1 INTRODUCTION

Table 1
Overview of the main projections for food, feed, fiber and biofuels, and implications for land, water, energy, markets and the climate

Increased demand for food	› Food demand is expected to increase by 60% in 2050 over the 2005/2007 base.[8] › Increased food demand is caused by population growth (70%) and by higher per capita calorie intake and change in diets (30%).[9] › Annual world agricultural production needs to increase by some 77% in developing countries and 24% in developed countries.[10] › The growing global population and increasing per capita consumption of meat and dairy products will increase global animal protein demand by 60% by 2030.[11] › To keep pace with increasing food demand, the following production increases must take place by 2050:[12] – Cereal production must increase by 940 million tonnes to reach 3 billion tonnes; – Meat production must increase by 196 million tonnes to reach 455 million tonnes; – Oil crops by must increase by 133 million tonnes to reach 282 million tonnes.
Increased demand for fiber	› Demand for wood panels is expected to increase by 3% annually until 2030.[13] › Demand for roundwood will increase annually by 1.8% until 2017, and then by 1% until 2030.[14] › Paper consumption is expected to increase annually by 4.1% until 2020 and by 3.5% until 2030.[15]
Increased demand for biofuels	› Demand for biofuels (biodiesel and ethanol) is expected to increase threefold by 2050.[16] › The area needed to meet biofuel demand in 2030 is estimated to be between 2.5-20 times the current area designated for biofuel production, depending on sources of biofuel and the development of 2nd generation biofuels.[17]
Impact on land	› The major increase in food production (90%) has to come from intensification on existing land through higher yields and cropping intensity, whereas extensification plays a minor role.[18] › By 2050, global arable land will increase by 4.5%, of which 107 million hectares in developing countries (esp. sub-Saharan Africa and Latin America). In developed countries, arable land will decrease by 40 million hectares.[19] › The area available for rainfed agriculture is potentially enough to meet global demand,[20] but it is risky to bank only on this. Investments in irrigated agriculture are also needed.

[8]FAO 2012b, [9]Ibid. [10]Ibid. [11]PBL 2009, [12]FAO 2012b, [13]FAO 2009, [14]Ibid. [15]Ibid. [16]IEA 2013, [17]USDA 2008; GBC 2010; FAPRI-ISU 2011, [18]FAO 2012b, [19]Ibid. [20]FAO 2011b

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Table 1
Overview of the main projections for food, feed, fiber and biofuels, and implications for land, water, energy, markets and the climate (continued)

Impact on water	› By 2050, irrigated agriculture on 16% of the total cultivated area is expected to be responsible for 44% of total crop production.[21] › By 2050, the area equipped for irrigation will expand by 6.6% (20 million hectares) over the base 2005/2007-2050, mostly in Africa, and East and South Asia.[22] › Most of the expansion in irrigated land will be achieved by converting rainfed agriculture into irrigated land.[23] › Sharp increases in domestic and industrial water use will increase competition over water with agriculture.[24] › Competition over water resources could cause an 18% reduction in the availability of water for agriculture by 2050 globally.[25]
Impact of climate change on agriculture	› Higher temperatures increase the water requirements of crops and livestock. An increased annual variation in crop and livestock production is expected due to increased temperature and extreme weather events,[26] exacerbating the productivity risks of rainfed production, particularly in semi-arid areas vulnerable to drought.[27] › Yields go down due to temperature increases during critical crop stages (chilling hours reduced by 30-60% by 2050 under conservative scenario).[28] › Increasing temperatures cause animal stress and decrease productivity; management and energy costs rise for temperature regulation.[29] › Elevated CO_2 concentrations cause reduced nitrogen and protein content in most crops, which means a lower nutritious value[30] and a need for greater fertilizer use to support crop growth. It also reduces the forage quality of grasses and thus the quality of livestock produce.[31] › Weeds, diseases and insects benefit from higher temperatures, and weeds also benefit from higher CO_2 concentrations (more than crops). This increases stress on crops and requires greater pest and weed control efforts.[32] › There is uncertainty and regional variation with respect to the multiple effects of climate change (e.g. benefits of stimulated crop growth and water use efficiency due to higher CO_2 can be offset by increased water requirements due to increased temperature).[33] › Extreme weather events could affect soil and soil water availability due to erosive power, water logging, or heat waves.[34] Yet, land use change and practices could have a greater effect on soil erosion than climate change. › South Asia is expected to be hit hard by climate change. It is the region with the greatest expected yield decline for nearly all crops.[35]

[21]FAO 2012b, [22]Ibid. [23]Ibid. [24]CA 2007, [25]Strzepek and Boehlert 2010, [26]IPCC 2007; IFPRI 2009, [27]CA 2007, [28]USGCRP 2009; FAO 2011b, [29]FAO 2008, [30]Taub 2010, [31]USGCRP 2009, [32]Ibid. [33]FAO 1996; USGCRP 2009; FAO 2011b, [34]IPCC 2007, [35]IFPRI 2009

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Table 1
Overview of the main projections for food, feed, fiber and biofuels, and implications for land, water, energy, markets and the climate (continued)

Impact on energy	› The food sector currently accounts for around 30% of the world's total energy consumption.[36] › Global energy demand is projected to increase by 80% in 2050.[37] › Agricultural commodity prices are sensitive to increased energy prices – price elasticity is around 0.27.[38] › Public finances will be affected too – energy inputs in agriculture (fertilizer, pumping) are heavily subsidized in China, India, Yemen and several African countries. › An increase in food production of 60% will lead to an increase in energy consumption in agriculture of 84%.[39]
Greenhouse gas emissions	› Global greenhouse gas emissions are expected to grow by 50% between 2012 and 2050, mostly driven by energy demand and economic growth in key emerging economies.[40] › Agriculture is responsible for 13.5% of total greenhouse gas emissions – especially nitrous oxide (N_2O) and methane (CH_4).[41] › 75% of global land-use change is attributed to agriculture, which contributes an additional 12-14% of global greenhouse gas emissions.[42] › The energy supply sector is accountable for 25.9% of global greenhouse gas emissions.[43] › The combined effect of all the structural and technological changes is that in 2050 CO^2 emissions will be 2.25 times greater than in 1990.[44]
Agricultural commodity markets	› Commodity prices are likely to remain high and volatile.[45] › With increased demand or scarcity setting the boundaries in some regions, there will be more international food trade and with it more price volatility.[46] › Rising oil prices translate into higher agricultural production costs. Energy prices pass through to food (elasticity 0.27) and fertilizer prices (elasticity 0.55).[47] › With prolonged high oil prices, future food and fertilizer commodity prices will also be high and price spikes will last longer.[48] › Food trade needs to buffer fluctuations in food production (due to climate change).[49]

[36]FAO 2011a, [37]OECD 2012, [38]Baffes 2009, [39]Pimentel and Pimentel 2008, [40]OECD 2012, [41]IPCC 2007, [42]Vermeulen et al. 2012, [43]IPCC 2007, [44]EC 2007, [45]OECD-FAO 2011 [46]Baffes 2007 and 2009; Allan 2011, [47]Baffes 2009; OECD-FAO 2011, [48]Baffes 2007 and 2009, [49]CA 2007

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Overview of the main projections for food, feed, fiber and biofuels, and implications for land, water, energy, markets and the climate (continued)

Impact on water quality	› The build-up of nitrogen and phosphorus compounds due to agricultural water pollution could cause catastrophic shifts (eutrophication) in aquatic ecosystems, both marine and freshwater.[50] › Salinity limits the productivity of agricultural crops, particularly in arid and semi-arid climatic zones, and is often irreversible.[51] In many cases secondary salinization is due to the low quality of water used in irrigation, but rising sea levels also causes salt intrusion. › High nitrate and nitrite concentrations in drinking water are considered dangerous for human health, as they might cause cancers and (though rarely) infant methaemoglobinaemia (the reduced ability of red blood cells to release oxygen to tissues).[52] › Globally at least 4 to 6 million hectares of land are irrigated with either untreated wastewater or polluted water, but other estimates suggest this number is closer to 20 million hectares, almost 8% of the global irrigated area.[53] › FAO[54] estimates that globally about 34 million hectares (about 11% of the total irrigated area) are currently affected by salinity. An additional 60-80 million hectares are affected to some extent by water logging and related salinity.

The current challenges set the scene for a new "Green New Deal"[55] – simultaneously addressing the numerous pressures and investing in better resource use – as an antidote to the current underinvestment or the previous overinvestment in property rather than in productive assets. The core of the Green New Deal is that solutions and investment address different challenges at the same time and hence tap into different cost and benefit streams, making them more profitable than if they had been addressed individually.

The idea behind working on the nexuses between water, energy and food is that this will co-optimize production increases, reduce pressure on water and land, and achieve higher energy efficiency while avoiding negative side effects. This is the subject of a second analysis, which draws on different solutions and sees how they affect the different dimensions.

The next paragraphs present the challenges at stake under business as usual scenarios. Section 2 forecasts future demand for food, fodder and fiber; sections 3 to 6 present implications for land, water, energy, climate and markets.

[50]Scheffer et al. 2001, [51]Rozema and Flowers 2008, [52]WHO 2011, [53]WHO 2006; Jiménez et al. 2010; Bruinsma 2011, [54]FAO 2011b

[55]Green New Deal refers to the New Deal of U.S. president F.D. Roosevelt and is a political concept developed in 2008 at the start of the economic crisis to stimulate environmentally sound initiatives. The concept strives for a win-win-win solution by combating the economic crisis of 2008, climate change and peak oil (when the global peak in oil production will be reached and an eternal decline in production will start). In 2008, the United Nations presented the Green Economy initiative, which is also known as the Global Green New Deal. In October 2011, the Dutch government presented a Green Deal and the UK government launched a Green Deal in October 2012; both are designed to stimulate the implementation of energy-saving measures for properties.