upon terms, quantifiable measures, metrics and methods of assessing the status of sustainable nutrition. One such challenge is defining 'sustainable nutrition' itself. Deriving widely accepted definitions and approaches to addressing sustainability considerations (economic, environmental and societal) requires convening broad groups of stakeholders, as in a recent effort co-led by this reviewer [1]. Guided by the previous definition of 'sustainable diets' and seeking quantifiable measures, that group agreed upon seven metrics of sustainable nutrition: food nutrient adequacy, ecosystem stability, food affordability and availability, socio-cultural wellbeing, food safety, resilience, and waste and loss reduction, with each metric comprising multiple indicators, all measured on a 0–100 scale [1]. Other metrics of food system performance have recently been proposed [17], but regardless of which particular metrics are chosen, they can be used to develop and monitor the effectiveness of policies and actions intended to achieve sustainable nutrition [18–20]. Such metrics can also be used to characterize system changes following an intervention [21].

However, one of the major difficulties is that food systems are complex adaptive systems or so-called 'wicked problems' [22], involving multiple interactions between human and natural components [23], with the systemic nature of these interactions calling for multidimensional approaches and integrated assessment and simulation tools to guide change [24]. Novel systems modelling approaches have recently been proposed, such as causal factor analysis [25] and a method based on theories of vulnerability and resilience [26]. Resilience, the capacity that ensures adverse stressors and shocks do not have long-lasting adverse development consequences [27] is an extremely important property of food system performance that – when present – helps maintain sustainable nutrition. All of these various attempts to model the complex behaviour of food systems are in their infancy, and further development is both expected and needed.

The environmental component of sustainable nutrition is generally quantified through some form of Life-Cycle Assessment (LCA), which attempts to quantify the full suite of environmental impacts associated with a particular food or diet, beginning with the production of inputs and then including all of the intervening steps leading up to consumption and management of waste [28]. As noted in pivotal paper by Heller *et al.*, the full application of LCA to food systems requires the development of regionally

specific life cycle inventory databases for food and agriculture and expansion of the scope of assessments beyond only GHGs [29]. Other elements of LCA are still being debated in the literature. For instance, the use of different functional units (e.g. calories, protein content, etc.) for reporting the relative environmental sustainability (e.g. carbon and water footprints, etc.) of different foods dramatically alters their apparent relative impacts [30]. It must also be emphasized that the development of such tools is still in its infancy, especially as it relates to quantifying the relative economic and societal benefits of various foods.

One interesting quantitative approach is the use of optimization methods to identify foods and dietary patterns that would lower the risk of non-communicable diseases at low cost and with low GHG emission profiles [31]. Another innovative idea for measuring healthy and sustainable dietary behaviours is through the use of smart phone-based applications [32].

The nutrient composition of foods and diets is relatively well understood, but all of the connections to health outcomes are not as clear [33]. Perhaps most importantly, there is no consensus on key issues related to non-communicable disease, nor on the incorporation of a broader range of qualitative approaches that can address important cultural and ethical dimensions of food [34].

Summarizing this first main point, the current literature is peppered with numerous attempts to define and quantify sustainable nutrition, but progress on actually improving food system outcomes is still held hostage by the lack of agreement on both terminology and the various measures, metrics, and methods of assessing the status of sustainable nutrition.

Sustainable Diets and Foods

Diets and the individual foods or types of food that they include have profound implications for sustainable nutrition, but the connections between national-scale food system performance and the diet and health of individuals – by gender, age and socio-economic status – are still poorly understood and characterized [3, 35]. It is important to understand what constitutes a sustainable diet, but this then needs to be communicated and implemented effectively if positive change is to occur. Studies show that understanding of sustainable diets is poor and there are many misconceptions (e.g. the overestimation of the protein requirements for a healthy diet), which could contribute to the barriers towards changing dietary intakes [36].

In the years since the initial definition of 'sustainable diets' endorsed at the 2010 conference in Rome [4], a number of authors have sought to further refine terminology and promote 'healthy and sustainable diets'. For instance, a group of Australian authors [37] has asserted that a 'healthy and sustainable' diet is based on three overarching principles: any food that is consumed above a person's energy requirement represents an avoidable environmental burden in the form of GHGs, use of natural resources and pressure on biodiversity; reducing the consumption of discretionary food choices, which are energy-dense and highly processed and packaged, reduces both the risk of dietary imbalances and the use of environmental resources; and a diet comprising less animal- and more plant-derived foods delivers both health and ecological benefits. Unfortunately, such diets are often relatively expensive, with the poorest consumers – often those most in need of their health benefits – also being the least able to afford them [38, 39].

The so-called Mediterranean diet [40] has been advanced as a dietary pattern that helps achieve sustainable nutrition, with benefits to both human health and the various dimensions of sustainability – environmental, economic and socio-cultural [41]. Other researchers have emphasized that adopting a healthy lifestyle and preserving the cultural elements of the Mediterranean diet should be considered in order to acquire all its benefits and preserve its cultural heritage [42].

Numerous individual foods have been promoted as having a particularly helpful role, including orange-fleshed sweet potato [43], potato [44], pulse crops [45], as well as underutilized minor crops, such as amaranth, drumstick tree and mungbean [46]. Individual components of foods and food additive have also received attention, such as fatty acid profiles consumption patterns [47] and the use of tannins to improve composition, quality and shelf life of ruminant products [48]. Additionally, increased consumption of fruit and vegetables (so long as this happens without increased intake of refined carbohydrates) can improve health in many populations [49].

Animal-sourced foods have received a particularly large amount of study, and the sustainability of the livestock industry is currently one of the most hotly debated issues in the literature [50]. Although such foods do not fulfil current global protein consumption, one author team has suggested that about one-third of the protein each person needs can be produced without competition for land between feed and food production [51]. Dairy products are nutrient rich and, in many countries, dairy contributes significantly to nutrient intake, but milk production and processing contribute to GHG emissions, estimated at 2.7% (cradle-to-retail) of the world's total [52]. The current body of research, despite methodological differences, generally shows that reducing intake of animal-based products – particularly ruminant meat – proportionally decreases the overall environmental impact of a diet. However, livestock systems often have major economic and socio-cultural benefits. The challenge is how to manage these complex trade-offs to enable livestock's positive impacts to be realized while minimizing and mitigating negative ones [53].

Dairy products have received particularly keen attention in the sustainable nutrition literature. It is generally found that nutrient-rich dairy products as part of a healthy diet

can play an important role in helping meet nutrient recommendations not easily met with other foods and can help lower risk of certain chronic diseases [54]. The role of dairy products in the United Kingdom was studied by modelling nutritional adequacy, financial cost and GHG emissions of diets containing high, low and average amounts of dairy products (milk, cheese, yogurt and ice cream) [55]. A reduction in diet-related GHG emissions by 20% while maintaining high nutritional quality seems realistic. This goal could be achieved at no extra cost by reducing energy intake and energy density and increasing the share of plant-based products [56]. Moderate GHG reductions ($\leq$30%) were compatible with nutritional adequacy and affordability without adding major food group shifts to those induced by nutritional recommendations adequacy [57]. Higher GHG reductions either impaired nutritional quality, even when macronutrient recommendations were imposed, or required non-trivial dietary shifts compromising acceptability to reach nutritional adequacy [57].

In another study of UK diets, it was found that dietary GHG emissions in self-selected meat eaters are approximately twice as high as those in vegans [58]. Other results for the UK suggest that public health and climate change dietary goals are in broad alignment with the largest results in both domains occurring when consumption of all meat and dairy products are reduced [59]. Another UK research team found that diet that meets dietary requirements for health and costs about the same as the current British diet can achieve 36% lower GHGs by modestly reducing meat and dairy products [60].

Despite the growing number of relevant articles now appearing in the literature, as noted at the outset of this section, there are still no published studies linking national-scale food system performance to the diet and health of individuals. There has been some limited assessment of the higher cost of healthier and more sustainable diets, but the literature is completely silent on the methodologies that would be needed to conduct full evaluations by gender, age and socio-economic status. Only when this connection is made will it be possible to quantify the ability of the recommended adoption of so-called 'sustainable diets' to actually result in improved sustainability and nutrition outcomes – at national, regional and global scales.

Local and Regional Efforts

Many activities and interventions are underway at local and regional levels in an attempt to enhance sustainable nutrition, but they are generally not well coordinated or resourced. In theory, community-derived good practices could support and reinforce global networks of sustainable community food systems, foster transformation and ultimately enhance the sustainability and resilience of food systems [61]. For instance, local food production, school meals and nutrition education can be linked through integrated programmes and policies, improving access to healthier foods; however, government leadership, strong legislation, civil society participation and inter-sectoral decision-making are all essential for meaningful impact [62]. Various regional efforts and issues associated with sustainable nutrition are summarized briefly below, listed in alphabetical order by country or region.

Bangladesh: The Homestead Food Production programme promotes an integrated package of home gardening, with the aim of increasing the health and nutritional status of women and children [63]. Another nutritious food available in Bangladesh is mola, a native fish. Developers of a Mola Production Program state that if it were to be implemented for at least 20 years, it would dominate – have higher health benefits and lower total costs – than a national vitamin A wheat flour fortification programme [64].

Brazil: A participatory assessment of the experience of land reform beneficiaries in seven municipalities in Mato Grosso highlighted the opportunities and challenges related to participation in mediated 'farm-to-institution' food procurement programmes, and assessed their influence on key food sovereignty principles, including agro-ecological transition, increased market stability and farmer autonomy [65].

China: The world's most populous country has the opportunity to increase food and nutrition security both nationally and globally through a comprehensive policy agenda that focuses on institutional reforms, investments for and in agriculture, productive social safety nets, mutually beneficial trade, and the exchange of know-how and technologies among developing countries and donors [66].

Italy: It has been reported that urban roof-top gardens in Bologna could provide enough vegetables to satisfy 77% of the city's demand [67]. The study also advances the hypothesis that implementation of such practices would provide an added environmental benefit, by enabling the connection of biodiversity-rich areas across and close to the city.

Nepal: Sustainable nutrition is threatened by the deterioration of food systems, changing food habits, lack of knowledge about the cultivation, use and nutritional value of neglected and underutilized food crops [68]. There is also a need for enabling policies for effective and long-term gender promotion for the sustainable development of livestock sector [69].

Sub-Saharan Africa (SSA): A new approach for nutrition research is needed that stimulates a demand from policy-makers for research in SSA and holds them accountable for incorporating research into policy and practice [70]. Throughout East Africa, there is a need to invest in innovative, context-specific, climate-smart agricultural practices that support sustainable livelihoods and development, and improve food security at the household level [71]. An analysis in Kenya found that food preferences, the local function of food and local practices negatively affect

the regularity and composition of meals [72]. In Malawi, a proposal was made by civil society organizations for a national food security bill, which includes the suggestion of setting up a fund aimed at financing the delivery of sustainable nutrition to the population [73].

United States: A vigorous debate continues over the presence of sustainability considerations in government-issued dietary guidance. A February 2015 report by the US Dietary Guidelines Advisory Committee (DGAC) recommended, for the first time, that food system sustainability should be an integral part of dietary guidance in the 2015 Dietary Guidelines for Americans [74]. Although this approach was not ultimately adopted by the government policy-makers, the political battle to incorporate sustainability into dietary guidelines is ongoing.

Policies for Sustainable Nutrition

For nations to achieve sustainable nutrition security, all people must have access to a variety of nutritious foods and potable drinking water; knowledge, resources and skills for healthy living; prevention, treatment and care for diseases affecting nutrition status; and safety-net systems during crisis situations, such as natural disasters or deleterious social and political systems [75]. Policy-based actions and other interventions to provide the world's growing population with a more secure and sustainable supply of nutritious food is possible but requires an accurate and comprehensive understanding of the dynamics surrounding sustainable nutrition pathways [76]. The solutions are inherently trans-sectoral, engaging practitioners and experts across agriculture, rural development and public health [77]. Policy should support action along entire food supply chains [78], including the food consumption process as a whole: i.e. growing, purchasing, cooking and eating [79]. Ethical issues arise as well. Key ethical issues include how to make societal decisions and define values about food security that impact nutrition outcomes, and the ethical trade-offs between environmental sustainability and ensuring that individual dietary and nutritional needs are met [80]. As policy is developed and implemented, it is essential for the entire spectrum of stakeholders to be intentionally engaged, in order to establish common understanding and improve the odds of success [81].

Environmental sustainability must be a key consideration in the development of effective food system policies, including agricultural biodiversity [82]. Without integrating sustainability as an explicit dimension of food security, today's policies and programmes could become the very cause of increased food insecurity in the future [83]. Mainstreaming ecological considerations in technology development and dissemination can help usher in an era of evergreen revolution and sustainable food and nutrition security [84]. Connecting agriculture policies with positive nutrition and health outcomes has long been identified as a particular challenge [85]. New efforts are now underway to ensure that the pursuit of climate-smart agriculture practices (e.g. conservation tillage, which builds resilience to weather extremes and contribute to climate mitigation through the sequestration of soil carbon), is accompanied by effective monitoring of nutrition outcomes [86].

The effectiveness of food security policies is determined by selecting the best bundle of policy instruments for the specific context and country and that trade-offs between policy instruments should be well understood, in order to achieve the right goals and avoid perverse outcomes [87]. Specific policy recommendations that have been proposed as ways to enhance sustainable nutrition include a 'food-based' approach, which aims at increasing the availability and consumption of the diverse range of foods [88]; and the so-called 'sustainable intensification' strategy [89]. However, others have indicated that an entirely new conceptual framework of the environment–public health nutrition relationship is needed to identify actions aimed at redesigning food systems [90]. Others have asserted that communities concerned with obesity and others forms of malnutrition need to work more closely together to demand food systems change [91]. Still others suggest that placing human rights at the centre of strategies to mitigate and adapt to the impacts of climate change and international solidarity is essential to advance sustainable development and to create a climate for sustainable nutrition [92]. It seems clear that well-designed policies targeting the demand for particular foods could simultaneously improve the health of the global population, and reduce GHG emissions [93]. Policies and actions at all levels require more and better inter-sectoral research to simultaneously address nutrition and environmental sustainability [94].

Trade policies must be carefully designed to avoid unintended negative consequences. For instance, more liberal trade policies may bring food insecurity to some households [95]. Efforts are also underway to reduce childhood undernutrition by analysing and testing opportunities to enhance the key role that women play in improving poultry and crop integration and efficiency to strengthen household nutrition in an ecologically sustainable manner [96]. One published set of recommendations is to align agricultural interventions with those in health services, water and sanitation and social protection; implement approaches to accelerate learning for development implementation and policy and investment enabling; build local and national capacity to adapt and innovate; and empower women and disadvantaged communities, in which the burden and solutions to sustainable nutrition security are often found [97].

Policies directed at the management of land use are critical. Forests and tree-based systems are a critical element of productive and sustainable landscapes and offer the possibility of more holistic and integrated approaches [98]. Agricultural biodiversity can engender dietary diversity and promote healthier diets [99]. Agroforestry concepts and practices can form an effective,

efficient and fair pathway towards the achievement of many Sustainable Development Goals (SDGs) [100]. Greater attention to the direct and indirect benefits of forests in food security, livelihoods and nutrition should enhance local and global efforts to end hunger and improve the nutrition of communities living in forested areas as well as those living in areas removed from forests [101].

Policies regarding capture fisheries and aquaculture should also be promoted in ways that support sustainable nutrition [102]. Safeguarding the diversity and complementarity of roles played by capture fisheries and aquaculture is essential [103]. The way society chooses to govern fisheries is an ethical choice, however, not just a technical one, and there is a need to add an ethical dimension to sustainability science as applied to fisheries [104]. There are good opportunities for policies that encourage the integration and re-use of waste products from aquaculture (e.g. sediments) at other points within the food system [105].

From the above, it is clear that the literature is still rather unsettled on the specific policies that are needed to ensure sustainable nutrition. Nevertheless, it can be concluded that trans-sectoral, ethically based policies and other interventions are needed across entire food supply chains in order to attain sustainable nutrition. Ultimate success will require an accurate, comprehensive understanding of the dynamics surrounding sustainable nutrition pathways, with facilitated consensus-building across the full spectrum of food system stakeholders.

Conclusion/Summary

Food systems face a major challenge to deliver sustainable nutrition, meeting accelerating global demand in a manner that will both sustainably meet human nutrition needs and comply with planetary constraints. This review of the current literature on sustainable nutrition resulted in four key findings. First, carefully defining terminology and agreeing upon quantifiable measures, metrics and methods of assessing the status of sustainable nutrition is essential to improving food system outcomes. Secondly, a wide gulf still exists between our current understanding of national-level food system performance and its connection to the diet and health of individuals, by gender, age and socio-economic level. Thirdly, a range of activities and interventions are underway at local and regional levels in an attempt to improve sustainability and nutrition outcomes, but they suffer from a lack of leadership, resources and reliable measures of success. Lastly, trans-sectoral, ethical policy-based actions and other interventions are needed across entire food supply chains in order to successfully attain sustainable nutrition, but they will require an accurate, comprehensive understanding of the dynamics surrounding sustainable nutrition pathways, with facilitated consensus-building across the full spectrum of food system stakeholders.

These conclusions imply a number of possible areas for future work, including further refinement and application of food system metrics for quantifying sustainable nutrition status; bridging the current gap between national-scale food system performance and individual dietary behaviour; better coordination of current efforts intended to measure and enhance sustainable nutrition; and greater investments in new methods for the collection, analysis and dissemination of data on food system performance – all of which should enable policy-makers and other food system actors to set meaningful goals, track progress on SDGs and evaluate the potential impact of food system interventions intended to improve both human and planetary health.

Acknowledgements

Many experts contributed to recent research and discussions that served as the underlying basis for this review. Space prohibits mentioning all of them, but they include: Tara Acharya, Thom Achterbosch, Lindsay Allen, John Antle, Joanne Arsenault, Senthold Asseng, Tim Benton, Steve Betz, Laura Birx, Tim Bodin, Jessica Bogard, Ken Boote, Pauley Bradley, Jim Buizer, Alona Bunning, Marisa Caipo, Andrea Carrothers, Abhishek Chaudhary, Larry Clemens, Joyce Coffee, Janet Collins, Karen Cooper, Laura Cubillos, Nancy DeVore, Dona Dickinson, Michael Doane, Adam Drewnowski, Joshua Elliott, Frank Ewert, Jessica Fanzo, Chris Field, John Finley, Erin Fitzgerald, Katie Flahive, Tara Garnett, Martijn Gipmans, Nick Goeser, Rachel Goldstein, Kaiyu Guan, John Hall, Jonathan Haskett, Michael Hayes, Paul Hendley, Chad Henry, Mario Herrero, Tom Hertel, Jerry Hjelle, Bill Hohenstein, Mark Howden, John Ingram, Kathy Jacobs, Molly Jahn, Sander Janssen, Aled Jones, James Jones, Doug Karlen, Mike Knowles, Sue Krebs-Smith, John Kruse, Karen Lapsley, Marie Latulippe, Ray Layton, Shawna Lemke, Whitney Leet, Josette Lewis, David Lobell, Stephen Long, Keith Lividini, Mike Lohuis, Hermann Lotze-Campen, Robin Lougee, Amy Luers, Geraldo Martha, Rex Martin, Marty Matlock, John McDermott, Moira McDonald, Morven McLean, Hans van Meijl, Jerry Melillo, Richard Moss, Gerald Nelson, Rosie Newsome, Himadri Pakrasi, Lindene Patton, Peter Raven, Roseline Remans, T.C. Richmond, Malcolm Riley, Sherman Robinson, Sally Rockey, Mark Rosegrant, Cynthia Rosenzweig, Anne Roulin, Sherman Robinson, Jeff Rumney, Serge Savary, Karen Scanlon, Barbara Schneeman, Christy Melhart Slay, Marco Springmann, Pamela Starke-Reed, Chris Stone, Tim Sulser, Sherry Tanumihardjo, Gene Takle, Gail Tavill, Greg Thoma, Allison Thomson, Thijs Tollenaar, Dominique van der Mensbrugghe, Michael Wach, Paul Wagman, Keith Wiebe, Stan Wood, Don Wuebbles, Gary Yohe, Manfred Zeller, David Zilberman and Monika Zurek. The work of these tremendously gifted scientists, who were all so generous with their time and expertise, is warmly appreciated.

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