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CLIMATE CHANGE
A RISK ASSESSMENT

David King, Daniel Schrag, Zhou Dadi, Qi Ye and Arunabha Ghosh

Project Manager: Simon Sharpe
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Centre for Science and Policy
THE RISK OF WATER STRESS

Professor Nigel Arnell, Director of the Walker Institute for Climate System Research.

Water resources are under stress in many regions due to increasing demands and, in places, falling quality. Climate change has the potential to change the risks of water stress. The focus in this section is on strategic definitions of water stress, which are based on generalized indicators of the amount of water that is available and the demands on that resource. Operational definitions, on the other hand, are typically based on the reliability of the supply of appropriate quality water and are strongly determined by local conditions.

What do we want to avoid?

The most widely used sets of indicators of high-level water resources stress are based on the ratio of total resources to population (‘resources per capita’) and the proportion of resources that are withdrawn for human use. The first is simpler but does not reflect stresses introduced by high per-capita water use, for example where there is significant irrigation for agriculture; on the other hand, data on current and future water withdrawals can be highly uncertain.

There are three widely used thresholds for defining levels of water stress on the basis of per capita availability. Basins or countries with average annual resources between 1000 and 1700 m³ per capita per year are typically classed as having ‘moderate water shortage’, and if resources are below 1000 m³ per capita per year then the region is classed as having ‘chronic water shortage’. If resources are below 500 m³ per capita per year then the shortage is ‘extreme’. The thresholds are essentially arbitrary, although derive ultimately from an assessment of exposure to water resources stress in Africa.

In 2010, almost 3.6 billion people, out of a global population of around 6.9 billion, were living in watersheds with less than 1700 m³ per capita per year (Table W1), and almost 2.4 billion were living in watersheds with less than 1000 m³ per capita per year (chronic water shortage). Approximately 800 million people were living in watersheds with less than 500 m³ per capita per year (extreme water shortage).

Table W1: Numbers of people (millions) living in water-stressed watersheds. The figures for 2050 are based on a medium population growth assumption, and the ranges represent the effects of low and high growth assumptions.

<table>
<thead>
<tr>
<th>Region</th>
<th>&lt;1700 m³/capita/year</th>
<th>&lt;1000 m³/capita/year</th>
<th>&lt;500 m³/capita/year</th>
<th>Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>N. Africa</td>
<td>162</td>
<td>150</td>
<td>94</td>
<td>209</td>
</tr>
<tr>
<td>W. Africa</td>
<td>54</td>
<td>17</td>
<td>4</td>
<td>309</td>
</tr>
<tr>
<td>C. Africa</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>110</td>
</tr>
<tr>
<td>E. Africa</td>
<td>94</td>
<td>10</td>
<td>2</td>
<td>193</td>
</tr>
<tr>
<td>Sn Africa</td>
<td>47</td>
<td>20</td>
<td>0</td>
<td>210</td>
</tr>
<tr>
<td>S. Asia</td>
<td>1,394</td>
<td>1,172</td>
<td>199</td>
<td>1,706</td>
</tr>
<tr>
<td>SE Asia</td>
<td>7</td>
<td>0</td>
<td>0</td>
<td>605</td>
</tr>
<tr>
<td>E Asia</td>
<td>1,202</td>
<td>691</td>
<td>386</td>
<td>1,546</td>
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<tr>
<td>Central Asia</td>
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<td>0</td>
<td>0</td>
<td>46</td>
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<tr>
<td>Middle East</td>
<td>166</td>
<td>93</td>
<td>71</td>
<td>214</td>
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<td>Australasia</td>
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<td>20</td>
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<tr>
<td>C. Europe</td>
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<tr>
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<tr>
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<td>Meso-America</td>
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<td>0</td>
<td>197</td>
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<tr>
<td>Brasil</td>
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<td>0</td>
</tr>
<tr>
<td>South America</td>
<td>15</td>
<td>4</td>
<td>4</td>
<td>198</td>
</tr>
<tr>
<td>Global</td>
<td>3,576</td>
<td>2,376</td>
<td>809</td>
<td>6,868</td>
</tr>
</tbody>
</table>
How will exposure to water stress change in the future?

Through the 21st century, changes in total population will result in changes in exposure to water resources stress. By 2050, under a medium population growth assumption, the number of people living in watersheds with less than 1000 m³ per capita per year will increase to around four billion – a bigger proportion of the global population than in 2010. The effects of population growth on the number of people living in watersheds with less than 500 m³ per capita per year are even more pronounced: it will double by 2050 to around 1.8 billion people. The magnitudes of the changes are influenced to a certain extent by the assumed changes in population (as shown in Table W17), but even under low-growth assumptions there are significant increases in exposure to water scarcity at global and regional scales.

Climate change will also affect the number of people living in water-stressed conditions. Figure W1 shows the change in numbers of people living in watersheds with chronic water shortage (less than 1000 m³ per capita per year) through the 21st century, for the globe as a whole and for five regions, under no climate change and under two different climate change pathways (RCP2.6 and RCP8.5, low and high greenhouse gas emission scenarios respectively). The shaded areas show the range of potential numbers due to uncertainty in the pattern of resource change due to climate change. The plots all assume the medium population growth projection.

Figure W1: The number of people living in water-stressed watersheds (<1000 m³ per capita/year), with and without climate change. The plots show two climate pathways (RCP2.6 and RCP8.5). The solid line represents the median estimate of impact for each pathway, and the shaded areas show the 10% to 90% range. A medium growth population projection is assumed.

In the absence of future climate change, the numbers of people living in watersheds with chronic water shortage decreases in East Asia from 2030, and in South Asia from 2060. If climate change is included, it results in more rainfall and river runoff in East Asia. This combines with the reduction in population to reduce apparent water shortage – but there is a chance (shown by the shaded area) that climate change would slow the reduction in exposure to water shortage. Similarly, Figure W1 shows that climate change could substantially increase the number of people living in watersheds with chronic water shortage in South Asia – or reduce them. In the US and the Middle East climate change is very likely to increase exposure throughout the century, and in North Africa is more likely than not to produce an increase in exposure.

Calculating risk

Figure W2 shows the risk by region that climate change increases by more than 10% the numbers of people living in watersheds with chronic water shortage under the two climate pathways. By 2050, the largest of these probabilities are in central Asia, Europe, the USA, Central America and southern America. By 2100, the probabilities that exposure to shortage will increase are considerably greater in most regions than in 2050. Under the low emissions climate pathway the probabilities are smaller in most regions than under the high emissions pathway, particularly by 2100.
Figure W2: The risk that climate change increases by more than 10% the numbers of people living in water-stressed watersheds, relative to the situation with no climate change, under the two climate pathways. A medium growth population projection is assumed.

2050: Probability number of people with chronic water shortage increasing by more than 10%

2100: Probability number of people with chronic water shortage increasing by more than 10%

The risks posed by climate change to water scarcity can also be assessed at the basin scale. Figure W3 shows the probability that resources per capita falls below defined thresholds in nine major basins that are, or likely will be, exposed to water resources stresses (note that the thresholds vary between basins). The dotted lines show probability of falling below the thresholds under the two climate pathways assuming population remains at 2010 levels, and the solid lines show probability under the medium growth population projection. The difference between the solid and dotted lines represents the effect of population change on probability (and of course this difference varies with population projection).

Figure W3: Risk of resources per capita falling below specified thresholds for nine illustrative watersheds under two climate pathways (note that the thresholds vary between watersheds). The dotted line shows risk with current (2010) population, and the solid line shows risk under the medium population growth projection.
What is a plausible worst case for water stress due to climate change?

There are considerable uncertainties in the projected impacts of climate change on water stress, even assuming a single projection for changes in population. The chance of impacts exceeding some defined threshold – as shown in the previous section – represents one aspect of this uncertainty, but another assessment of risk can be based on a plausible ‘worst case’.

By 2050, up to 630 million people may be added to the 4 billion people (Table W1) living in watersheds with chronic water shortage, under high emissions and the most extreme climate scenario. Figure W4 shows the ‘worst case’ by region in 2050, along with the 10th percentile from the distribution of impacts (the upper part of the shaded region in Figure W1). In some regions the worst case is little different to the 10th percentile, but in others is considerably larger reflecting greater uncertainty in projected impacts. However, the worst cases shown in Figure W4 do not occur simultaneously: the global ‘worst case’ is not equal to the sum of the regional worst cases. Under no one plausible pattern of climate change does every water-stressed region see the maximum reduction in runoff.

Figure W4: Plausible ‘worst case’ impacts of climate change in 2050 on water stress. The graph shows the increase in numbers of people living under chronic water shortage under the RCP8.5 climate pathway and the medium growth population projection. There is a 10% probability that the impact is greater than that shown by the blue dots, and the red dots show the maximum calculated impact.
As climate models improve their representation of atmospheric dynamics and the distribution of precipitation then the precise quantitative estimates of impacts on water stress will change, but for years to come differences between models will remain and there will therefore be a distribution of potential climate change impacts for any one place.

The impacts of climate change on water shortage are assessed by using a hydrological model to translate climatic changes to changes in runoff. As with climate models, different hydrological models can give different responses to the same input data. Comparisons of the effects of hydrological model uncertainty are still in their infancy, but early indications are that adding impact model uncertainty adds to the range of potential impacts. Moreover, it is likely that hydrological models have similar biases (they all tend to overestimate river flows in dry regions, for example) and none yet explicitly incorporate the effects of changes in glacier volumes which may affect future resources in some regions.

Projections of future population are also uncertain (as shown in Table W1), because they are based on different assumptions about changes in fertility rates, mortality rates and migration. It is not possible to assign likelihoods to different population projections, so it is necessary to estimate risks separately under different plausible population narratives and projections.

Finally, the actual effects of climate change on ‘real’ water shortages will depend on the management infrastructure and institutions which are put in place to cope with water shortage. There is already a very considerable difference between developed and developing countries. Some management interventions will offset the effects of climate change, but others may not. The effects of future adaptation on the ‘real’ consequences of future water shortages will therefore depend on (i) the extent to which adaptation takes place (limited by a number of factors including finance and institutional capacity, alongside potential physical constraints such as the availability of feasible locations for storage reservoirs) and (ii) how effective the adaptation measures are in practice.

Lessons from risk assessment

The key conclusions from this section are therefore:

- Climate change alters substantially the future risk of exposure to water shortages, but the effects are strongly exaggerated or reduced by changes in population. Put the other way, the pressures on water resources posed by increasing populations are substantially altered – exaggerated or reduced – by climate change.

- Climate change reduces the probability of exposure to water shortages in some regions – particularly in parts of east and south Asia - but this may be associated with substantial changes in flood risk (see chapter 14).

- The risks posed by climate change are typically less under low emissions than high emissions, but the difference varies from place to place depending on how close watersheds in a region are to the water shortage threshold. In some cases, risks are less under high emissions than low emissions, because larger increases in runoff are enough to push watersheds out of the water shortage category.

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Endnotes

5. Shared Socio-economic Pathway (SSP) 2. https://secure.iiasa.ac.at/web-apps/ene/SspDb/. This is similar to the UN 2012 medium population projections.
6. SSP1 and SSP3 are used to represent the extremes: these are very similar to the UN 2012 low and high population projections.