Global Food Security 3 (2014) 125–132

Contents lists available at ScienceDirect

Global Food Security

journal homepage: www.elsevier.com/locate/gfs

# Food wedges: Framing the global food demand and supply challenge towards 2050

Brian A. Keating*, Mario Herrero, Peter S. Carberry, John Gardner, Martin B. Cole

*CSIRO Sustainable Agriculture Flagship, Ecosciences Precinct, Block B Level 3, Dutton Park, Qld 4102, Australia*

ARTICLE INFO

*Article history:*
Received 3 March 2014
Received in revised form
22 August 2014
Accepted 25 August 2014

*Keywords:*
Global food security
Food demand
Food wedges
Solutions
Pathways
Framework

ABSTRACT

A projection of global food demand to 2050, with assumptions on population growth, dietary shifts and biofuel expansion, provides an estimate of the amount of additional food needed over the next 40 years to satisfy human needs. This additional food demand, expressed in kilocalories, represents a "mega-wedge" akin to the carbon stabilisation wedges of Pacala and Socolow (2004). This food demand challenge consists of three component "food wedges" classed according to their target pathways: i.e. pathways that target reducing food demand; pathways that target increasing food production; and pathways that target sustaining the productive capacity of food systems. In this paper we examine these wedges in terms of prospective pathways through which food supply and demand can stay in balance over the next 40 years. Within these wedge classes, we nominate 14 pathways that are likely to make up the food security 'solution space'. These prospective pathways are tested through a survey of 86 food security researchers who provided their views on the likely significance of each pathway to satisfy projected global food demand to 2050. The targeting of pathways that contribute to filling the production gap was ranked as the most important strategy by surveyed experts; they nominated that 46% of the required additional food demand is likely to be achieved through pathways that increase food production. Pathways that contribute to sustaining the productive capacity are nominated to account for 34% of the challenge and 20% might be met by better food demand management. However, not one of the 14 pathways was overwhelmingly ranked higher than other pathways. This paper contributes a simple and comprehensive framing of the "solution space" to the future food demand challenge and a portfolio of investment pathways proposed to meet this challenge.



## 1. Introduction

The performance of the global food system over the last 50 years has been nothing short of remarkable. Total food supply has increased almost threefold in the face of a twofold increase in population and very significant shifts in diet related to economic development. The proportion of undernourished people in developing regions decreased from 23.2% in 1990–92 to 14.9% in 2010–12 and the Millennium Development Goal (MDG) of halving the percentage of people suffering from hunger by 2015 appears to be within reach (UN, 2012, 2013). Despite this impressive progress, one in eight people remain chronically undernourished in 2014.

At the start of the 21st Century, a sense of complacency had crept into the collective global consciousness. Expanding food supply to meet a rapidly growing human population was generally seen as 20th Century problem that had been solved by the Green Revolution (Hazell and Ramasamy, 1991). In 2000, agriculture was seen by many as a "sunset industry" in the developed world and our science and business institutions were consumed by the "sunrise industries" of the "Silicon Revolution". However, this perception was overturned dramatically by the food price shocks of 2007/08 and 2009/10, a 3- to 6-fold increase in prices of selected commodities, and significant human suffering and political unrest (Mitchell, 2008). Since this time there has been an explosion of interest in the global food security challenge.

There is no shortage of reports and analyses produced over the last five years that seek to diagnose the global food security challenge ahead (CA, 2007; IAASTD, 2009, Beddington et al., 2012). A search of the Web of Science (Thomson Reuters) database reveals 1075 papers published between 2008 and 2013 with the term 'food security" in the title – a 4-fold increase over a decade earlier. Such reports tend to be dominated by exploration of the drivers of food demand increase and prospects for a food supply response (IAASTD; 2009). Other reports target individual demand or supply interventions (Bouwman et al., 2005, Fraiture et al., 2007; Nelson et al., 2009; Valin et al., 2013). The "Safe Operating Space" exploration of food security (Beddington et al., 2012), based on the principles of Rockstrom et al. (2009), elegantly frames the

* Corresponding author.
*E-mail address:* Brian.Keating@csiro.au (B.A. Keating).

http://dx.doi.org/10.1016/j.gfs.2014.08.004
2211-9124/

problem and describes the interconnected forces of population growth, consumption growth, environmental change and food security.

Despite the plethora of studies focused on the “problem definition space”, there is no simple and comprehensive framing of the “solution space”. Assessing the food security solution space presents significant challenges due to the lack of available high resolution data to study comprehensively and consistently all aspects globally. In addition, issues of additivity and trade-offs of the different solutions, adequate costs and adoption rates, assumptions about technological change and the breath of application of practices make such analyses difficult (Von Lampe et al., 2014).

Traditionally, the global change community has used integrated assessment tools, partial equilibrium and computable general equilibrium models, together with crop and livestock simulation models to assess the impacts of a narrow set of options (yield increases, climate change impacts, technological change, improved markets) under different socio-economic conditions (Nelson et al., 2014; Valin et al., 2014; Von Lampe et al., 2014). While these tools and approaches continue to develop, even the most comprehensive cannot fully quantify all possible pathways. Nevertheless, new modelling efforts are constantly improving our understanding and modelling of the global food system (CIMSANS, 2014; Von Lampe et al., 2014).

In this paper we seek to create a framing for the “solution space” for matching global food demand and supply over coming decades. This framing parallels the carbon stabilisation wedges postulated by Pacala and Socolow (2004). We simply address the questions of what are the options by which food supply can be matched to future food demand and how do these options compare in terms of relative significance in the global food budget and ease of implementation? Our focus is primarily on the “food availability” element of food security. We recognise that the physical supply of food (availability) is only one dimension of food security, with other key determinants being food utilisation and nutritional value and food accessibility (World Food Summit, 1996).

## 2. Estimating future global food demand

Establishing a food demand trajectory is an essential first step in framing the “solution space” of food supply. The basic drivers of change in food demand are well recognised and primarily relate to population growth, demographics and shifts in the level and composition of diets with income changes and urbanisation. Societal changes in attitudes and values, as well as environmental change, affecting food preferences and/or supply might also impact on demand trajectories but these appear to be minor influences to date in the face of the key demographic and diet drivers.

The diversion of food products to biofuels also adds to the demands on global agricultural land, water and production activities and it is logical to include a biofuel demand element in future agricultural production targets (Searchinger et al., 2008; Havlík et al., 2011). Finally, the issue of food waste from producer to consumer is a important term in the global food balance (Godfray et al., 2010). Some food waste is implicitly embedded in food consumption data (e.g. at the processing, distribution and household end of food supply chains), while other sources of food waste (e.g., at the producer and farm-gate end of the supply chain) are excluded.

A figure of 70% expected increase in food demand by 2050 is often quoted and attributed to FAO (Bruinsma, 2003). Alexandratos and Bruinsma (2012) explain the source of this figure and the pitfalls inherent in reducing a complex set of food and non-food commodity trajectories down to a single figure. The total volume of agricultural products (in tonnes) is sometimes used, but this approach is deficient in that it combines very heterogeneous commodities into a single undifferentiated unit. The calorific value of food products is also used as a common unit to develop aggregated demand trajectories from very different commodities (Valin et al., 2014). This approach has some value as it can be simply related to per capita consumption statistics, but care is needed in considering non-food demands such as for biofuels and/or for animal feed, as the amounts of different commodities could be under or over-estimated depending on the degree to which non-food uses of food products are included. Also, nutritional security (Traore et al., 2012) is acknowledged as extending well beyond meeting the food energy requirements in diet and these issues are not captured in a calorific measure.

FAO's most recent revision of agricultural demand to 2050 has used international dollar prices to weight a diverse set of commodities under a single index of production (Alexandratos and Bruinsma, 2012). Price-weighted production metrics will capture changes in the agricultural production mix from lower value commodities to higher value commodities commonly associated with development. For example, China's food consumption per capita measured by FAO's price-based volume index doubled from 1989–91 to 2005–07 but increased by only 16% when expressed in terms of calories. This reflects rapid diet shifts to higher value horticultural and livestock based commodities.

There are upsides and downsides of all aggregated metrics. We have chosen to use an energy-equivalent basis (kcal $yr^{-1}$), acknowledging that it captures only one dimension of human diet and that it does not fully address shifts in diet preferences with income growth.

Keating and Carberry (2010) constructed a simple set of food demand scenarios based on population forecasts (UN 2012) and per capita consumption of food energy, either with existing consumption patterns for developed and developing countries maintained, or with the developed world staying static and the developing world increasing per capita consumption to match the developed world by 2050. That analysis suggests an increase in food demand over the 2010 to 2050 period as low as 35% (with 8.1 billion people) to more likely 50–80% increases with 9.2 billion people; the variation relates to consumption per capita shifts and biofuel diversions.

Valin et al. (2014) recently compared the food demand routines in ten global food system and economic models. In the reference scenario (AGMIP-SSP2), food demand increases by 59–98% between 2005 and 2050, slightly higher than the most recent FAO projection of 54% from 2005–2007. The range of results is large, in particular for animal calories (between 61% and 144%), caused by differences in demand systems specifications and income and price elasticities. Four estimates of future food demand are compared in Table 1. The analysis developed here is independent of the absolute estimate of demand, but it is conceptually important for the demand estimate to include all sources that are relevant to the supply pathways under consideration. For this reason, we have used the upper bound of the Keating and Carberry (2010) analysis, given it includes waste and biofuel considerations.

## 3. A “mega wedge” of additional food demand

We were inspired in our work on the food security challenge by the work of Pacala and Socolow (2004) who were confronted with a similar problem in exploring the global greenhouse gas abatement challenge. They identified two projections for atmospheric greenhouse gas emissions, namely an upper “business as usual”