Chapter 3

Trends that drive the land-water-energy nexus

This chapter outlines the main biophysical and socioeconomic trends that are projected to emerge in absence of feedbacks from the nexus bottlenecks. It describes trends for sectoral and macroeconomic activity, and the corresponding trends in agricultural production and land use. Together, these baseline projections form the reference for investigating the consequences of the nexus bottlenecks in the next chapter.

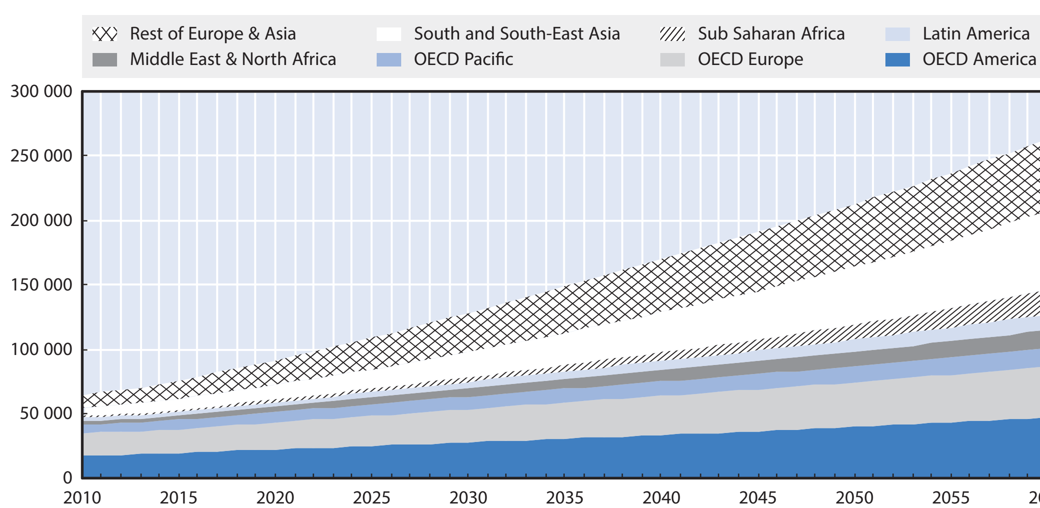
3.1. Macroeconomic trends

In ENV-Linkages, baseline developments of sectoral and regional economic activities are projected for the medium- and long-term future, up to 2060, based on socio-economic drivers such as demographic developments, macroeconomic growth and sector-specific trends (see also the discussion on megatrends in Chapter 1).[1] The baseline projection for the most important elements in the ENV-Linkages model, and the associated land use and water use projections from IMAGE, are presented here; further baseline projections from ENV-Linkages are described in Annex A.

The regional projections of GDP indicate that the slowdown in population growth projected in the coming decades (see Annex A) does not imply an equivalent slowdown in economic activity. While long run economic growth rates are gradually declining, Figure 3.1 shows that GDP levels in the no-damage baseline are projected to increase more than linearly over time. The largest growth is observed outside the OECD, especially in Asia and Africa, where a huge economic growth potential exists. The share of the OECD in the world economy is projected to shrink from 64% in 2010 to 38% in 2060. These projections are fully aligned with the OECD Economic Outlook (OECD, 2014) and include the main effects of the recent financial crisis as they emerged until 2013 and are consistent with the central scenario of the OECD@100 report on long-term scenarios (Braconier et al., 2014).

Figure 3.1. **Trend in real Gross Domestic Product (GDP), baseline projection**

(Billions of USD, 2005 PPP exchange rates)



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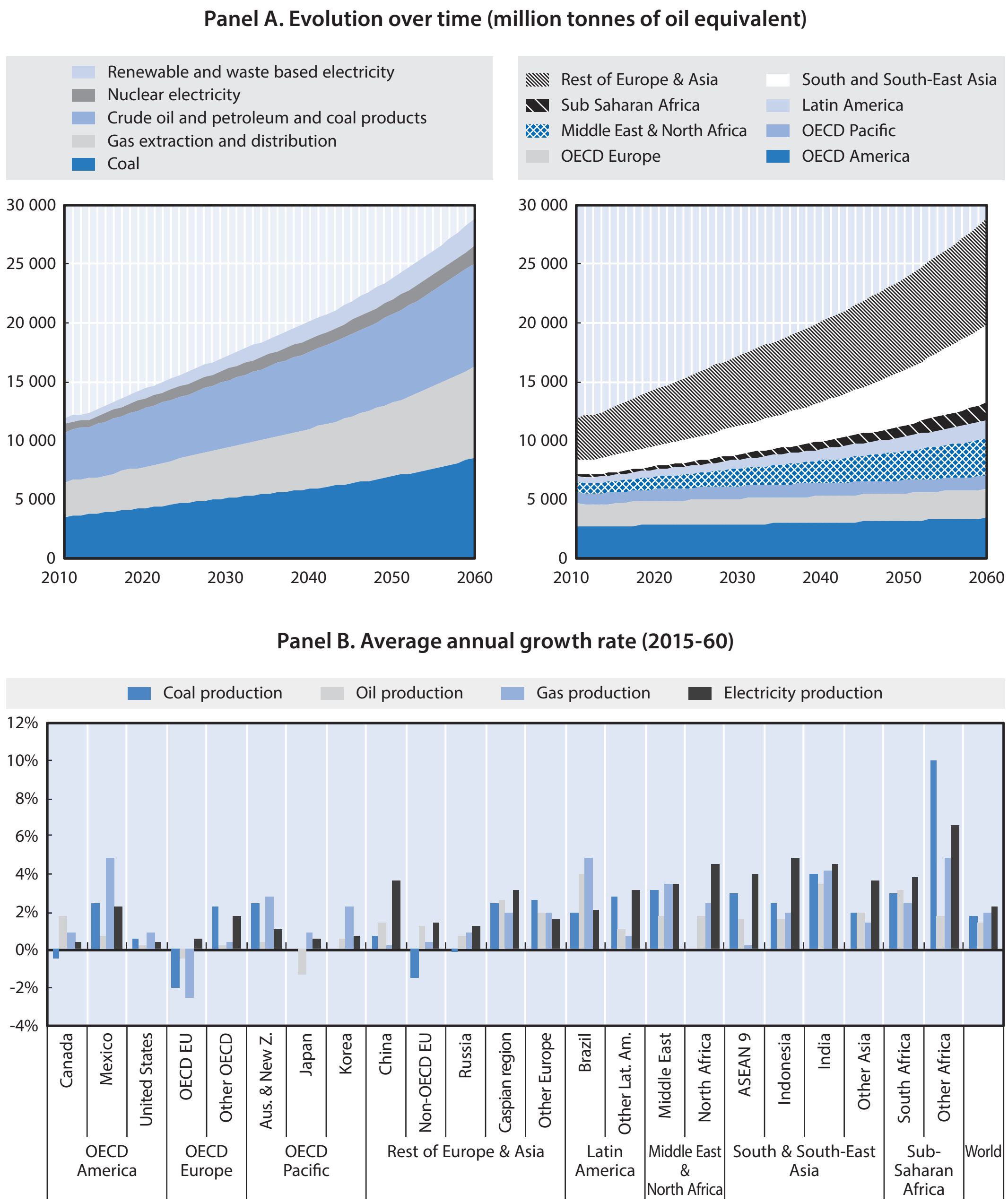
Source: OECD (2014) for OECD countries and ENV-Linkages model for non-OECD countries.

3.2. Energy trends

Baseline energy projections until 2035 are calibrated to be in line with the Current Policies scenario of the International Energy Agency's World Energy Outlook (IEA, 2015), and extrapolated to fit the macroeconomic baseline projections thereafter. In fast-growing economies such as China, India and Indonesia, the need to support economic growth with cheap energy drives an increased use of coal, which is abundant and cheap in the absence of carbon pricing. In OECD regions, however, energy use is projected to switch towards more gas, not least in the United States. Furthermore, in the OECD region, energy efficiency improvements dominate and imply a relative decoupling of energy use and economic growth. The resulting effects on energy production by fuel and region are given in Figure 3.2.

Figure 3.2. **Energy production, baseline projection**



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Source: ENV-Linkages model based on IEA (2015), *World Energy Outlook* projections.

The examination of the projected energy trends helps to identify the second possible potential bottleneck of the LWE nexus. Figure 3.2 shows that, in line with the macroeconomic developments, the increase in future energy demands are projected to be strongest in rapidly developing economies (Sub-Saharan African countries and India, followed by other Asian countries, China excepted). Moreover, despite a growing share of renewables in electricity production, the increase in fossil-fuel energy demand is almost in line with the increase in total energy demand. Under current policies, both fossil-fuel extraction and fossil-fuel based power generation are projected to grow in the coming decades, and these activities are very water-consuming.

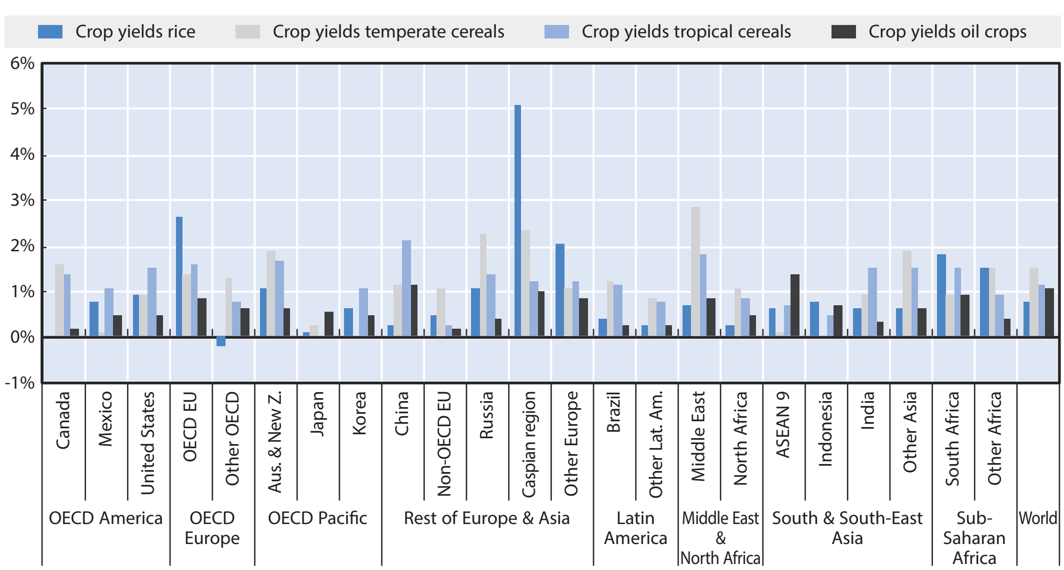
Liquid fossil energy resources are unevenly distributed across countries, with oil production projected to continue to be produced mostly in the regions that are now large exporters (Middle East, Former Soviet Union countries and Latin America), while gas extraction is projected to diversify to more regions. Countries with relatively small (or no) domestic sources of fossil fuels will generally meet the extra demand for energy through a substantial increase in electricity generation (this applies to all Asian countries as well as Sub-Saharan African countries).

3.3. Agricultural trends

It is well-known that food demand is difficult to model robustly over the long run as the underlying megatrends affect development and income growth affects consumer demand (e.g. Valin et al., 2014). The baseline construction in ENV-Linkages pays particular attention to modelling household preferences and therefore food and agriculture consumption trends in a plausible manner. Furthermore, agricultural trends, and especially crop yields, are harmonised with the IMAGE model, to ensure consistency between both models. The projections on demand for crops as represented in the ENV-Linkages baseline are built on dedicated runs with the International Food Policy Research Institute (IFPRI)'s IMPACT model (Rosegrant et al., 2012) using the socioeconomic baseline projections from ENV-Linkages and excluding feedbacks from climate change on agricultural yields. Notice also that the trend that an increasing share of food consumption takes place outside the household sphere but in restaurants and other collective or private outlets is projected to continue. This implies a gradual shift from household consumption of food to food demand by the services sector.

Figure 3.3. **Yield developments for selected crops by region, baseline projection**

(Average annual growth rate 2011-60)



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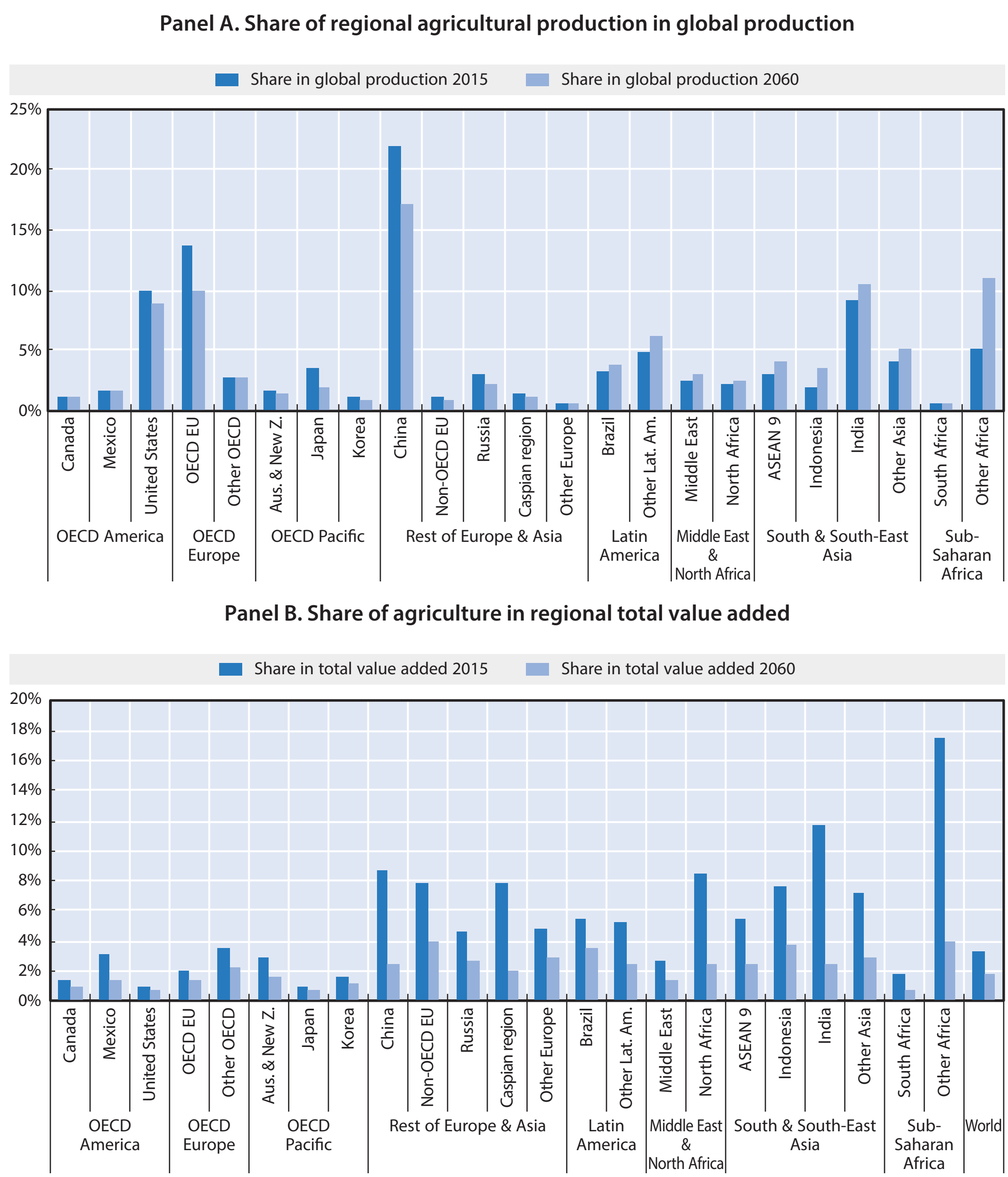
Source: IMAGE model.

Figure 3.3 summarises the assumed yield growth rates in various regions, according to the baseline projection. In line with historical trends, yields are projected to continue to grow, but the pace of growth is slowing. Most regions in Africa and Latin America still have ample room for yield growth, as agricultural management practices will be more and more modernised to catch-up to the most advanced countries' levels. In contrast, yields in North America and EU countries are substantially higher in the short run, but projected to not improve much more.

Figure 3.4. **Relative size of the agricultural sector by region, baseline projection**

(Percentage of total)



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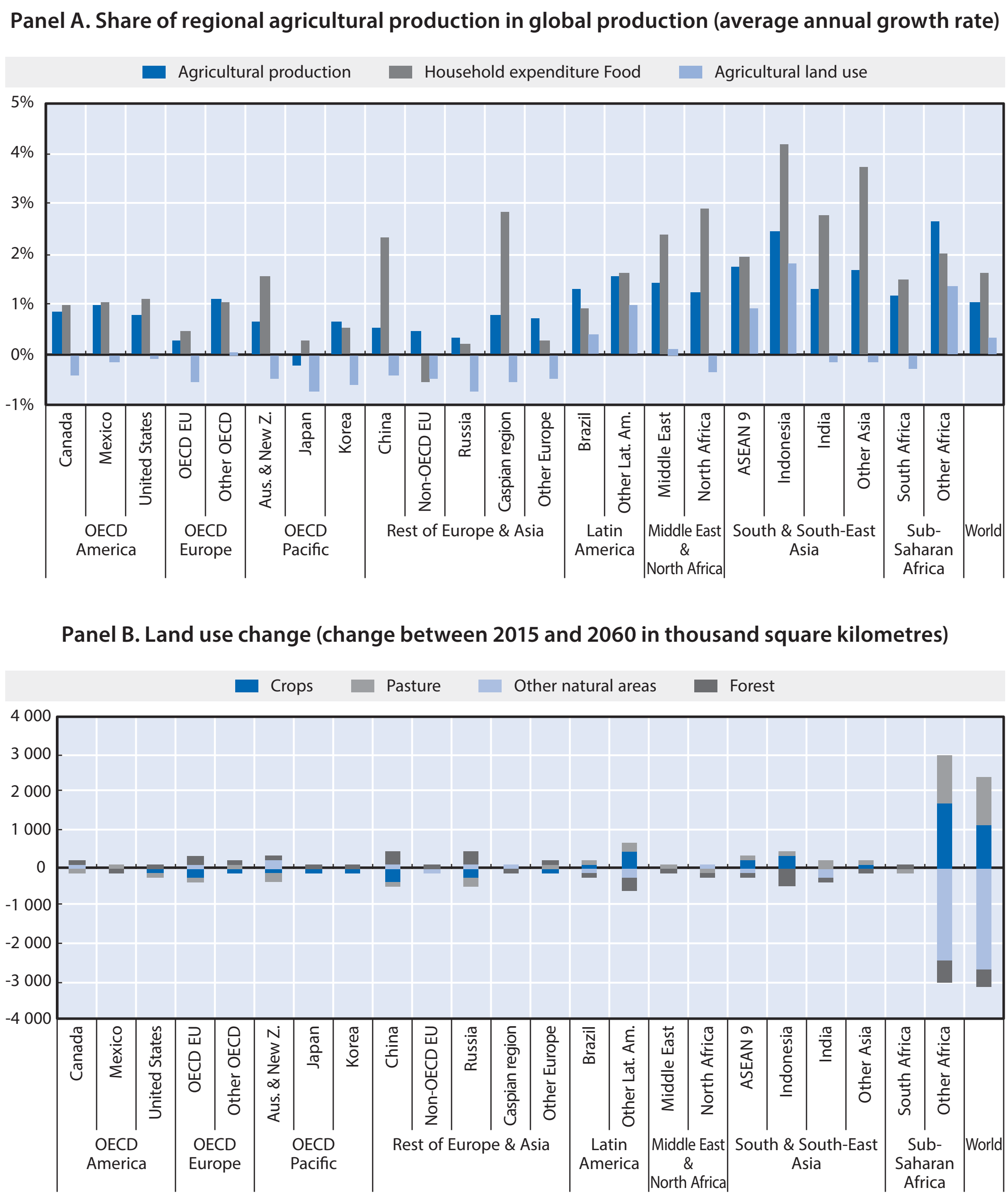
Source: ENV-Linkages model.

The agricultural trends in the baseline scenario show that agriculture production (defined as the sum of real gross output over crops and livestock sectors) will increase in all regions between now and 2060. From 2011 to 2060, world agricultural production shifts away from less rapidly growing countries, including mostly OECD countries and China whose share in world agricultural output declines (Figure 3.4, Panel A), to less-developed but faster growing countries. The increase in agricultural production is closely related to the increase in food demand (Figure 3.5). Nonetheless, as Panel B of Figure 3.4 shows, the share of the agricultural sector is projected to decline in all regions, and converge across

Figure 3.5. **Growth in the agricultural sector and land use change, baseline projection**



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Source: panel A: ENV-Linkages model; panel B: IMAGE model.

countries, i.e. fall sharpest in the regions that now have the highest share (the African regions, India, China and the Caspian Region).

The increase in demand for agricultural products puts upward pressure on agricultural land use, as indicated in Figure 3.5, to cover the extra needs for food production. But increasing yields imply that in some regions production increases can be met while simultaneously reducing agricultural land use. Agricultural production is still projected to increase because of the lower-than-historical but continued increase in yields assumed in the baseline (driven by better land efficiency and better total factor productivity in the crop sectors).

Based on the baseline projections of economic activity, the associated land use patterns are presented in panel B of Figure 3.5 and Table 3.1.

Table 3.1. **Land potentially available for agriculture in 2015**

		Agricultural land (thousands km^2)	Remaining potential land supply (thousands km^2)	Total potential land supply for agriculture (thousands km^2)	Current land use (% of total)
OECD America	Canada	675	491	1 166	58%
	Mexico	1 075	391	1 466	73%
	United States	4 148	1 319	5 467	76%
OECD Europe	OECD EU	1 677	879	2 556	66%
	Other OECD	465	302	767	61%
OECD Pacific	Australia & New Zealand	4 624	869	5 494	84%
	Japan	51	0	51	>99%
	Korea	19	0	19	>99%
Rest of Europe & Asia	China	5 563	752	6 315	88%
	Non-OECD EU	272	126	398	68%
	Russia	2 155	1 224	3 379	64%
	Caspian region	2 927	137	3 064	95%
	Other Europe	630	187	817	77%
Latin America	Brazil	2 636	1 764	4 400	60%
	Other Latin America	3 491	2 085	5 576	63%
Middle East & North Africa	Middle East	2 164	151	2 315	93%
	North Africa	1 008	37	1 045	96%
South & South-East Asia	ASEAN 9	672	902	1 574	43%
	Indonesia	478	722	1 200	40%
	India	1 802	419	2 221	81%
	Other Asia	2 185	406	2 591	84%
Sub-Saharan Africa	South Africa	996	96	1 092	91%
	Other Africa	9 272	5 386	14 658	63%

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Source: IMAGE model.

3.4. Water use trends

The associated regional irrigation water use profiles are shown in Figure 3.6; see also Figure 1.3 in Section 1.4 for the baseline projection of total water demand. Temperature and precipitation are characterised by substantial inter-annual variability, and the combined impact on crop growth and water requirements, and by implication irrigation water withdrawals, is highly non-linear. To capture this, the LPJmL module in IMAGE simulates each year many times with varying climate data, derived from 30 year historical time series, rather than averaging the weather upfront. The model reports for each year the moving average of the 30 simulations, which explains the irregular pattern over time in Figure 3.6. In relatively small agricultural areas, the inter-annual variability plays out more strongly than for larger areas which typically experience different weather conditions in the same year that dampens the impact. This is illustrated in Figure 3.6 by the results for Japan and Korea.

Total world water demand, that is the amount of water withdrawn from freshwater sources, increases 23% between 2015 to 2060 in the baseline from 3 790 to 4 670 km^3. The increase is less than population and far less than GDP, so the water use intensity per capita and per unit of GDP drops. In 2015 irrigation is the dominant user (61%), followed by electricity production (15%), municipal use (14%) and industry (10%). Water for irrigation does not increase much until 2060, as the irrigated area is not projected to grow much in future. Hence the other sectors account for the overall growth in water use: electricity +46%, industry +38% and municipal +71%. As a consequence, the share of irrigation drops to 40% by 2060. Of the global total irrigation water demand in the baseline in 2060, around 40% is supplied from non-renewable groundwater sources; the volume and share vary strongly between regions. At some future point in time, these supplies cannot be continued as they are bound to become depleted.

Figure 3.6. **Water supply for irrigation from different sources, baseline projection**

(Cubic kilometres)

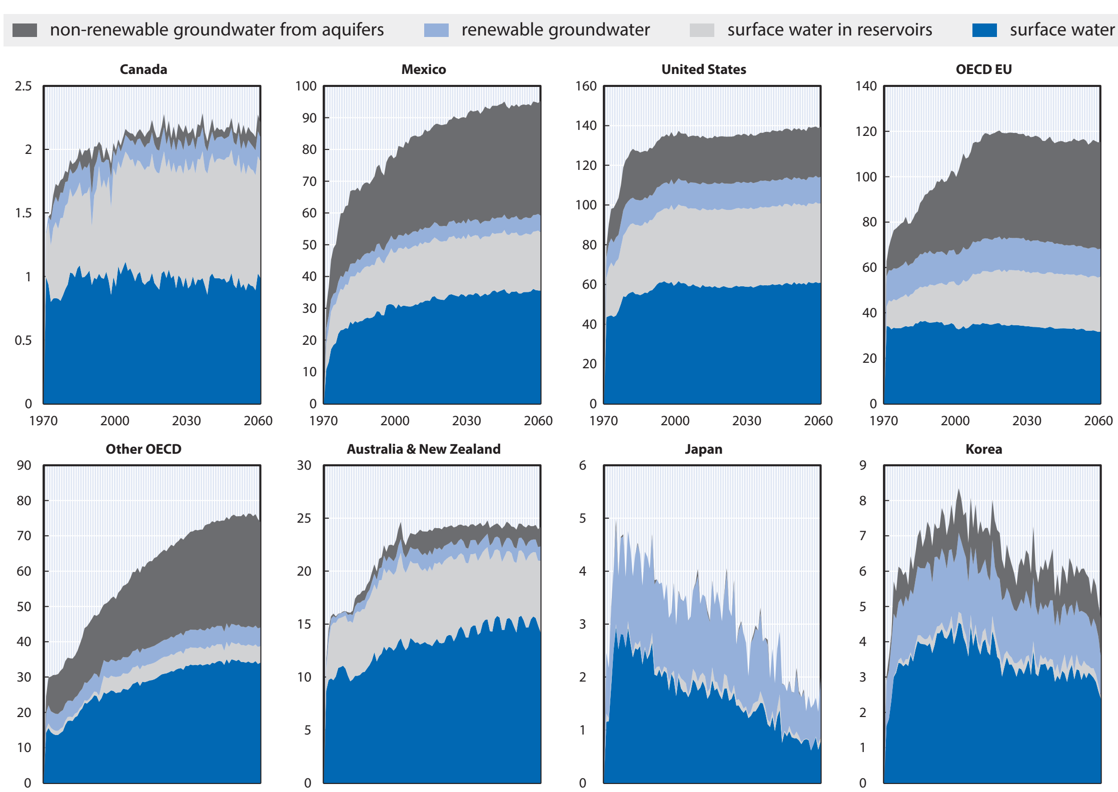
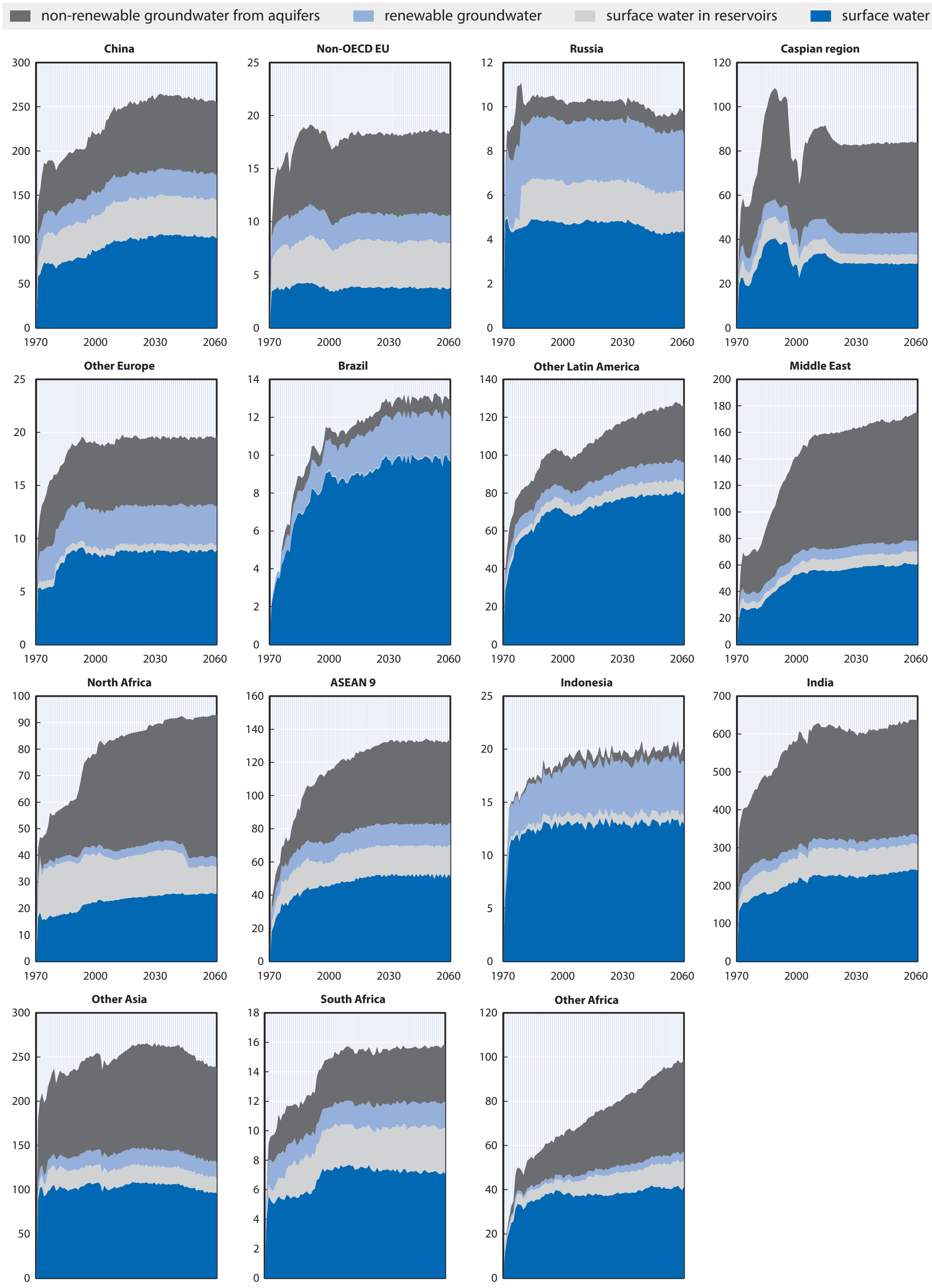


Figure 3.6. **Water supply for irrigation from different sources, baseline projection** *(continued)*



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Note: Annual fluctuations stem from the variability in rainfall, as projected in the LPJmL model, and from changes in land use.

Source: IMAGE model.

Note

1. The baseline used in this report is the same as in the other CIRCLE reports, but with modifications in the agricultural sector to harmonise with the IMAGE model. While this baseline does not directly match any of the Shared Socioeconomic Pathways (Dellink et al., 2017; Riahi et al., 2016), it is based on the same methodology as the SSP projections, and follows the philosophy of the "middle of the road" scenario SSP2.

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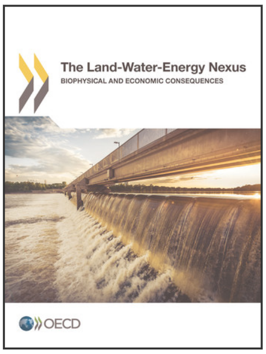

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