Hunger amidst plenty: 
World trends in undernourishment and malnutrition

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ABSTRACT

Agricultural production in general, and specifically the output of food products, has consistently grown ahead of population in recent decades, thus increasing food output per capita. But food products may be used also for non-food purposes (seed, animal feed, non-food industries) or may be lost or wasted after being produced. There are also people unable to get the food they need, for economic or social reasons, and people who suffer malnutrition due to lack of food or as a consequence of poor health and sanitation. This paper analyses trends in the prevalence of undernourishment (insufficient dietary energy) and malnutrition (stunting, wasting, underweight and overweight) across the developing world. Using existing projections and scenarios the paper also discusses the likely future prospects of hunger and its major cause, extreme poverty. A Technical Appendix explains sources and methods used.

Undernourishment and malnutrition in the developing world are rapidly decreasing, though the pace of decrease is very slow in Africa (especially in anthropometric measures of child malnutrition) relative to Asia and Latin America. The world as a whole is on track to meet the Millennium Development Goal of halving by 2015 the prevalence of undernourishment estimated for 1990-92, but this would not yet be achieved until a much later time in regions like Sub-Saharan Africa or South Asia.

However, projections suggest that by 2050 and at world level both undernourishment and malnutrition would reach non-significant levels of prevalence (roughly around or below 5%); even in the poorer regions these levels would be achieved at some point between 2050 and 2080, even under very conservative assumptions. The world is thus expected to be on the verge of eradicating chronic hunger for the first time in history.

On the other hand, overweight and obesity are on the rise in all continents, amongst children and adults, male and female. The 'food problem' is now including an epidemic of overweight whereas famines are rarer and chronic hunger appears to be on the wane in most countries. Just a few countries report increasing levels of undernourishment or malnutrition, and they are mostly countries afflicted by prolonged violence or facing a collapse of the State apparatus. On the other hand, projections suggest that by 2050, though at the world scale there would be a low prevalence of these problems, some areas or countries may still be suffering from higher levels of both, albeit lower than they suffer now.

The opinions expressed herein are those of the authors and do not necessarily reflect those of the Research Centre of the Universidad del Pacífico (CIUP) or the University itself.
Does more food mean less hunger?

Food security is defined as a situation in which all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life (WFS 1996, 2009; Maletta 2014a). This involves producing enough food for a growing population, conveying it (mainly through trade) from point of production to point of consumption, and livelihoods allowing people to access food and biologically utilise it.

Food production greatly increased in recent history. Real output of primary food products from crops and livestock has more than trebled since 1961, and likewise for total agricultural output including non-food products, whereas world population has doubled, thus leading to a significant increase of around 50% in world per capita agricultural and food output in the latest half century (Maletta 2014b). Most remarkably, this was achieved without much increase in the use of land: about 95% of output growth is attributable to increased land productivity in the broad sense, including both crops and livestock. The growth of crops is mainly due to higher physical yields (tonnes per harvested hectare), increased cropping intensity (more harvested hectares relative to total crop land), and increased value of the harvested products (more value at constant prices per tonne of crop output). This enormous increase in food output, which grew by a factor of 3.3, is in turn dwarfed by growth in food trade, which has increased by a factor of 8.5 in half a century (Maletta 2014c). In summary, food is produced in increasing amounts, both total and per capita, and a growing share of it is traded and transported across borders around the world. Expansion of production and trade increased food availability in the world as a whole and in all its regions. Food per capita consumption has also increased in all regions of the world (Maletta 2014d).

However, per capita figures on food production or consumption are just population-level averages that may mask gross internal inequalities (e.g. some people get food aplenty whilst others starve). Therefore one must deal with distributional aspects concerning differences in access to food by households, and in actual intake and utilisation of food by individuals, as reflected in indicators of undernourishment and malnutrition, the main manifestations of hunger, and in the parallel indicators of rising overweight and obesity coming from both richer and poorer parts of the world.

As will be seen shortly, it turns out that, just as food production, food trade and food consumption grew, access to food by households and individual nutrition have also improved. Hunger and malnutrition do indeed persist in many parts of the world despite such improvements, but their prevalence has decreased and continues to decrease almost everywhere; the exceptions are a few unfortunate countries where hunger and malnutrition have actually increased in recent times, due to natural disasters, persisting extreme poverty, war, civil strife, or State failure.

As the increase in food consumption was accompanied in most countries by a rising income and various social changes, the composition of food consumption also changed, and this may be a mixed blessing; changes were generally towards a more varied diet with more fruit, vegetables, fish and dairy products, but (in many countries) also towards a diet with excessive dietary energy, and more laden with fats. A more varied diet is a positive development, but excessive food intake in general and particularly excess consumption of fat are detrimental to people's health, not from the lack of food but from excessive feeding. This has led to an expanding worldwide epidemic of overweight and obesity in both developed and developing countries, whilst the prevalence rates of undernourishment and malnutrition show, as we shall see, a clear tendency to decrease. For a vast majority of human populations around the world, the 'food problem' is rapidly shifting from starvation to obesity, from scarcity to excess, even if there is still hunger around the world, and occasionally even famine.

Food security requires not only food availability (through production and trade) and adequate average (per capita) food consumption but also physical and economic access to food 'by all people at all times'. Even if per capita supplies are adequate, some people may fail to get the required quantity and quality of
food. Given availability, physical access to food is usually not a problem, as food can ordinarily be put within reach of everybody through transport and trade, except perhaps during some emergencies: getting food may not be physically easy for people stranded by a flood, caught in the midst of violent conflict, or hit by a devastating natural disaster like an earthquake or a tsunami. In most situations, however, food and other commodities are indeed regularly provided by voluntary trade and transportation, and made accessible for people wherever solvent demand exists. Even in emergency situations, humanitarian aid may physically bring food (albeit not always in sufficient quantity or variety) to people in need. Subsistence farmers, on the other hand, have normally physical access to the food that they produce, though this source of food is subject to the vagaries of climate and (even in good years) seldom covers more than a fraction of total food needs. In fact, peasants in developing countries who grow food for their own consumption are often among the groups with the highest prevalence of malnutrition and undernourishment. Being a food producer does not guarantee adequate access to food. The real problem is not physical but economic access to food, which is frequently unequal among people, and this also affects small farmers because they almost always need some food they are not producing.

Economic access to food is attained by people mostly through three channels: food purchases in the market, household food production, and food transfers in kind. The end result is an allocation of available food supply among households, and among individuals within households. Actual food consumption by individuals can vary within the same household, and of course across households. Part of the variation in food consumption across individuals and households are due to differences in food needs (e.g. babies require, and usually consume, fewer calories than adults). Such differences may also reflect intra-household discrimination, leading to unequal satisfaction of individual food needs, often related to gender, whereby husbands and sons get more and better food at the expense of wives and daughters (Bouis & Peña 1997; Harriss-White 1997). Access to food may also vary over time: first, it can vary by season, especially in subsistence farming areas during the late part of a poor agricultural year (before the next harvest), when some peasant families may run out of food stocks from the previous season; running out of self-produced food stocks is a problem only if those households lack money revenue to buy food in the market; economic access to food may also vary from one year to the next due to climatic or economic fluctuations. All this affects one key component of food security, namely stability of food access.

This paper reviews evidence about changes in poverty and access to food, and in anthropometric indicators of nutritional status, especially among children. Anthropometric failure (such as stunting and wasting among pre-schoolers) reflects both insufficient food intake and poor biological utilisation of food (influenced by health and sanitation). Anthropometric signs of overweight and obesity reveal inadequate feeding practices, lack of exercise, and imply higher exposure to various life-threatening diseases.

We review first the evidence on poverty, especially extreme poverty, because lack of income is the key factor underlying limited access to food. Then we discuss the prevalence of undernourishment in recent history and its prospect for the future, and finally the evidence on anthropometric indicators of malnutrition. All show signs of improvement, and prospects are generally encouraging, but none of these scourges has yet been vanquished.

**Trends in poverty**

The main cause of deficient access to food is poverty. A low level of food consumption (usually matched by low levels of consumption of all goods and services) is a reflection of a low level of income. Inco-

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1 In the most common definition, poverty is the condition of households where income or consumption is below a given poverty line. Under this definition, the poverty line can be alternatively defined in relation to either current income or current value of consumption. The latter is generally preferred, both conceptually (people may use savings, credit, or other resources in order to smooth consumption over time and make up for short-term fluctuations in income) and empirically (measurement of consumption in household expenditure surveys is regarded as more reliable than reported income in other household surveys). There are also 'multidimensional' approaches that include also other, non-monetary aspects of poverty.
Poverty has been declining over time in recent decades, and especially so in recent years. This is not the place to review the enormous literature on poverty, but a rapid reference is necessary. A good recent account is Chen & Ravallion (2012), with important additional considerations in Ravallion (2013). These authors summarise the World Bank’s vast store of information from income, expenditure and consumption surveys around the world, applying a single ‘poverty line’ to measure the prevalence of poverty. For this purpose income and expenditure are measured in Purchasing Power Parity (PPP) dollars, and the uniform ‘extreme poverty’ line is the amount of international PPP dollars necessary on average in the poorest countries to purchase a basic consumption basket, a line currently set at $1.25 a day per person in PPP dollars at 2005 prices. According to that measuring rod, and based on survey data, poverty prevalence in developing nations fell from 52% in 1981, to 43% in 1990, to 34% in 1999, to 22% in 2008, and is projected to attain 16% by 2015 (Table 1 and Figure 1).

Table 1. Prevalence of poverty in the developing world, 1981-2015
(World Bank estimates based on household income and expenditure surveys)

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<tbody>
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<td>65.0%</td>
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<td>50.7%</td>
<td>35.9%</td>
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<td>17.1%</td>
<td>14.3%</td>
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<td>E. Europe/Central Asia</td>
<td>1.9%</td>
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<td>1.5%</td>
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<td>3.9%</td>
<td>3.8%</td>
<td>2.3%</td>
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<td>0.5%</td>
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<td>LAC</td>
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<td>13.6%</td>
<td>12.0%</td>
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<td>11.1%</td>
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<td>5.5%</td>
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<td>8.0%</td>
<td>7.1%</td>
<td>5.8%</td>
<td>4.8%</td>
<td>4.8%</td>
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<td>2.7%</td>
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<td>61.1%</td>
<td>57.4%</td>
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<td>36.0%</td>
<td>23.9%</td>
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<td>54.4%</td>
<td>56.5%</td>
<td>59.4%</td>
<td>58.1%</td>
<td>58.0%</td>
<td>55.7%</td>
<td>52.3%</td>
<td>47.5%</td>
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<td><strong>Total developing</strong></td>
<td>52.2%</td>
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<td>40.9%</td>
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<td>34.1%</td>
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<td>25.1%</td>
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<td>84.0%</td>
<td>69.4%</td>
<td>54.0%</td>
<td>60.2%</td>
<td>53.7%</td>
<td>36.4%</td>
<td>35.6%</td>
<td>28.4%</td>
<td>16.3%</td>
<td>13.1%</td>
<td>n.a.</td>
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<tr>
<td>Developing, exc. China</td>
<td>40.5%</td>
<td>39.1%</td>
<td>38.1%</td>
<td>37.2%</td>
<td>36.6%</td>
<td>34.3%</td>
<td>33.6%</td>
<td>31.5%</td>
<td>27.8%</td>
<td>25.2%</td>
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Source: Chen and Ravallion 2012. (*) Projection to 2015: Ravallion 2013 (Table 1 and Figure 2).

There is a marked acceleration in the decrease of poverty after the year 2000 (either including or excluding China, where the most spectacular reduction in poverty has occurred). However, poverty rates in Africa decline slowly and are still very high according to these figures: about 58-59% in the mid-1990s, decreasing only to 47.5% in 2008. Poverty in South Asia falls somewhat faster than in Africa, but remains high (36% in 2008, down from 45% in 1999 and 54% in 1990). The generally downward tendency in poverty rates is robust as regards the choice of poverty line: as the same authors have shown, choosing other lines (e.g. $2.00 instead of $1.25) leads to a similarly decreasing trend, although (by defini-
tion) a larger proportion of people will be below a higher poverty line (Chen & Ravallion 2012, Table 3; also Ravallion et al 2009; Ravallion 1994, 2010). In our case, however, a frugal line such as PPP $1.25 per day (at 2005 prices) may be more adequate because poverty is taken here as a constraint for access to food. Since food is usually a priority for expenditure in poor households, and undernourishment measures the most basic form of hunger (failure to meet the minimum dietary energy needs), only those in severe poverty tend to fall into undernourishment. The World Bank $1.25 line is in fact the average poverty line of the 15 poorest nations, where undernourishment is highest, and income is so low that not even a modicum of food can be afforded by a large proportion of people. It is mostly below such low level of income as represented by that meagre poverty line that people find it difficult or impossible to cover their minimum food needs. Higher poverty lines may be useful for other purposes, but may also be less appropriate for the specific task of identifying people unable to meet their basic food needs. The prevalence of extreme poverty by the late 2000s and projected for 2015, as estimated by Ravallion (2013), suggest that little more than one billion people are in such appalling living conditions. Ravallion then asks ‘how long it will take to lift one billion people out of poverty’ (actually meaning reducing by one billion the numbers of the poor), under different assumptions on income growth and income inequality. He uses two hypotheses: in the more pessimistic one, the developing world outside China would return to the (lower) rate of reduction in the prevalence of poverty that was observed in the 1980s and 1990s whilst China staying on its track; in that case it would take about 50 years to lift one billion people out of extreme poverty. In a more optimistic scenario, poverty rates in developing countries outside China would keep diminishing at the (faster) pace prevailing since 1990, and China would also retain its historical performance in this regard. Under this second scenario, one billion people would be lifted out of poverty by 2025-2030. Under current population projections, this reduction in the ranks of the poor would imply reaching a 3% poverty prevalence rate, sharply down from the 16% projected for 2015 for developing countries as a whole. In practice, reducing the overall rate to 3% allows that some countries (that are now developing) reach levels approaching zero poverty, whilst others remain at higher levels, just like is the case today. Even if world extreme poverty becomes not significant in the future, it would still be a pressing reality in some parts of the world. The World Bank approach to the measurement of poverty, exemplified in Chen's and Ravallion's work, is based on income or expenditure estimates taken from household surveys. There has been an extensive discussion on the possible defects of reported household income, expenditure, or consumption: it has been noted that survey-based estimates often fall well below per capita figures from National Accounts, and in many cases the reported level of income or consumption is logically untenable, implying for example the existence of a large proportion of people whose reported expenditure or income would not cover the food needed for basal metabolism even if such expenditure or income were entirely devoted to food (Bhalla 2003; Ravallion 2003; Deaton & Kozel 2005). These shortcomings of survey-reported income or consumption imply that estimates of inadequate food access (and indeed estimates of poverty) derived from such data are likely to be overstated. The discussion on these issues has motivated the emergence of a mixed approach, whereby per capita income (or consumption expenditure) is taken from

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2 Results based on the 2005 revision of the International Comparison Program (ICP), as those obtained by Ravallion (2013) may be probably adjusted downwards (towards less poverty) in the near future. A new benchmark PPP rates based on 2011, partly published in 2014, give considerably different results than the 2005 round (WB 2013; Deaton & Aten 2014), after correcting for some peculiar factors affecting the previous round of PPP estimates. The ICP 2005 revision generally made developing countries poorer and international differences wider than was expected under the previous (1993) PPP version (updated for inflation); reasons for this were discussed, among others, by Deaton (2010). The ICP 2011 revision somewhat reversed the effect on poverty of the previous one, according to some preliminary analysis (Chandy & Kharas 2014) whereby world poverty under 2011 PPP would be lower than was expected under the 2005 PPPs (also updated for inflation). However, Chandy & Kharas estimates are preliminary; at the time of writing no definitive new poverty figures based on the 2011 PPPs are as yet available.
National Accounts (e.g. per capita private consumption or personal disposable income), whilst the degree of inequality in the distribution of income or consumption across people or households is estimated from data in household surveys. Besides applications of this approach in particular countries, e.g. India (see Deaton & Kozel 2005), some historical analyses of poverty at the world level have been also based on this idea, e.g. Bourguignon & Morrisson 2002 or Sala-i-Martin 2006. The general result of these studies is that for any given poverty line the prevalence of poverty is lower when per capita income or consumption are adjusted according to National Accounts. It is also found (with either method) that world poverty has a steady tendency to fall over the long term.

Using National Accounts as the basis for measuring poverty has the advantage of allowing the decomposition of income inequality into portions within and between countries. Sala-i-Martin (2006), measuring poverty at the world level with income estimates derived from National Accounts and income inequality derived from surveys and other sources, estimates that two thirds of the variability of income across people is explained by disparities in national per capita incomes across nations (relative to the world mean), and only one third by domestic income inequality (relative to each national mean). If everyone be granted the per capita income of their respective nation, two thirds of world income inequality would persist. Similar conclusions are reached by Chotikapanich et al 2007, and Warner et al 2011, among others. For instance, Warner et al 2011 estimate that the between- region disparities contributed 65% of global inequality in 2005; between-country inequality within each region explains an additional portion (which varies across regions). Numerical results in this field may vary depending on using one or another update of PPP exchange rates and other methodological details, but most studies agree on the basic fact that international, rather than domestic, inequality explains most global inequality among people. In many fast-growing countries (e.g. China) economic growth entailed both a reduction of poverty and an increase in domestic inequality (Khan & Riskin 2001; Riskin et al 2001). The general reduction of inequality found by Sala-i-Martin (2006) is the net result of two opposite processes: slightly increasing inequality within countries and strongly decreasing inequality between countries.

Both approaches in the study of poverty and inequality (estimates of income or consumption based either on National Accounts or household surveys) lead anyway to the same conclusion: world poverty rates are gradually going down, and would become quite small in the coming decades even under pessimistic assumptions. Poverty reduction implies progress in access to food, and thus less hunger. As seen before, per capita food production and per capita food consumption are both on the rise. The next two sections look at world hunger at individual and household level using two gauges: FAO’s measure of undernourishment reflecting insufficient habitual supply of dietary energy, and WHO’s anthropometric indicators of child malnutrition based on height and weight. These indicators are far from covering all aspects of food security, but do look at central issues and have the virtue of being available for most countries and regions over a long span of time.

Overcoming extreme poverty would be a tremendously important factor to overcome hunger. However, data show that undernourishment and malnutrition (especially micronutrient deficiencies and the resulting failures in children's growth and development) may appear also amongst people living above extreme poverty, even in middle-income or high-income countries.

**Undernourishment**

*Data and definitions*

The falling tendency of world poverty rates foretells a falling tendency in global undernourishment, especially when the poverty line corresponds to extreme poverty since that is the level of deprivation where people are more likely to habitually consume less than the minimum amount of food that is the basis of the FAO concept of undernourishment.
For measuring the prevalence of undernourishment at population level, the key concept used by FAO is that of **dietary energy needs**. These correspond to the bodily energy expenditure of people keeping an acceptable body weight and performing a certain level of physical activity. The technical basis for estimating dietary energy needs is periodically updated by expert meetings under the auspices of FAO and WHO. The latest update is FAO 2004 (the previous one was FAO/WHO/UNU 1985). Background discussions for the latest update are reflected in FAO 2003b and Shetty 2005.

FAO defines undernourishment as a habitual food supply providing less than the **Minimum Dietary Energy Requirement** (MDER); the methodological aspects are summarised in FAO 2008 and also in the technical notes accompanying recent FAO-SOFI issues (2012, 2013, 2014) as well as Cafiero & Gennari (2011) and Cafiero (2013, 2014). The MDER is defined as the average habitual amount of dietary energy required to keep the minimum acceptable weight (for each age group, sex, and height) and to perform light physical activity, plus the energy required for pregnancy, lactation and growth. The mean MDER of a population, as well as the normal or average energy requirement, varies across countries, and may also vary over time in a given country, depending on differences or changes in age-sex composition and mean height attained by individuals. For people of given sex and age, MDER may vary due to variation in individual heights and other factors like body shape or metabolic efficiency).

FAO's indicator of the prevalence of undernourishment is not sensitive to short term variations in food supply or income, nor is it able to account for intra-household inequality of access. It is defined in terms of **habitual** consumption (approximated by three year averages), and estimates the distribution of available food based on measured or estimated variation across households as regards income or consumption.

**Trends**

The historical record on undernourishment tells a generally positive story: its prevalence has decidedly gone down in all major regions of the world since 1990 (Table 2 and Table 3). The most recent worldwide estimate (11.3% in 2012-14) is nearly on track to attain the Millennium Development Goal of halving by 2015 the 18.7% world prevalence of 1990-92 (i.e. reaching 9.35% in 2015). It is also on track to attain the same goal in developing countries as a whole, where the level of 1990-92 (23.4%) has gone down to 13.5% in 2012-14 and may reach the MDG target (11.7%) by 2015 or shortly afterwards (Figure 2). Many countries already reached their national MDG target in this regard, though some regrettably lag behind. There are some parts of the world, such as Sub-Saharan Africa, where the prevalence is high and the decrease is slower, but even there the trend is downwards.

**Table 2. Prevalence of undernourishment by region, 1990-92 to 2000-02 (percentage of total population)**

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<td>18.3</td>
<td>17.9</td>
<td>17.2</td>
<td>16.6</td>
<td>16.1</td>
<td>15.7</td>
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<td>Developed countries</td>
<td>1.8</td>
<td>1.7</td>
<td>1.7</td>
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<td>1.9</td>
<td>2.0</td>
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<tr>
<td>Sub-Saharan Africa</td>
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</tr>
<tr>
<td>China</td>
<td>23.9</td>
<td>24.5</td>
<td>23.4</td>
<td>22.0</td>
<td>20.1</td>
<td>18.5</td>
<td>17.6</td>
<td>16.9</td>
<td>16.5</td>
<td>16.3</td>
<td>16.1</td>
</tr>
<tr>
<td>Rest of E. Asia</td>
<td>9.6</td>
<td>10.3</td>
<td>11.2</td>
<td>12.0</td>
<td>12.9</td>
<td>13.7</td>
<td>14.3</td>
<td>14.5</td>
<td>14.5</td>
<td>14.6</td>
<td>14.6</td>
</tr>
<tr>
<td>South East Asia</td>
<td>30.7</td>
<td>30.1</td>
<td>28.9</td>
<td>27.4</td>
<td>25.8</td>
<td>24.7</td>
<td>24.0</td>
<td>23.8</td>
<td>23.4</td>
<td>22.9</td>
<td>22.3</td>
</tr>
<tr>
<td>South Asia</td>
<td>24.0</td>
<td>23.0</td>
<td>23.2</td>
<td>23.1</td>
<td>22.8</td>
<td>21.9</td>
<td>21.3</td>
<td>20.7</td>
<td>19.6</td>
<td>18.8</td>
<td>18.2</td>
</tr>
<tr>
<td>India</td>
<td>23.8</td>
<td>22.2</td>
<td>22.4</td>
<td>22.2</td>
<td>21.6</td>
<td>20.5</td>
<td>19.2</td>
<td>18.1</td>
<td>17.3</td>
<td>17.0</td>
<td>17.6</td>
</tr>
<tr>
<td>Rest of South Asia</td>
<td>24.5</td>
<td>25.2</td>
<td>25.3</td>
<td>25.7</td>
<td>25.7</td>
<td>25.4</td>
<td>24.8</td>
<td>23.7</td>
<td>22.4</td>
<td>21.3</td>
<td>21.0</td>
</tr>
<tr>
<td>Western Asia</td>
<td>6.3</td>
<td>7.2</td>
<td>7.4</td>
<td>8.0</td>
<td>8.3</td>
<td>8.5</td>
<td>8.8</td>
<td>8.9</td>
<td>8.8</td>
<td>8.7</td>
<td>8.6</td>
</tr>
<tr>
<td>LAC</td>
<td>15.3</td>
<td>14.7</td>
<td>14.6</td>
<td>14.3</td>
<td>14.0</td>
<td>13.7</td>
<td>13.5</td>
<td>13.4</td>
<td>12.9</td>
<td>12.3</td>
<td>11.5</td>
</tr>
</tbody>
</table>
There has been in general a remarkable trend towards lower prevalence of undernourishment in all regions. Most individual countries also decreased, but there have been a few exceptions at the level of individual countries as some nations actually increased their prevalence of hunger, mostly due to prolonged conflict, collapse (or near collapse) of the State, or other unfavourable political conditions. Among

3 Thus the rise in undernourishment since 2010 in North Africa is probably related to recent political turmoil. Estimates are missing for some countries with severe conflict situations that may have increased their level, e.g. Somalia, Syria or the Democratic Republic of Congo. In addition, data for Least Developed (or Low Income) countries, even when they exist, are often defective; the most frequent problem is underestimation of subsistence food production, especially for earlier dates (Svedberg 1991, 1998, 2000, 2002) and thus their actual undernourishment is probably lower than reported.
such exceptions, from 1990-92 to 2012-14 (FAO SOFI 2014) the estimated prevalence of undernourishment increased by 15.6 percentage points in Iraq, 14.8 points in Zambia, 14.2 points in North Korea. In some other countries (Tanzania and Swaziland the estimated prevalence went up by about 10 points). In a few other countries (as in North Africa) the prevalence increased by 4 or fewer points but these smaller increases may not be statistically significant. In spite of the declining level of undernourishment, it is nonetheless the fact that 13% of the population in developing countries (11% of all mankind) are still undernourished. Poverty and hunger are on the wane, but they are still with us.

The absolute number of undernourished people is often cited, though it is not an adequate trend indicator when total population is increasing (see Technical Appendix). However, even by that improper measuring rod, the situation has greatly improved: there were (by FAO estimates) about 980 million in 1990-92, which fell to 922 million in 2000-02, and to 805 million in 2012-14 (a decrease of 18% in the absolute number of undernourished persons since 1990-92 in spite of population growing in the meantime by 91%). If the absolute number of the hungry is considered as a valid indicator, it is only fair to watch also the number of the non-undernourished, which increased by 148% from 4393 million in 1990-92 to 6341 million in 2012-14 whilst the hungry decreased by 175 million from 980 to 805 million. Thus the world has since 1990 added two billion people with enough food access as to avoid undernourishment, and reduced by 175 million the ranks of the undernourished despite the increase in total population. Even by the inadequate metric of absolute numbers the undernourishment situation has greatly improved.

Absolute numbers are instead quite relevant to examine the geographical distribution of the hungry. According to FAO SOFI 2014 and its background statistics, the undernourished in 2012-14 were concentrated in Southern and Eastern Asia and in Sub-Saharan Africa. These three regions comprised 80.9% of all undernourished people in the world, as shown in Table 4.

<table>
<thead>
<tr>
<th>Region</th>
<th>Millions</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>World</td>
<td>805.3</td>
<td>100.0%</td>
</tr>
<tr>
<td>Developing countries</td>
<td>790.7</td>
<td>98.2%</td>
</tr>
<tr>
<td>Sub Saharan Africa</td>
<td>214.1</td>
<td>26.6%</td>
</tr>
<tr>
<td>South Asia</td>
<td>276.4</td>
<td>34.3%</td>
</tr>
<tr>
<td>East Asia</td>
<td>161.2</td>
<td>20.0%</td>
</tr>
<tr>
<td>South East Asia</td>
<td>63.5</td>
<td>7.9%</td>
</tr>
<tr>
<td>LAC</td>
<td>37.0</td>
<td>4.6%</td>
</tr>
<tr>
<td>Other developing</td>
<td>25.9</td>
<td>4.8%</td>
</tr>
</tbody>
</table>

Source: FAO SOFI 2014 and FAOSTAT, Food Security Indicators. LAC: Latin America and the Caribbean.

**Prospects for the future**

Any projection of undernourishment must be based on projections of food production, population, and distribution of food consumption. For longer term projections account should also be taken of the probable effects of climate change and increases in the use of crops as feedstock for making biofuels. All these factors are highly uncertain and thus projections explore various scenarios, not making a specific prediction about what will happen, but expressing the logical implications of a given scenario, which may or may not materialise.

FAO has been publishing projections of future agricultural development since the early 1980s, first projecting expected developments until the year 2000, and then looking further in the future; the latest exercise looks to 2030 and 2050 (FAO 2006; Alexandratos & Bruinsma 2012). In the context of the more recent FAO projections of agricultural production to 2050, Fischer (2011) has produced a series of projections to 2050 and 2080, incorporating into FAO’s model the expected impacts of climate change and the production of biofuels, with updated information relative to his former work in previous years (Fis-
Once per capita food supply has been thus projected, the expected prevalence of undernourishment is estimated on the basis of a well-known curvilinear correlation between undernourishment and the degree of adequacy of per capita dietary energy supply (or apparent consumption) relative to minimum dietary energy requirement (i.e. ratio of kcal/person/day to MDER), as explained in the Technical Appendix. The worldwide results thus attained are reflected in estimates of undernourishment, summarised in Figure 3 and Table 5.

---

**Figure 3.** Worldwide projected prevalence of undernourishment, 2000-2080, including effects of climate change and increasing use of biofuels. Based on FAO agriculture and population projections, A2 GHG emissions scenario, Hadley and CSIRO climate models, and the two 'worst-case' biofuel use scenarios (Fischer 2011).

**Table 5.** Projected worldwide undernourishment (2000-2080).

<table>
<thead>
<tr>
<th></th>
<th>2000</th>
<th>2030</th>
<th>2050</th>
<th>2080**</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Baseline projection (FAO)</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Population (million)</td>
<td>6047</td>
<td>8231</td>
<td>9105</td>
<td>9752</td>
</tr>
<tr>
<td>GDP (billion 1990 USD)*</td>
<td>27136</td>
<td>62165</td>
<td>98014</td>
<td>119686</td>
</tr>
<tr>
<td>Agricultural GDP (billion 1990 USD)*</td>
<td>1259</td>
<td>1836</td>
<td>2192</td>
<td>2349</td>
</tr>
<tr>
<td>Undernourishment (million)</td>
<td>833</td>
<td>760</td>
<td>530</td>
<td>150</td>
</tr>
<tr>
<td>Undernourishment (% prevalence)</td>
<td>13.8%</td>
<td>9.2%</td>
<td>5.8%</td>
<td>1.5%</td>
</tr>
<tr>
<td>2 Impact of climate change (Hadley)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Change in undernourishment (million)</td>
<td>0</td>
<td>1</td>
<td>-3</td>
<td>28</td>
</tr>
<tr>
<td>Undernourishment (million)</td>
<td>833</td>
<td>761</td>
<td>527</td>
<td>178</td>
</tr>
<tr>
<td>Undernourishment (% prevalence)</td>
<td>13.8%</td>
<td>9.2%</td>
<td>5.8%</td>
<td>1.8%</td>
</tr>
<tr>
<td>3 Impact of climate change (CSIRO)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Change in undernourishment (million)</td>
<td>0</td>
<td>24</td>
<td>4</td>
<td>19</td>
</tr>
<tr>
<td>Undernourishment (million)</td>
<td>833</td>
<td>784</td>
<td>534</td>
<td>169</td>
</tr>
<tr>
<td>Undernourishment (% prevalence)</td>
<td>13.8%</td>
<td>9.5%</td>
<td>5.9%</td>
<td>1.7%</td>
</tr>
<tr>
<td>4 Average of 2 and 3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Change in undernourishment (million)</td>
<td>0</td>
<td>13</td>
<td>1</td>
<td>24</td>
</tr>
<tr>
<td>Undernourishment (million)</td>
<td>833</td>
<td>773</td>
<td>531</td>
<td>174</td>
</tr>
<tr>
<td>Undernourishment (% prevalence)</td>
<td>13.8%</td>
<td>9.4%</td>
<td>5.8%</td>
<td>1.8%</td>
</tr>
<tr>
<td>5 CC Hadley + biofuels (TAR-V3)***</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Change in undernourishment (million)</td>
<td>0</td>
<td>82</td>
<td>39</td>
<td>40</td>
</tr>
<tr>
<td>Undernourishment (million)</td>
<td>833</td>
<td>842</td>
<td>569</td>
<td>190</td>
</tr>
<tr>
<td>Undernourishment (% prevalence)</td>
<td>13.8%</td>
<td>10.2%</td>
<td>6.2%</td>
<td>1.9%</td>
</tr>
<tr>
<td>6 CC CSIRO + biofuels (TAR-V3)***</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Change in undernourishment (million)</td>
<td>0</td>
<td>108</td>
<td>46</td>
<td>32</td>
</tr>
<tr>
<td>Undernourishment (million)</td>
<td>833</td>
<td>868</td>
<td>576</td>
<td>182</td>
</tr>
<tr>
<td>Undernourishment (% prevalence)</td>
<td>13.8%</td>
<td>10.5%</td>
<td>6.3%</td>
<td>1.9%</td>
</tr>
</tbody>
</table>
Prevalence of undernourishment (number of the undernourished as percentage of world population) is computed on the basis of FAO reference population up to 2050 (Fischer 2011, Table 3.1) and world population estimates for 2080; the latter, not disclosed by Fischer 2011, is taken here to be 9752 million, based on FAO’s estimate for 2050 (9105 m) and the annual growth rate for 2050-80 (0.23%) implicit in the 2010 Revision of the UN population projections.

As seen in Figure 3 and Table 5, these projections of future rates of undernourishment envisage a gradual tendency to non-significant levels, starting with a worldwide prevalence of 13.8% in 2000 and leading to a worldwide prevalence between 1.5% and 2.1% in 2080. Prospects may be only slightly altered by recent retrospective adjustments in estimates of undernourishment (FAO SOFI 2012, 2013, 2014).

Climate change and biofuels are thus estimated to have a negative but very small impact on the prevalence of undernourishment and its decline along the 21st century, compared to a future without climate change and without expansion of liquid biofuels for transport. A somewhat wider difference between the various climate and biofuel scenarios is expected in the near future, causing undernourishment estimates for 2030 to vary across scenarios from 9.2% to 11.4%, a range of 2.2 percentage points; inter-scenario variability is narrower for 2050 (5.8%-7.0%, or 1.2 percentage points) and minimum for 2080 (1.5%-2.1% or 0.6 points). Very remarkably, the inclusion or exclusion of climate change and biofuels makes little difference in the end result concerning undernourishment: all variants are close to each other and well within their own uncertainty margins. This is due, on the one hand, to the view of agriculture as an adaptive system, whereby farming adapts to changes in the environment that distributed over two or more generations of farmers, and on the other hand, data on availability of usable suitable land (AB 2012; Maletta 2014b) which would be tapped whenever projected productivity growth is unable to cope with projected increasing demand.

Fischer’s estimates of climate change impact are based only on the A2 emission scenario, implying high carbon emissions and lower economic development in a fragmented world; his various biofuel hypotheses are (paradoxically enough) not allowed to influence the A2 emission pathway, based on the sole use of fossil fuels. In fact, under increased biofuel use, emissions and warming should be lower. However, the resulting estimates strongly suggest that climate change and biofuels would have just a small influence on the generally declining tendency in the prevalence of undernourishment, which would in all cases

### Table 5. Projected worldwide undernourishment (2000-2080).

<table>
<thead>
<tr>
<th></th>
<th>2000</th>
<th>2030</th>
<th>2050</th>
<th>2080**</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CC Hadley + biofuels (TAR-V1)</strong>*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Change in undernourishment (million)</td>
<td>0</td>
<td>148</td>
<td>99</td>
<td>55</td>
</tr>
<tr>
<td>Undernourishment (million)</td>
<td>833</td>
<td>908</td>
<td>629</td>
<td>205</td>
</tr>
<tr>
<td>Undernourishment(% prevalence)</td>
<td>13.8%</td>
<td>11.0%</td>
<td>6.9%</td>
<td>2.1%</td>
</tr>
<tr>
<td><strong>CC CSIRO + biofuels (TAR-V1)</strong>*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Change in undernourishment (million)</td>
<td>0</td>
<td>176</td>
<td>104</td>
<td>48</td>
</tr>
<tr>
<td>Undernourishment (million)</td>
<td>833</td>
<td>936</td>
<td>634</td>
<td>198</td>
</tr>
<tr>
<td>Undernourishment(% prevalence)</td>
<td>13.8%</td>
<td>11.4%</td>
<td>7.0%</td>
<td>2.0%</td>
</tr>
<tr>
<td><strong>Average of scenarios 5 to 7</strong>*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Change in undernourishment (million)</td>
<td>0</td>
<td>129</td>
<td>72</td>
<td>44</td>
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<tr>
<td>Undernourishment (million)</td>
<td>833</td>
<td>889</td>
<td>602</td>
<td>194</td>
</tr>
<tr>
<td>Undernourishment(% prevalence)</td>
<td>13.8%</td>
<td>10.8%</td>
<td>6.6%</td>
<td>2.0%</td>
</tr>
</tbody>
</table>


(**) Population 2000-2050: Fischer 2011, Table 3.1; population 2080: estimated from the figure for 2050, and the 2050-80 growth rate envisaged in the 2010 Revision of UN Population Projections. Total and agricultural GDP estimated to grow at decelerating rates in 2050-80, as per projected trends up to 2050 (Fischer 2011, Table 3.2); shown for illustrative purposes only.

(***) Combined effect of climate change (A2 climate scenario) and biofuels (TAR-V3 and TAR-V1, the worst for undernourishment among various biofuel use scenarios). CC=Climate change. Source: Fischer 2011, Tables 3.1, 3.2, 3.5, 3.18, 3.23, 3.26, 3.33 and 3.41, and p.115.
lead by 2050-80 to a world with very low prevalence of hunger. In fact the effect of climate change alone, projected by either Hadley or CSIRO models, and not considering biofuels, is practically nil. Almost all the projected impact, especially in 2030 and 2050 but not in 2080, comes from projected use of biofuels, because the only biofuels considered are those based on food crops; the effect of climate change alone is not significant. If biofuels were not based on short-cycle food crops, but on crop residues or non-food permanent crops, or on crops grown on relatively marginal land not required for food crops, the impact would be much lower. The effect of biofuels, however, is almost irrelevant by 2080, even in projections considering only food-crop-based biofuels grown on existing cropland.

Recent updates in undernourishment estimates (FAO SOFI 2014) indicate that the world rate has already fallen to 11.3% in 2012-14, and is likely to reach by 2015 (or shortly thereafter) the MDG target of 9.2% (half the 1990-92 rate); it is then unlikely to remain at 9.2% by 2030 as per Fischer's forecast without climate change, which is based on older, higher and rather stagnant undernourishment estimates. In the light of the more recent FAO-SOFI figures, Fischer 2011 projections seem slightly overstated. Even so, by Fischer 2011 estimates and including the effects of climate change and biofuels, world undernourishment would be just 6.6% in 2050 and clearly non-significant (maximum 2%) by 2080. With the more recent SOFI estimates on board, those states of affairs would be reached much earlier.

Fischer 2011 also offers similar prospects for each major world region, but only to 2050. Unfortunately, regional figures for 2080 are not explicitly published in Fischer 2011. Figures for 2080 have been estimated here (Table 6) based on Fischer's worldwide results for that year and indications in his text about the impact in absolute numbers for some of the regions (Fischer 2011, Table 3.18). These prospects by region mirror the worldwide decline (Table 6).

### Table 6. Prevalence of undernourishment, 2000-2080, including impact of climate change (A2 emission scenario) and biofuels (TAR-V3 scenario).

<table>
<thead>
<tr>
<th>Baseline projection (FAO-00 of IIASA)</th>
<th>2000</th>
<th>2030</th>
<th>2050</th>
<th>2080*</th>
</tr>
</thead>
<tbody>
<tr>
<td>World total</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sub Saharan Africa</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asia (developing)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rest of the world</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Climate change (A2), no biofuels effect</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>World total</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sub Saharan Africa</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asia (developing)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rest of the world</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Climate change (A2) and biofuels (TAR-V3)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>World total</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sub Saharan Africa</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asia (developing)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rest of the world</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Estimated from Fischer 2011 (Figure 3.8(B), Tables 3.1 and 3.18, and p.115). Scenario A2 used only for emissions and economic development, but with the population of the FAO baseline.

(*) Regional distribution of impact for 2080: estimated from world total, the percentage distribution of impacts by 2050, and indications about the impact in absolute numbers for some of the regions in Fischer 2011, Table 3.18). Population in 2080: projected from Fischer reference projection to 2050 (his Table 3.1) and growth rates 2050-80 from the UN 2010 Revision of population estimates, which closely agrees with the projection implicitly used (but not published) by Fischer.

Undernourishment in Sub-Saharan Africa, according to these projections, would be still significant in 2050, but would be nonetheless more than halved relative to 2000, with Fischer's estimates for those years falling from 29.8% to 13.9% (or 15.2% if biofuels are included).

Further decreases in 2050-80 are expected in all regions under this scenario, especially in Sub-Saharan Africa, since we know the overall prevalence by 2080 is projected to be about 2% at the world level, im-
plying about 3% for developing countries. Most regions were expected to have already low absolute undernourishment figures by 2050; the only regions with numbers large enough in 2050 to make a significant contribution to the foreseen reduction in 2050-80 are Sub-Saharan Africa and South Asia. Fischer does not publish regional results for 2080, but available figures in his report suggest Sub-Saharan Africa in 2080 would have about 4.5% prevalence and Asia about 1.2-1.4% (with South Asia about 3%, and negligible levels in other developing regions). The developing world as a whole would fall from 6.6% in 2050 to about 3% in 2080, and the world total to about 2% as seen before; all these figures are below the 5% significance threshold estimated by FAO for its undernourishment indicator. Numbers below 5% are statistically not distinguishable from zero.

In summary, Fischer 2011 projects a small overall effect of climate change and biofuels on the future prevalence of undernourishment, relative to a baseline scenario not considering such factors. Prospects are similar (and for Sub-Saharan Africa slightly better) than those obtained in Fischer et al 2002a and 2002b. Most of this small effect would be caused by biofuels based on food crops, not by climate change (besides using land suitable for food production, crop-based biofuels also push prices up, thus affecting economic access to food). Undernourishment is projected to be extremely low by 2080, both at world level and by region. After 2050 the bulk of the remaining undernourished people would be in South Asia and Sub-Saharan Africa; the above projections for 2080 imply also a very low prevalence in those regions (4.5% in Sub-Saharan Africa, 1.9% in Asia as a whole, and probably about 3% in South Asia).

**Nutritional status**

Adequate nutrition depends not only on household access to food, but on actual individual intake and subsequent biological utilization of nutrients in the body. Those nutrients are not only those providing dietary energy but also those supplying protein, vitamins and minerals. Individual intake depends on not just household access but also intra-household distribution of food; discrimination against some household members may reduce the intake of specific individuals (e.g. feeding young girls relatively less food than young boys, as is frequent in some countries). Intra-household waste may also hinder actual intake.

After food intake, biological utilisation of food (and hence nutritional status) depends not only on household or individual access to food, or individual food intake, but also on individual health conditions, access to health care, access to safe water, and sanitation. Infections may waste energy by dissipating heat in the form of fever, and they may also reduce appetite and cause nutrient loss through diarrhoea. This may affect the nutritional status of people in a chronic or a transient manner, causing for instance stunting (low height for age) and/or wasting (low weight for height) in young children, and medical conditions linked to lack of specific nutrients, e.g. anaemia (blood iron deficiency), scurvy (lack of vitamin C), or night blindness (insufficient vitamin A). Child stunting, an important indicator of child malnutrition, is crucially affected by a deficient supply of calcium, the main raw material for the growth of bones, and other micro-nutrients required for tissue deposition and growth.

The most widely used indicators of nutritional status are anthropometric, mostly based on weight and height. These indicators compare actual height or weight with the reference weight or height of healthy children that are growing normally, or assess the weight of adults in relation to their height, in terms of reference values measured in healthy individuals. The most usual indexes for children under five are stunting (low height for age) and wasting (low weight for height). Child underweight (low weight for age) is also used. Stunting reflects the accumulated effect of past failures in food intake and health; wasting (excessive thinness) is an indicator of current or short term malnutrition. Underweight can be caused by stunting, wasting, or both. All these measures are based on reference growth curves for children. Standard height and weight curves for children have changed from older NCHS curves (based on healthy US children and adopted by WHO since 1983) to more recent curves from the Multicentre Growth Reference Study (MGRS) covering healthy and well fed children in selected areas of four continents measured between 1997 and 2003, adopted by WHO since 2005. The MGRS collected primary
growth data and related information from about 8500 healthy and well-fed children in widely diverse ethnic backgrounds and cultural settings (Brazil, Ghana, India, Norway, Oman and the USA). Data must be expressed in terms of a consistent standard, either the MGRS or the NCHS, for the sake of comparability. For children over five and adults the usual indicator is the Body Mass Index. The Body Mass Index is weight (in kg) divided by the square of height (in m). Acceptable values for adults are those between about 18 to about 25. For ages up to 19, WHO provides reference BMI distributions by sex and age, these tables are used to define as acceptable values of BMI those between -2 and +2 standard deviations, encompassing 95% of the reference population (see WHO 1995 and WHO 2006).

Anthropometric measurements are not routinely produced on a continuing basis, but in special surveys taken at various intervals over time, and not in all countries. Thus trends over time are usually obtained by statistical techniques combining series of surveys in various countries to obtain estimated trends by region. The most salient trends worldwide and in most countries and regions are (1) a decreasing trend in nutritional deficiency (as measured by stunting, underweight and wasting in children), and (2) a rather rapid increase in the prevalence of overweight and obesity at all ages.

**Stunting**

There are two successive assessments of progress in stunting produced by the staff of the Nutrition division of the World Head Organization: one published at the turn of the century (De Onís et al 2000) under the hesitatingly interrogative title 'Is malnutrition declining?', which reviewed surveys from 1980 to the mid-1990s and found that yes, malnutrition was declining; and a new, more assertive study (De Onís et al 2011), covering surveys from 1990 to the late 2000s, and extending the same conclusion to later years. The first study uses the older NHCS standard of normal height for age, whilst the most recent study uses the newer MGRS standard (WHO 2006, 2007), and they are therefore not directly comparable. Both, however, tell the same story: the prevalence of stunting is diminishing all over the world, albeit at variable speed in the various world regions. The study published in 2000 included 241 surveys from 106 developing countries, taken between 1973 and 1998. The 2011 version included 576 surveys from 148 countries, taken between 1966 and 2008. In both studies, a multilevel regression model was used (dated surveys within countries, and countries within world regions). The results are those in Figure 4.

![Figure 4. Estimated trends of prevalence of stunting in children under five (MGRS standard), in developing countries (all, and three regions), 1980-2020. Estimates for 1990-2020: De Onís et al 2011, based on survey measurements up to 2008. Estimates for 1980-85 were originally based on the old NHCS standard; shown converted to the MGRS stand-](image)

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4 The Body Mass Index is weight (in kg) divided by the square of height (in m). For ages up to 19, WHO provides reference BMI distributions by sex and age, these tables are used to define as acceptable values of BMI those between -2 and +2 standard deviations. Figures for age 19 are also used for adults (WHO 2007). Prior to these tables, acceptable values for adults have been long considered to be those between about 18 to about 25, but this interval is now been replaced by the ±2 standard deviation interval derived from WHO 2007.
ard; the values shown for 1980-85 are based on the trend found with the NCHS standard in De Onís et al 2000, chained in 1990 to the series 1990-2020. Points to the left of the vertical line (i.e. up to 2008) are multilevel regression estimates based on surveys taken up to 2008. Points to the right of the vertical line are projections.

The estimates at regional level were produced at five-year intervals (from 1980 in the first study, from 1990 in the second one), and projected into the near future (up to 2005 in the first study, and up to 2020 in the second one). For the purpose of the present paper, the two series have been merged, adopting the MGRS standard throughout, in the following manner: (1) for 1990 onwards, the results from De Onís et al 2011 are used, presenting the estimated prevalence in each region at five-year intervals; (2) for years before 1990 (i.e. 1980 and 1985), the trend of the MGRS-based prevalence was supposed to have been similar to the trend obtained by De Onís et al 2000, based on the NCHS reference curve.

The huge database of health and nutrition surveys processed by Mercedes de Onís and her collaborators at WHO headquarters shows a decline of stunting in all three developing regions, albeit very slowly in Africa (from 43% to 38% between 1980 and 2010, projected to 37% by 2020) but quite faster in Latin America (from 30% to 10%) and very rapidly in Asia (from 57.5% in 1980 to 27% in 2010, projected to 19% by 2020). For the whole developing world, stunting also shows a decreasing trend from 51.7% in 1980 to an expected 23.7% in 2020. This process of sustained reduction in the prevalence of child stunting reflects improvement not only in food consumption but also in health and sanitation. The persisting high level and slow decline in Africa is the main remaining concern at this level of aggregation.

**Underweight**

Underweight is usually indicated by the proportion of children under five with weight at least two standard deviations below the reference median weight for given age. Using its new (MGRS) anthropometric standards, WHO estimates (Figure 5) that the worldwide prevalence of underweight for children under 5 declined from 25.4% in 1990 to 16.2% in 2010.

![Figure 5. Prevalence of underweight (low weight for age) among children under five, 1990-2010. Source: WHO (http://www.who.int/nutgrowthdb/estimates/en/).](image)

The decline in underweight occurred in all regions: in Africa (21.5% to 19.3%), in Asia (33.8% to 19.5%), in LAC (7.5% to 3.3%), and of course in all developing countries as a whole (28.7% to 17.9%). The smallest decline in prevalence occurred in Africa, compared to other regions, but it was a decline nonetheless. The persistence of relatively high underweight (and stunting) in Africa and Asia indicates that much more time and effort is needed in such regions to eradicate malnutrition, not just by improving food access but also health and sanitation.

**Wasting**

Stunted children have a height deficiency relative to normal height for age as measured in healthy well-nourished children; underweight children show weight deficiency relative to the normal weight for age, which is in turn estimated for children with adequate height for age. Thus both measures are related to
insufficient linear growth, reflecting long term or cumulative nutritional failure. Wasting (low weight for height), instead, indicates excessive thinness relative to attained height, and is regarded as a measure of current or short term nutritional deficiency. It is the exact opposite of overweight or obesity (discussed next), defined as excessive weight for attained height. Both can be applied to adults as well as children. Wasting is often transient at individual level: children or adults may lose weight and get wasted due to severe bouts of diarrhoea or a seasonal lack of food, but usually they do not remain wasted for long: many recover shortly, getting into the range of acceptable weights for their height, or they get worse and die. Population-level prevalence of wasting, even if persisting, is thus often the result of high turnover of wasted individuals.

According to WHO estimates for 2010, in developing countries the prevalence of wasting among preschool children was 9.6%. The prevalence was much higher in South-Central Asia (16.1%) and much lower in Latin America (1.6%, statistically non-significant). The huge population of Eastern Asia (excluding Japan) had a very low prevalence (2.1); Southeast Asia was near the developing-world average at 8.9%. WHO estimates (http://www.who.int/nutgrowthdb/estimates/en/) that the worldwide prevalence of wasting has fallen only slightly from 1990 to 2010: the prevalence of wasting in children under five living in developing countries is estimated to have been 10.0% in 1990, 9.8% in 2000, and 9.6% in 2010. But it has increased in Africa (from 8.3% to 10.0%). It fell slightly in Asia as a whole (11.6% to 10.6%), even in South-Central Asia (18.0% to 16.1%); and also in Latin America and the Caribbean where its prevalence is extremely low (falling from 2.1% to 1.6%). These long term changes are generally small. Unlike other indicators of malnutrition, wasting is strongly affected by short term bouts of hunger and disease in specific locations, and thus fluctuations around the trend are more marked. It is then not much used as a long term indicator.

**Overweight**

Overweight is a major problem in contemporary nutrition. Children are regarded as overweight if their weight is at least two standard deviations above the normal weight for age. Adult conditions are usually defined by the absolute BMI value: 25≥BMI>30 for overweight and BMI≥30 for obesity (see the official WHO recommendations at http://apps.who.int/bmi/index.jsp?introPage=intro_3.html.

Whilst nutritional deficiency indicators (stunting, underweight and wasting) have been diminishing, obesity and overweight are increasing. This process is occurring in all regions, in almost all countries, developing and developed, for both sexes and all ages including small children, though its intensity is lower in Asia and higher in Latin America. Under-five overweight (Figure 6) is particularly worrying, but obesity is rampant mainly among adults.

![Figure 6. Prevalence of overweight (including obesity) in children under five. Source: De Onís et al 2010.](image)

The worldwide prevalence of overweight and obesity among preschool children has increased from 4.2% in 1990 to 6.7% in 2010. It is expected to reach 9.1% in 2020 (De Onís et al 2010, based on 450 surveys in 144 countries). It increased by 4.3 percentage points (from 3.7% to 6.1%) in developing
countries, and by 3.8 points (from 7.9% to 11.7%) in developed ones; in other words, it increased relatively more in developing than developed countries. It increased from 3.2% to 4.9% in Asia, from 4.0% to 6.5% in Africa, and from 6.8% to 6.9% in Latin America and the Caribbean. The tendency to higher prevalence of child overweight is thus not confined to rich countries: it grows in poorer ones as well.

Adolescent and adult overweight and obesity are also on the rise, especially in Northern America and Eastern Europe, where more than half the population is overweight. In those regions obesity afflicts on average more than a fifth of the population, and over a third in some countries, especially among women. About 12% of the world population over age 20 was obese in 2008 (Body Mass Index ≥ 30), including 10% of men and 14% of women. Prevalence of adult obesity is related to income: it was 3.8% in Low Income countries, 6.6% in Lower Middle Income ones, 24% for Upper Middle Income, and 21.6% in High Income countries; in all cases prevalence was higher among women (WHO 2011:113).

These figures for adults refer to obesity proper (BMI≥30), but prevalence is at least twice as large for the more inclusive concept of overweight (BMI≥25). The most recent data (all during the 2000s) on prevalence of adult overweight in some selected countries were: 66.9% in the US, 66.5% in Germany, 62.7% in New Zealand, 61% in the UK, 59% in Canada, 49% in France and Australia, 44% in Italy, 40.6% in Brazil, 59.7% in Chile, 55% in Peru, 42% in Iran (WHO 2011:104-113; see also WHO Global Database on Body Mass Index, [http://apps.who.int/bmi/index.jsp](http://apps.who.int/bmi/index.jsp).

Intriguingly, however, Asian trends are different. Overweight prevalence in the two most populous countries is much lower: China 18.9% and India 4.5%. Among developed countries, Japan has also a relatively low score, with only 23% overweight. Since this discrepancy between East and West extends to other less populous Asian countries, both developing and developed, it is arguable that some specific Asian factors (cultural, genetic or both) tend to produce less overweight and obesity in that continent, even in countries experiencing a rapid process of economic growth.

To sum up, evidence shows a general decline in the prevalence of nutritional deficiency in children as indicated by anthropometric measures (stunting, wasting, and underweight) and a general increase in overweight and obesity among children and adults. The latter conditions attain very high levels in developed countries, or more generally at medium and high levels of per capita income. The prevalence of stunting, underweight and wasting in Africa, although declining, are still high and their decrease is slower. The slower reduction in Africa is not due to insufficient growth of food production (which in Africa grows actually faster than the world average) but to poor health and sanitation, widespread poverty, and (in some parts of the continent) persisting violent strife endangering lives and livelihoods.

Poverty, the main cause of nutritional deficiency, is generally diminishing, even in Africa, though indeed not yet enough. However, according to Ravallion 2013 scenarios, extreme poverty would practically disappear by 2030-50, and with it most of undernourishment (dietary energy deficiency), though some other forms of malnutrition (especially regarding micro nutrients) may persist for longer.

**Conclusions**

In the half century since 1961 food output has consistently grown ahead of population, thus increasing world food supply per person. This growth happened indeed in all world regions, but was faster in the developing world. Asia was fastest, followed by Latin America and Africa. The more developed regions (North America and Europe) grew at a much slower rate. World food production has increased by a factor of 3.3 between 1961 and 2011. Trade in agricultural and food products has increased much faster than production, as an expression of a more inter-dependent world food system. Whereas food output trebled, food trade grew by a factor of 8.5 in real terms. Since population grew much more slowly (barely doubling in that half-century), the amount of food per capita increased by nearly 50%, and is more widely transported and traded around the world.
Per capita dietary energy supply (or apparent consumption) has steadily increased and undernourishment has consistently decreased over time in all regions and at the world scale. Consumption of all major food items has increased, and especially non-staple foods such as fruit, vegetables, and many foods of animal origin, whilst per capita food consumption of cereals (the main staple foods) is declining.

Undernourishment prevalence is steadily decreasing, and is expected to become non-significant in most parts of the world along the coming decades. In a very pessimistic scenario, prevalence in all regions but Sub-Saharan Africa (SSA) will be below 5% by 2050; SSA itself will be just above the level of significance by 2050, and will have reached well below that level by 2080. Since the assumptions for this scenario are highly pessimistic, the actual course of events is likely to be better.

Concurrently, key indicators of malnutrition (stunting, wasting and underweight in children under five) are also improving consistently in all parts of the world, though figures are still high in some regions (chiefly Sub-Saharan Africa). The opposite problems (overweight and obesity) are rapidly increasing, even in children under five and also in other age groups, in developed and developing countries.

Even if our intent is chiefly examining trends, rather than offering policy proposals, the above review clearly suggests some key policy-relevant insights or hypotheses:

- People affected by food insecurity are concentrated in South Asia and Sub-Saharan Africa.
- Producing enough food is not the main challenge. The key for reducing undernourishment and malnutrition is improving the standard of living of the poor by diversifying their livelihoods, facilitating access to education and better jobs, and enhancing access to health care and sanitation, leading to higher incomes, easier access to food, and better biological utilisation of food.
- Low income and extreme poverty are the main factors for lack of access to food. Most of income inequality among people comes from differences between countries concerning per capita income; domestic inequality explains only a fraction of total inequality. Reducing domestic inequality will also help, but may have less overall impact than convergence between countries towards higher levels of income. Such convergence has been already happening through faster growth in developing countries, compared to richer ones. Continued convergence requires continued and faster growth in developing countries, and most especially an acceleration of economic growth and social development in South Asia and Sub-Saharan Africa, the two world regions with the highest rates of undernourishment and malnutrition.

Violence and corruption hinder in many countries the pace of reduction of malnutrition and undernourishment, as does the lack of preparedness for recurring natural disasters. Such factors divert valuable resources and lose valuable opportunities for economic growth and livelihood improvement, and perpetuate food problems. Good governance is thus another key factor: most of the few countries where undernourishment has increased suffer corrupt or tyrannical governments, failed States, and violent strife.
TECHNICAL APPENDIX

Assessment of access to food

The centrality of access in the concept of food security implies using adequate definitions and measures of food access. Access is of course different from actual food intake by individuals. For instance, a household may have an income that is deemed more than sufficient to acquire adequate food and cover other necessities as well, but internal household decisions may allocate that income in such a way that food is not acquired by the household in the amounts allowed by income (e.g. if the household uses the money for gambling, illicit drugs, or other such purposes), or not consumed by individual household members according to their needs and possibilities (e.g. if intra-household food distribution is not equitable).

In fact, the definition of food security adopted since the 1990s does not emphasize actual food intake but only food access, i.e. the capability or entitlement to the acquisition of sufficient and adequate food, irrespective of the actual use of such entitlement or capability. Thus people with income above the cost of a basket of basic goods and services (including adequate food) should be deemed to have good economic access to food, even if the money is ultimately used otherwise. This is the same approach used to measure poverty in terms of a poverty line: the line itself may be derived from the cost of a basket of essential goods and services, but earning an income at or above the poverty line does not ensure that it would be actually used to purchase that basket of essential goods and services.

Thus household food access is not equivalent to individual food access (or actual consumption), due to household waste and also due to unequal intra-household distribution of food access or intake (relative to individual needs). Data on the distribution of food consumption comes in most countries from household-level surveys, which typically ignore individual consumption. Most measures of food access (and also measures of poverty) are thus defined and evaluated at household level, and applied equally to all household members. Thus if a household has access to 20% less (or more) dietary energy than the sum of individual member needs, it is implicitly assumed that every individual member also consumes 20% less (or more) than their needs. Actual individual consumption of food is indeed rarely measured on a massive scale. Very little information is available on individual consumption or access to food, or intra-household distribution (of food, income, welfare or other consumption). Individual intake (and biological utilisation) of food is mostly measured by its anthropometric and health consequences, through health and nutrition surveys, and not so frequently through measurements of actual individual intake. Nutrition surveys also reflect actual use of food for food purposes, thus adjusting for household waste in an indirect manner.

Several approaches have been applied to measuring food access and thus make the food security concept operational, in tandem with its own conceptual evolution. In the 1970s and 1980s the indicators most often used concerned national self-sufficiency, such as the share of consumed food calories that are produced domestically, or the gap (if any) between domestic production and domestic consumption of staple food. After the 1996 World Food Summit re-defined food security in terms of access to food, the most important internationally-used indicator is the prevalence of undernourishment. It is supplied by FAO in its reports on The State of Food Insecurity in the World (SOFI), published annually since 1999, and was also estimated for previous periods in FAO’s fifth (1986) and sixth (1996) World Food Surveys. To understand the FAO indicator of the prevalence of undernourishment, a brief review is given first of how per capita dietary energy needs are determined.

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5 See Haddad et al 1997 for discussions of theoretical, practical and methodological issues associated with intra-household distribution of resources.
Dietary energy needs

The basics of this matter may be summarised as follows. The body expends energy that is generated on the basis of substances found in food, such as carbohydrates or fats (see Technical Appendix for details). Body cells generate and spend energy for various purposes:

- Basal metabolism (energy spent by staying alive at rest).
- Metabolic response to food (energy spent by ingesting, digesting and metabolising food).
- Physical activity.
- Pregnancy and lactation.
- Child/adolescent growth.  

Such energy is generated by burning (oxidizing) a simple sugar (glucose) transported in blood cells along with the necessary oxygen. Glucose is manufactured in the body by metabolising certain food components (carbohydrates, protein, fat, or alcohol) and transformed into energy according to bodily needs. Unused sources of dietary energy end up turned into fat and stored away. Body fat stores are necessary to a certain extent but, to avoid harmful health effects, stored fats should be within a safe range (as percentage of total body mass). Deficient or excessive body fat increases risk of disease and mortality. This determines (by sex and age group) a range of acceptable body weights for any given height.

Dietary energy needs at population level have been established by the UN since the 1950s, and are periodically updated by a joint group of experts under the aegis of WHO, FAO and the United Nations University (see the latest version at FAO 2004, and background papers at FAO 2003b and Shetty 2005). Dietary energy requirements at population level are based on average total energy expenditure (TEE) of healthy people with acceptable body weight for their sex and age, undertaking various levels of physical activity (and growing normally in the case of children). TEE is usually measured in daily kilocalories per person (kcal/person/day, abbreviated as kcpd). Even among healthy individuals, good health is compatible with a range of body weights and a range of physical activity levels.

The range of acceptable body weights and total energy expenditure by sex and age is usually computed separately for children under five and for older individuals. Among healthy children under five, there have been direct measurements of energy expenditure per kg of body weight, and also tables showing the distribution of height and weight for age and sex. The weight and height attained by well-nourished healthy children under five do not vary much across ethnic groups all over the world, and thus a single height-for-age growth curve and acceptable margins about it have been determined (WHO 2006: Tables 19-20 for boys and Tables 27-28 for girls). Likewise, there is a single weight-for-age growth curve and acceptable margins about it (WHO 2006: Tables 38-39 for boys and Tables 49-50 for girls). WHO 2007 offers also standard curves for weight by height (Tables 57-58 for boys and 66-67 for girls). The standard growth curves give the percentile distribution of height and weight by age, and weight by height, for healthy children of either sex growing normally and performing normal physical activity for their age. Normal TEE for those children is given for the median weight and height, i.e. at the 50th percentile of the reference distribution; that median level of TEE is the one considered for normative purposes at population level (FAO 2004, Ch. 3 and 4).

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6 Energy needs for pregnancy, lactation and growth includes: (a) energy that could have been generated by the food nutrients (e.g. protein) that are converted into new tissue; (b) energy content of mother's milk; and (c) energy spent in the metabolic activity required for new tissue deposition and mother’s milk secretion.

7 The stature of children up to 24 months of age is measured as length (lying down); above 24 months it is measured as height (standing). They differ from each other: at 24 months height is about 0.7 cm shorter than length, due to gravitational (compression of inter-vertebral discs) and postural reasons; growth curves have thus a 'step' of 0.7 cm at 24 months reflecting the change in measuring technique. Graphical growth curves for ages from 0 to 59 months are sometimes standardised in terms of length, i.e. actual length up to 24 months, and height+0.7 cm at ages over 24 months, to avoid the appearance of a 'step' or 'jump' in length at that age (e.g. WHO 2006, Figures 64 and 79).
Thus (for children under five) normal needs depend on a normative height, and corresponding weight, to be attained at each age. This is not the case for older ages, or for estimating minimum needs of dietary energy, where acceptable weights are determined according to attained (rather than normative) height for each age and sex. The main indicator of acceptable weight for attained height is the Body Mass Index (BMI), defined as the ratio of weight (in kg) to the square of height (in metres). The reference BMI distribution reflects the range of weights of healthy people, which has a normal distribution. The acceptable range of BMI values corresponds to people storing in their bodies an amount of fat deemed not to endanger their health. WHO 2007 contains the reference distribution of BMI values for each sex at ages 5 to 19; the values for age 19 are used also for older individuals. During recent decades (from the 1980s to the early 2000s) norms regarding acceptable weight relied on a range of BMI values, typically 18.5 to 24.9. People below 18.5 were regarded as too thin, those with BMI≥25 were classed as overweight (and as obese if BMI≥30); these ranges, however, were valid only for adults, and more importantly, they seemed to differ across ethnic groups (some groups seemed perfectly healthy whilst being outside the acceptable range, e.g. below 18.5 in various Asian populations). The issue is not completely resolved; more recent norms are more tolerant of different criteria for establishing the limits; besides, there is a tendency to use the reference BMI reference distribution instead of fixed values. Thus current custom regards as acceptable all BMI values between the 5th and the 95th percentile of the BMI reference distribution, and the corresponding range of weights for each sex, age group, and attained height; this includes children and adults. It is understood that good health could be maintained at any weight within that range. Using the BMI table requires measurements or estimates of average attained height by sex and age, from childhood to adulthood.

Current estimates of bodily energy expenditures (and thus dietary energy needs) for each sex and age are given in FAO 2004. The estimation method varies with age:

- For infants under one year of age, direct measurements of total energy expenditure (TEE) have been obtained from healthy infants, yielding energy needs by age and sex (FAO 2004:14).
- For older children up to 17 years of age, total energy expenditure per kg of body weight is estimated for each sex and age (FAO 2004: pages 26-27 for children performing moderate physical activity; and pages 29-30 for children performing light or heavy physical activity). To estimate TEE for each age and sex it is necessary: (a) to know or estimate the average attained height by age and sex; (2) to choose a reference weight for that height; and (3) to establish a reference level of physical activity. Average attained height by age and sex may be measured or estimated on the basis of health surveys or other sources. The range of acceptable weight-for-height by sex is derived from the reference distribution of BMI, as explained before; the normal reference weight corresponds to the median of the reference BMI distribution, whilst the minimum reference weight corresponds to the 5th percentile.

- To add physical activity for adults, a factorial approach is used: TEE is defined as the product of the Basal Metabolic Rate (BMR) multiplied by a factor representing Physical Activity Level (PAL):

\[
\text{TEE} = \text{BMR} \times \text{PAL}
\]

The BMR is the amount of energy spent by the body just for staying alive at rest: keeping all internal organs working (heart, kidneys, liver, brain and so on), maintaining a stable body temperature, and the like. It is measured, for instance, in kilocalories/day per person, but for some applications it is expressed as kg/day per kilogram of body weight. Standard predictive equations estimate the expected BMR for each sex and age group as a linear function of body weight (FAO 2004:37). Therefore, to estimate BMR, reference weights by sex and age should be used. The most common reference weights are those corresponding to a given percentile of the BMI distribution; the 5th percentile is usually regarded as determining the minimum acceptable weight; the midpoint or normal weight is at the median of the BMI distribution, and the maximum acceptable weight is commonly considered to be at the 95th percentile of the reference distribution.
The PAL factor indicating level of physical activity (which also includes metabolic response to food) may vary from 1.55 for light activity, to about 1.80 for normal or moderately active lifestyles, and 2.20 for vigorously active lifestyles.

To estimate the total dietary energy needs of a population, mean individual needs by sex and age should be computed, in kcal/person/day, and multiplied by the size of the respective age-sex group. The mean daily energy requirements for a certain age-sex group (other than young children) requires knowing the mean height of that group, then estimating the reference weight for that height, the BMR for that weight, and a normal or average level of physical activity (usually estimated by a moderately active PAL of around 1.80). The total daily needs of all age-sex groups (in kcal/day) are then added up to obtain the total daily energy needs of the whole population. A small additional allowance should be added to cover the energy required for pregnancy and lactation, but it does not add much to the total energy needs of the population as a whole. The allowance per birth is usually estimated at 210 kilocalories per day (FAO 2004), which is multiplied by the number of births estimated on the basis of population size and the crude birth rate. The resulting total energy needs are finally divided by total population to express them in per capita terms, as kcal/person/day.\(^8\) Average energy needs for a typical population, computed for median reference weight and moderate physical activity, is usually about 2100 kcal/person/day, but it varies across countries (typically between 2000 and 2300) depending on mean height by sex and age, and the age-sex distribution: rich countries usually have (on average) taller people, and a higher proportion of adults, thus requiring more energy per capita than poor countries where people are typically shorter and children represent a higher share of total population. Average per capita needs tend to grow over time as countries attain higher levels of economic development.

**The FAO undernourishment indicator**

Undernourishment is based on the Minimum Dietary Energy Requirement (MDER), which corresponds to a habitual level of food energy intake (by sex and age) permitting maintenance of minimum acceptable body weight and performance of light physical activity, allowing also for pregnancy, lactation and child growth. The indicator is defined as the probability that a population member has habitual access to less than the minimum amount of dietary energy compatible with good health.\(^9\)

The computation of this indicator involves estimating: (a) the probability distribution of food consumption (in terms of dietary energy) across the population, based on data about household food acquisition or food expenditure; or, when these are not available, on household income or expenditure plus Engel coefficients showing the share of income or expenditure destined to food at each income level; and (b) a Minimum Dietary Energy Requirement (MDER) for each country and year.

**Per capita food supply and unequal access to food.** Per capita food supply in terms of dietary energy is usually estimated through Food Balance Sheets (FAO 2001, Maletta 2010d) based on supply and utilisation accounts for individual food products; for each country, supply equals domestic production minus net exports minus stock change; non-food utilisation includes the use of each product for seed, feed, non-food industries, waste and losses; food supply is estimated as a residual. The energy content of each food is added up to get total dietary energy supply, or apparent consumption, which is expressed in per capita terms and measured in kilocalories per person per day (kcal/person/day or kcpd).

The distribution of food consumption across the population has been usually approximated by the log-normal curve, meaning that the logarithm of dietary energy supply is assumed to be normally distributed

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\(^8\) The printed edition of FAO 2004 comes with a piece of software to compute the per capita dietary energy needs of a population, based on its age-sex structure, average adult height, and birth rate, for various levels of physical activity.

\(^9\) Following epidemiological terminology, prevalence equals total cases existing at a given date divided by total population (the date, in practice, may be the average over one week, month or year). Incidence refers to new cases occurred during a period (typically a year) as a percentage of total population at risk in the same period. Prevalence is a stock (at a given time) and incidence is a flow (per year), both relative to a reference population.
(FAO 2008). In the latest revision of the indicator (introduced in FAO SOFI 2012) this has been modified to use (depending on the case) either the skew lognormal or the skew normal distributions. These skewed probability distributions require three main parameters: the mean (based on per capita supply of dietary energy, given in food balance sheets) and the standard deviation and skewness of access to dietary energy (estimated from available household income and expenditure surveys). As per FAO methodology, the MDER of a given country at a certain date is estimated as follows (FAO 2008:7):

- For children below age 10 the reference body weight is the median of the range of acceptable weights (WHO 2006, 2007). Energy needs in this case reflect normal (moderate) activity level.
- For adults and children of age 10 and above, reference body weight for MDER is the minimum, estimated on the basis of the fifth percentile of the BMI distribution (WHO, 2007), for mean attained height by age and sex.

Energy needs reflect moderate physical activity for ages 10-17, and light physical activity for ages over 18.

The use of 'light' physical activity for adults in the definition of undernourishment may be debatable. People at risk of hunger may need to perform (on average) more than light physical activity in order to procure food and other necessaries. In fact, it is precisely the poor who are often required to do the heavier work; this work is for them an obligatory expenditure of energy, and therefore they may not be able to live at a habitually light level of physical activity. The 2012 methodological overhaul of FAO's undernourishment measurement offers an alternative indicator based on normal (rather than light) physical activity; however, it is just a rough approximation, yet to be perfected, because information is insufficient to determine the average amount of obligatory extra energy that people of each country must spend in order to do the work involved in their livelihoods.

Along its history, the FAO indicator has undergone several revisions, including a major one in 2012 (retrospective to 1990). Revisions have included several aspects:

- Updating (often retrospectively) the estimates of total population; this has been important in some countries (mostly in Africa) where previous estimates were just rough approximations due to the lack of a regular series of reliable censuses.
- Improving the food-balance-sheet estimation of food supply, by revising estimates of food production, food trade, losses, and non-food uses. In particular, the 2012 revision involved a major revision of estimates of retail losses (previous estimates reflected mainly losses occurring at the production and wholesale levels, omitting much of the loss occurring at retail level).
- Updating the estimated shape (variance and skewness) of the probability distribution of food access within the population, using new household expenditure surveys in various countries.
- Updating energy requirements by sex and age, as per the latest expert meeting convened to that effect by FAO and WHO (published as FAO 2004) as well as the new WHO growth standards for children (WHO 2006) and the new BMI reference distributions (WHO 2007), all of which have modified older standards adopted in the 1980s and used until the mid or late 2000s.
- Adjusting the mathematical model used to estimate the probability distribution of food access. Up to 2011, the model was the lognormal distribution; in the 2012 revision, the models adopted included the skew-lognormal and the skew-normal distribution, which require not only the mean and the standard deviation (as was the case with the lognormal) but also a skewness parameter (also derived from household surveys where they were available, or otherwise estimated).

As a consequence of these changes, the series has been homogenized since 1990 onwards. Annual estimates are available in the form of moving 3-year averages (from 1990-92 through 2012-14 at the time of writing, though the latest is just preliminary). Estimates for prior periods, such as those supplied by the World Food Surveys for 1969-71 and 1979-81 (FAO 1996), are not strictly comparable to more recent ones. In the present study the revised figures (as explained in FAO-SOFI 2012) are used for 1990-2014. The undernourishment indicator is restricted to dietary energy, not reflecting in detailed form the avail-

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10 A summary is found in FAO SOFI 2012; further details are offered in FAO SOFI 2014. See also FAO 2012, Cafiero & Gennari 2011, and Cafiero 2013, 2014.
ability or consumption of protein, vitamins or minerals. Some additional indicators which are available for most countries worldwide point in that direction, such as some rough indicators of dietary diversity (e.g. percentage of cereals and tubers in total energy supply).

The indirect method used by FAO to estimate undernourishment, based not on individual data for households or individuals but on aggregate data and a theoretical distribution model, is exposed to various sources of uncertainty and error linked to the accuracy of the average and uncertainty about the fitness of the chosen theoretical distribution. Besides, it refers to the probability of undernourishment for the average person, but people differ in their energy needs due to normal variation in height, body shape, sex, age, and physical activity. Thus individuals who are shorter than average may be consuming below the average MDER for their age and sex (computed for the average attained height), and yet they may be covering their minimum food needs; by the same token, individuals who are taller than average may not be satisfying their minimum dietary energy needs even if they access food energy at or somewhat above the corresponding average MDER. However, these and other inter-individual differences in needs (for example, genetically-based variation in individual metabolic efficiency) are supposed to be randomly distributed and expected mostly to offset each other.

Estimates of per capita food availability are regularly updated annually, as new data are obtained on output, trade and stocks. The standard deviation and skewness of the distribution of per capita dietary energy supply across households, as well as coefficients used to estimate non-food uses (seed, feed, losses, etc.) are usually based on more uncertain grounds, and taken as constant in the short term, to be updated only occasionally as new evidence is made available, e.g. when a new health survey shows change in mean attained heights. Even in a (real or simulated) population where everyone covers their individual minimum needs, the estimation procedure would always show a positive level of undernourishment; these 'false positives' may be as many as nearly 5% of such population, due to the compounded effect of the various sources of variation involved. In view of all these uncertainties and underlying variation, FAO regards undernourishment prevalence estimates below 5% as highly imprecise and statistically indistinguishable from zero. These low estimates are reported simply as 'less than 5%' in FAO tables, though the actual (and unreported) value could be computed by replicating the underlying estimation.11

Since dietary energy deficiency is the key determinant of malnutrition in the most affected parts of the world, the undernourishment indicator concentrates on dietary energy, and ignores insufficient consumption of protein, vitamins and minerals to the extent that these are uncorrelated to the consumption of dietary energy; countries (or persons) covering their energy needs might still have insufficient supply of other nutrients, sometimes called 'hidden hunger'. Survey-based scales of dietary diversity, which count the number of food groups (cereals, pulses, fruits, etc.) and the number of specific food items within each group (i.e. the various cereals, pulses, fruits, vegetables, etc.) that are actually consumed by a given household, as well as their frequency of consumption, tend to reflect adequacy or deficiency in protein and micro-nutrients, and have been increasingly used in field surveys to complement measures of dietary energy supply. They have been shown to have a significant correlation with actual consumption of dietary energy, protein and micro-nutrients (Hoddinott & Yohannes 2002). Their correlation with energy intake supports the use of energy deficiency as an approximation, especially in poor countries where undernourishment is more widespread. However, direct and systematic data on the distribution of dietary diversity (or micronutrient consumption) among people and households are not available on a regular country-by-country basis. Since staple food consumption is relatively inelastic, increases of dietary energy usually indicate an increase in dietary diversity and a reduction in micronutrient deficiency, but that

11 Five percent is also the relevant minimum level for evaluating progress toward Target 1-C (related to hunger) of the Millennium Development Goals. The target on undernourishment is considered to be achieved if a country has either reduced the prevalence of undernourishment to one half or less, relative to the 1990-92 baseline, or brought the estimated prevalence to a value below 5%.
is not always the case (some people, especially in rich countries, add calories chiefly in the form of extra fat and oil instead of fruits, vegetables, meat or milk, thus producing the paradox of obese people with hidden malnutrition). Unfortunately, no indicator of micro-nutrient deficiency covering the world and its regions is regularly produced. The situation can only imperfectly be gauged from the scattered cases for which data are available, and from consumption of micro-nutrient-rich foods like fruit and vegetables.

The undernourishment indicator, based on the estimated distribution of habitual consumption, and reported as an average for three-year periods, ignores seasonal or transient situations of food shortage at household or national levels, and may thus fail to reflect food insecurity derived from short-term instability of food supply. Besides, being based on ex post data, it also ignores insecurity about future access, i.e. the risk component of food security. By being based on objective facts, it ignores also the subjective dimension of food insecurity (e.g. fears that not enough food would be available in the near future), which may prompt people to adopt pre-emptive coping mechanisms of various sorts. The availability and distribution of such subjective feelings and coping mechanisms vary across households and are not well monitored on a worldwide basis. In spite of its shortcomings and due to its wide availability as well as its direct relation with estimated agricultural production via food balance sheets, FAO undernourishment measures are widely used, including their use in this study, along with some other indicators, especially anthropometric measures of malnutrition and data about food production and trade.

Assessment of nutritional status

Besides undernourishment, which refers only to food access, there are other measures that point to the effects of inadequate food utilisation by individual organisms, chiefly through anthropometric indicators of nutritional status. As mentioned before, utilisation depends not only on food access and consumption, but also on health factors such as infections, which hinder biological utilisation. Food access is an input into people's nutrition. Nutritional status is an outcome, usually measured by anthropometric indicators, e.g. height and weight. Attained height, especially, depends on genetic setup but is also influenced by environmental factors during childhood. Genetic factors and other random influences determine normal variation of individual heights about their average value; but the average value is influenced by environmental factors during childhood; the chief environmental factors in this regard are (1) food intake and (2) health conditions permitting biological utilisation of food. It has been established that genetic factors do not influence average attained height in the earlier years of life; healthy and well-fed children under five, belonging to different ethnic groups, attain similar average height, and a similar distribution of heights, regardless of ethnic group (WHO 1995, 2006). This allowed WHO to establish a universal reference growth curve for preschool children (WHO 2006), now based on an international study of healthy well-fed children from several continents and various ethnic groups (the MGRS or Multicentre Growth Reference Study). The relevance of ethnic (i.e. genetic) factors on attained height gradually increases after early childhood, determining different average heights for adolescents and adults in various ethnic groups, even among healthy and well-fed individuals.\(^\text{12}\) Height at ages over five is not used as an index of malnutrition: differences may be also caused by genetic factors unrelated to nutrition or health. For each gender and age, the height of healthy and well-fed children is normally distributed about the reference mean. In the reference (MGRS) population of healthy children, just a small percentage of children (2.3%) differ from the reference mean by over two standard deviations in either direction. In an actual population, the proportion of short children, i.e. at least 2 SD below the normal mean, is used as a

\(^{12}\) Thus, for instance, in spite of similar normal growth in childhood, well-nourished individuals descended from Nilotic tribes (originally living in Kenya, Ethiopia and neighbouring countries) attain on average a taller adult height than other African ethnic groups. A similar difference is observed between people from Hokkaido vs. other islands in Japan. Besides inter-ethnic differences, which are regarded as having a genetic origin, average stature for a given ethnic group may increase with economic development, as has in fact occurred in many countries during recent decades and centuries (Fogel 2004; Komlos 1994; Steckel & Rose 2002).
measure of the probability of **stunting** (shortness due to malnutrition). For a child whose height is 2SD below the normal mean, there would be a 0.977 probability she suffers stunting from chronic malnutrition, and a complementary 0.023 probability that the shortness is unrelated to health or nutrition. This indicator reflects the cumulative effects of children’s **long term** exposure to insufficient food intake and/or frequent infections hindering biological utilisation of food and thus impeding or delaying linear growth.

For each height (and for each age), in turn, healthy and well-fed children not having excessive body fat have an average normal **weight**; in the reference population, these weights are normally distributed about the reference mean, with only 2.3% at a distance of over two SD above or below the mean. In an actual population, the proportion of children with weights below -2 SD of the reference mean weight is used as an indicator of malnutrition; two such indicators are used: **wasting** (low weight for attained height) and **underweight** (low weight for age). Wasting refers to current **thinness** relative to the child’s actual height, and reflects short term food insufficiency (due to lower intake or poor biological utilisation of food); underweight reflects the combined effect of long-term linear growth (low height for age) and short-term wasting (low weight for height). Nutritional status in adults or adolescents regards only weight adequacy, relative to attained height. The main indicator is the Body Mass Index (BMI). In recent years WHO has published **reference BMI distribution tables** by sex and age, for normal individuals of ages 5 to 19 (WHO 2007); the figures for age 19 are intended also for adults of all ages.

Anthropometric insufficiency (in height, weight, or both) are indicators of the **probability** of malnutrition at population level; they are not **per se** indicators of **individual** malnutrition, especially in the case of stature but also for weight. To determine whether a particular child is actually malnourished other indicators are needed about individual health status (e.g. evidence from blood samples, presence of nutrition-related diseases such as scurvy or night blindness, etc.). Even among healthy and well-fed individuals there is a normal range of variation of height and weight; there are always some individuals that are naturally short, slender, stocky or very tall, irrespective of nutrition.

Trends in anthropometric indicators of malnutrition (chiefly stunting and wasting in children under five) are regularly collected by countries through health and nutrition surveys, and assembled by the World Health Organization in a central database (www.who.int/nutgrowthdb/estimates/en/). The WHO maintains also a world database on overweight and obesity, though it has not yet achieved sufficient world coverage. Worldwide trends in nutritional status are produced by means of multilevel regression models using information from successive surveys carried out in multiple countries, translated into worldwide or regional trends (e.g. de Onís et al 2000, 2010, 2011).

**Numbers and percentages**

In recent years it has become fashionable to refer to the **number** of affected people, e.g. the number of undernourished persons, or persons at risk of hunger, instead of focusing on their **percentage** relative to total population; for instance, FAO refers often to the number of undernourished persons, and several Millennium Development Goals are stated in terms of the number of persons affected. In fact both can be used, but absolute numbers involve an ambiguity resulting from the fact that total population is not constant: a change in the absolute number of the undernourished may be caused by change in prevalence of hunger but also by change in population size, or any combination of both.

If an increase in the absolute number of hungry or poor people were an indicator of a worsening social situation, then poverty in the United States of America would have to be regarded as greater today than at the time of the country’s independence in 1776: at that time, total population was a few million people (even including Native Americans and the inhabitants of the Midwest and Western territories that were still belonging to Mexico or France), of which the vast majority were undoubtedly poor by today’s standards; recent poverty statistics in the US show a poverty prevalence of 15%, with 46 million people below the official poverty line, several times as many as the **total** population of 1776. US infant mortality,
if measured by the *number* of infant deaths, would be greater now than in 1800 or 1900, just because population (and annual births) increased, implying larger numbers of infant deaths although infant mortality rates (and also birth rates) have been greatly reduced in the meantime.

If absolute numbers were a relevant measure, they should also be relevant for people that are free from hunger. Their number indeed has greatly increased, and in greater increments, even for countries or periods in which the number of the malnourished were increasing. Recent (FAO-SOFI 2012) estimates say the number of undernourished people in developing countries decreased by 122 million from 980 million in 1990-92 to 868 million in 2010-12. By the same account, the number of *non-undernourished* people increased much more, expanding by 1701 million, from 4405 million in 1990-92 to 6106 million in 2010-12. If one chooses to use absolute numbers, the increase in non-hungry people should be most relevant. They are more numerous, and grow faster than the undernourished decrease. This would still be true if the numbers of the undernourished had increased, say from 980 million to more than a billion, as they were feared to have done at some point in recent years before better figures came out (see for example FAO SOFI 2008, 2009 and 2010). Even in that case, the estimated numbers of the non-hungry were larger, and had increased by much more, than the estimated numbers of the hungry.

By the same token, a starving small country like Somalia or Haiti would appear as having less hunger than a more populous and better nourished country, if just the *number* of the hungry is chosen as an indicator: there are fewer hungry persons in Haiti than in Mexico or Brazil, though the prevalence of undernourishment is vastly higher in Haiti. The well-fed are more numerous in India than in Switzerland, Sweden or Luxemburg, but that piece of information is hardly an insightful one.

Are these absolute estimates worthwhile for assessing the severity or extent of hunger? In our opinion all this approach based on absolute numbers is profoundly misleading. Absolute numbers may have headline value, and may be useful for some purposes, e.g. for calculating how much food is necessary in an emergency in order to provide targeted food assistance to people in need. But for most uses, including international or inter-temporal comparisons, the correct statistics is the percentage or *prevalence*, in this case the number of undernourished people as a percentage of total population at a given time, just as the infant mortality rate (and not the absolute number of infant deaths) is the most significant index concerning infant mortality. The same principle is valid for poverty, illiteracy or unemployment, especially for making comparisons across countries or over long periods of time, where the relevant population at risk varies significantly.

**Technical aspects of undernourishment projections**

Projecting the future prevalence of undernourishment implies projecting per capita food supply, and inequalities in the future distribution of individual (or household) food consumption relative to food needs.

FAO has been publishing projections of agricultural growth and food demand, using an iterative multivariate model, periodically updated and extended since the original projection to the year 2000 (FAO 1981, Alexandratos 1988) through more recent projections that extended the outlook to 2010, 2015, and 2030-2050: see FAO 1995, 2003a, 2006, 2011; Alexandratos 2011; and Alexandratos & Bruinsma 2012 (hereafter designated as AB 2012). These FAO studies contain what seems the most complete set of agricultural projections for the coming decades. FAO projections combine detailed information at country and product level, regarding natural resources, past agricultural production, past and projected technological change, agricultural markets, and expected economic development in terms of income, trade, and other aspects. They are based on highly disaggregated knowledge about each product, country and agro-ecological zone, accumulated by FAO in the course of its work in all corners of the globe.

FAO's effort to foresee the future of agriculture and food are based on prospects of population, income, and trade, making extensive use of the FAOSTAT statistical database and delving also on the accumula-
ted store of in-house FAO information on each specific country and every specific crop and livestock, as well as its extensive soil and agro-ecological zone mapping databases.

The general approach of FAO projections is to start with projections of demand, determined essentially by population, income, and estimated income elasticities and Engel coefficients for the various agricultural products. Demand projections are thus prepared for every individual product in each individual country. Agricultural production projections are, therefore, not meant to reflect the maximum output that could be potentially attained, but the amount required by projected effective demand and local agro-ecological constraints. Future agricultural production is estimated for each country and each particular crop or livestock product, based on a wide array of expertise and information about each country and product, including data on natural resources (land, soils, water, and climate), macroeconomic conditions, agricultural technology, and international trade. Projected production does not represent the maximum production attainable, nor it expresses any desirable outcome, but the amount required to match projected demand, within constraints imposed by land, climate, inputs, and other relevant factors. Domestic demand is projected to be covered by local production and possibly imports; domestic production may require imports or, if in excess of domestic demand, may generate exports.

The conceptual model underlying FAO projections portends to take into account the possible impacts of climate change on agricultural production, but reports do not make this concern methodologically explicit; it is possible that such impact has been incorporated in a rather general manner. Also (except in recent versions) FAO projections do not consider the prospective impact of using crops for biofuel production. FAO has separately worked with IIASA, the International Institute for Applied Systems Analysis (Laxenburg, Austria) to produce specific versions of its projections of agricultural production incorporating the impact of climate change and biofuels (see for instance Fischer 2011).

The projections of undernourishment discussed in this study are based on the latest FAO projections of agricultural production, the UN Population projections (2008 Revision), and projections of GDP growth for FAO projections. GDP in Fischer 2011 is valued at 1990 prices. According to these baseline projections, world population in 2050 is estimated to be 9,105 million people and global GDP would be 98,014 billion dollars at 1990 prices. Total world GDP aggregated in PPP terms, according to the baseline projections, is assumed to grow in 2000-2050 at an annual rate of 2.48%. These population and GDP projections imply that world per capita GDP would increase at about 1.76% per year along the same period of 40 years, a marked slow-down relative to recent decades: world per capita GDP grew at a yearly 2.04% in 1990-2012; at 2.51% per year in 2000-2012, and at 1.82% per year in 2007-2012, the period marked by the Great Recession.  

Fischer 2011 starts with a baseline projection agricultural GDP to 2030, 2050 and 2080, for the world as a whole and its major regions, not considering climate change or biofuels. The baseline projection to 2080 was based on FAO (2011) agricultural and population projections to 2050 (population projected as per the UN 2008 Revision), and extended by Fischer to 2080; a projected population for 2080 was also adopted, but not explicitly published by Fischer; we have estimated population growth in 2050-80 based on Fischer figures for 2050 and the demographic growth rates from 2050 to 2080 as per the UN 2010 Revision (the 2008 Revision did not provide projections beyond 2050). We cannot be sure that this population projection to 2080 is exactly coincident with the one used by Fischer, but we are fairly confident that both are close to one another. As regards GDP, Fischer 2011 used, but also failed to publish, GDP and agricultural value added projections for 2080. For illustrative purposes, GDP figures for 2080 have been projected in the present account on the base of trends, assuming that annual growth rates of GDP and agricultural GDP in 2050-80 would slow down (relative to 2030-50) in the same proportion they are expected to slow down between 2000-30 and 2030-50 in Fischer's baseline projection. Fischer

reports that the worldwide baseline projection on the number of undernourished people would be 760 million in 2030, 530 million in 2050, and 150 million in 2080 (Fischer 2011:115). We use these figures to compute the expected prevalence of undernourishment at those future dates, relative to population (which are not explicitly given in Fischer’s text). These baseline projections ignore possible effects of climate change, and assume no expansion in the use of farmland or crops to produce biofuels.

Fischer then superimposes the effects of climate change on these baseline projections by means of two well-known climate models (Hadley Centre’s HadCM3 and Australia’s CSIRO), both including CO2 fertilization.14 Fischer uses, for these projections, the A2 scenario of GHG emissions, and its climate change outcomes, but coupled with the 2008 Revision of the UN population projections, thus avoiding the unlikely demographic hypothesis of the original A2 scenario.15 It is, however, regrettable that (unlike previous studies such as Fischer et al 2002 or Tubiello & Fischer 2007) Fischer 2011 does not explore the impact of other climate change scenarios, since the socioeconomic assumptions of A2 about the future (a fragmented world with slow economic growth and no convergence of developing and developed income levels) seem not very realistic in view of rapid globalization and robust evidence of a dynamic periphery in the world economy.

Regarding the use of crops to make biofuels, Fischer formulates several scenarios, depending on the percentage replacement of fossil fuels by biofuels, and the proportion of biofuels represented by first and second generation types. The two biofuel scenarios (among those considered by Fisher) having the most severe consequences in terms of land required and food production forsaken are the so-called TAR-V1 and TAR-V3 scenarios, and especially the former. Their assumptions as per Fischer 2011 are as indicated in the box.

<table>
<thead>
<tr>
<th>Two scenarios for future use of liquid biofuels for transport</th>
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<tr>
<td>TAR-V1</td>
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<td>TAR-V3</td>
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Source: Fischer 2011: 126 (Table 3.26). IEA is the International Energy Agency (www.iea.org). WEO 2008 is the IEA 2008 World Energy Outlook. Only liquid biofuels for transport are considered, ignoring solid or gaseous biomass-based biofuels, mainly used for power generation or heating.

A major feature of these projections is that only liquid fuels for transport are considered. Therefore, no consideration is given to scenarios of increasing use of solid or gaseous biomass-based biofuels, especially for power generation and heating as opposed to transport. These technological options are more benign for agriculture since they typically use marginal lands not competing with food production (they may also use farm residues, sawmill residues, and some forestry products).

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14 Besides the effects of climate change per se (changes in temperatures and precipitation), emissions of CO2 produce effects on plant growth; in so-called C3 plants (e.g. wheat) photosynthesis is enhanced, increasing yields; in so-called C4 plants (e.g. maize or sugar cane) yields do not increase much (except in dry environments) but plant water needs are reduced. Fischer also provides estimates without considering CO2 fertilization, not reproduced here because they are of purely academic interest: the CO2 effect must be taken into account.

15 A2 is one of the four basic scenarios used by the IPCC Third and Fourth Assessments; it assumes strong population growth in a poorly integrated and slowly developing world.
The complex integrated model used by IIASA-FAO projections of climate change impacts includes many aspects often disregarded, such as expected adaptive change in farming systems, CO2 fertilization, displacement of agro-ecological zones, changes in the crop mix according to projected demand, and so on. It is thus much more inclusive than other schemes relying on partial equilibrium analysis where climatic impacts on yields are evaluated under ceteris paribus conditions, not realistic for long-term analysis of a human-natural complex adaptive system such as agriculture.

Once future food supply is thus estimated, projections of undernourishment may be prepared exploiting the fact that prevalence of undernourishment is closely associated with the degree of adequacy between dietary energy supply and requirements. The degree of adequacy is the ratio of per capita dietary energy supply (or apparent consumption) to per capita minimum dietary energy requirements (MDER). If apparent consumption in a particular country is for instance 2700 kcal/person/day, and average requirements in the same country are 1800 kcal/person/ day, the adequacy ratio would be 2800/2100=1.50, commonly expressed in percentage form (as 150). For a given degree of adequacy, undernourishment can only vary due to differences in the variance and skewness of the dietary energy consumption distribution, which normally vary within a rather narrow range. Typically, adequacy levels above 160 imply that the expected prevalence of undernourishment is non-significant (below 5%): see an example in Figure 7. For a typical MDER of about 1800 kcal/person/day, the expected prevalence of undernourishment becomes non-significant at per capita consumption levels above 3000 kcal per day (though it may vary in specific countries due to various local conditions, e.g. very high inequality in food access.

![Figure 7. Correlation between the ratio of dietary energy supply relative to minimum requirements, and the prevalence of undernourishment, by country. Based on FAO data. Tubiello & Fischer 2007:1041.](image)

Possible effects of climate change and biofuels are incorporated in IIASA-FAO projections in a manner that takes account of the various factors involved. In particular, it is not based on any *ceteris paribus* condition whereby only the marginal effect of one variable is estimated, keeping all the rest constant. When projections deal with long-term tendencies and with complex human-natural systems such as agriculture, a systemic approach is mandatory, and all variables should be allowed to change. This is not the case in some other studies about the effect of climate change on agriculture that rely on static crop models calibrated to specific varieties and cultivars of just some crops, not properly incorporating substitution of varieties, change and adaptation of farming techniques, changes in agro-ecological zoning and land use, and shifts in the mix of products making up agricultural production. It is perfectly possible that a given variety of a crop, say maize, currently cultivated at certain geographical zone, would see its yield reduced if climatic conditions are different: any mathematical crop model can predict yields for any given level and distribution of temperatures and precipitation, keeping current cultivated areas and current cultivation techniques constant; but agriculture does not work that way, especially when the projection refers to changes in average climatic conditions expected to occur over several decades amidst great natural short term variability. Few or none of current farmers would be alive by 2050 or 2080; their land
would be then owned and managed by other people, mostly not yet born, which may or may not be their biological descendants; farm boundaries, organization and tenancy systems, as well as agro-ecological zones and land uses, would have changed as well; available seeds and breeds would not be just those existing today, as these are not the same that were used in 1950 or 1900; certain techniques existing today that are used now by just a few leading farmers would be more widespread in the future, or would have been replaced by new ones yet to emerge from agricultural research and farmer experimentation. Thus finding that certain current cultivar (as represented in a simplified crop model) would reduce its yield if grown at the same place with the same technique but under a different climate is not very revealing when one tries to project future agricultural production: every cultivar used today has been probably adopted because it was adapted to the current climate and the techniques of production available to each particular group of farmers, but this tells very little about the shape of agriculture five or ten decades ahead, just as the state of farming systems in 1798 could tell Malthus very little about what agriculture would look like in 1898, 1998 or, for that matter, 2098.

However, most projections on these matters use a precautionary principle mandating consideration of plausible worst-case scenarios, in which demand grows rapidly but technology develops more slowly than it used to do in the past. In the case of IIASA-FAO projections, productivity growth is assumed to proceed in the future at a much slower pace; for instance, the rates of growth resulting from the Fischer model of the world’s agricultural GDP vary between 1.20% and 1.54% in the various IPCC 2000 scenarios, well below the rates around 2.5% per year observed in 1961-2011. This in part reflects expectations of slower demographic growth but also assumptions about possibly slower technological change. Population and income projections are also based on prudent hypotheses of continuing demographic growth and slower economic development (even if climate change itself depends on rapid economic growth to generate sufficient the greenhouse gas emissions required for climate change to occur). Even at very fast (and most unlikely) demographic growth and relatively slow economic and social development (as in some of the IPCC worst-case scenarios such as A2 or A1F1), projections show undernourishment strongly diminishing during the 21st Century. For instance Fischer et al 2002 explored various scenarios formulated in IPCC 2000 and used in IPCC 2001 and IPCC 2007, projected with three different climate models. It was found, however, that under all scenarios and models the percentage effect of climate change on the reference worldwide agricultural GDP of 2080 would be rather small, varying in the Hadley model from −1.5% (A1F1) to −0.4% (B2) with intermediate values such as −0.9 (A2) and −0.5% (B1). The CSIRO model yields similar results: −0.8% (A2), −0.9% (B2) and −0.3% (B1). In the CGCM2 model the effect is slightly positive: +1.1% in A2 and +1.0% in B2 (Fischer et al 2002:109; Fischer et al 2005). These small percentage impacts are of scarce consequence when applied to an agricultural GDP which by 2080 would be several times larger than in the base year (1990 or 2000), and also significantly larger in per capita terms in spite of assumedly fast demographic growth. In fact, the projected impacts are smaller than the intrinsic uncertainty margins of such projections. It should be noted that the A2 scenario foresee a future (now seen as quite unlikely) of very rapid demographic growth, slow or absent mitigation of greenhouse gas emissions, and little convergence in economic development across world regions, whilst A1F1 involves slower demographic growth but rapid economic growth and strong intensification of fossil-fuel use. Even under these unfavourable conditions, these integrated assessment models found a rather small effect on agriculture, and a significant reduction in the prevalence of undernourishment (see Tubiello and Fischer 2007 for another such simulation based on the A2 demographic and socioeconomic scenario under various climate change hypotheses: it shows an agricultural GDP of 2080 expected to be lower by about 0.9% due to climate change, as compared to the case of no climate change, and world undernourishment to increase marginally with climate change from about 4% to about 5%. Tubiello and Fischer (2007) report their undernourishment projections just in absolute terms (million people); the projected impact on percentage prevalence is based on the underlying (A2) 2080 world population (13,656 million as per Fischer et al 2002:94).
REFERENCES


