Chapter 10: Asia
Supplementary Material

Coordinating Lead Authors: Rajib Shaw (Japan), Yong Luo (China), Tae Sung Cheong (Republic of Korea)

Lead Authors: Sharina Abdul Halim (Malaysia), Sanjay Chaturvedi (India), Masahiro Hashizume (Japan), Gregory E. Insarov (Russian Federation), Yoichi Ishikawa (Japan), Mostafa Jafari (Iran), Akio Kitoh (Japan), Juan Pulhin (Philippines), Chandni Singh (India), Kripa Vasant (India), Zhibin Zhang (China)

Contributing Authors: Rawshan Ara Begum (Bangladesh), Xi Chen (China), Rajarshi Dasgupta (India), Ronald C. Estoque (Philippines), Wanqin Guo (China), Garima Jain (India), Brian Johnson (USA), Tarek Katramiz (Syria), Pankaj Kumar (India), Xianbing Liu (China), Mythili Madhavan (India), Bijon Kumer Mitra (Bangladesh), Farah Mulyasari (Indonesia), Santosh Nepal (Nepal), Rekha Nianthi (Sri Lanka), Fereidoon Owfi (Iran), Gulsan Ara Parvin (Bangladesh), Shobha Poudel (Nepal), Atta-ur Rahman (Pakistan), Mihoko Sakurai (Japan), Amin Shaban (Lebanon), Dmitry Streletskiy (Russian Federation), Vibhas Sukhwani (India), Prabhakar S.V.R.K (India), Ai Tashiro (Japan), Tống Thị Mỹ Thi (Vietnam), Noralene Uy (Philippines), Xinru Wan (China), Cunde Xiao (China)

Review Editors: Soojong Myeong (Republic of Korea), Joy Jacqueline Pereira (Malaysia)

Chapter Scientist: Rajarshi Dasgupta (India), Yan Yang (China)

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<th>Detection: observed impacts</th>
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<th>Geographic region, sub-region</th>
<th>Time period</th>
<th>Evidence</th>
<th>Agreement</th>
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<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Heat waves</strong> <em>(urban)</em></td>
<td>T increase</td>
<td>India; Pakistan; Central Eastern China</td>
<td>1969–2005 (Ross et al., 2018) 1951–2015 (Misra et al. 2017) 1973–2012 (Mishra et al., 2015) 1948–2010 (Khan et al. 2018) 1961–2010 (Chen and Li, 2017)</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>(Ross et al., 2018); Decadal surface temperature trends in India based on a new high-resolution data set (Mishra et al., 2018); An integrated assessment approach for estimating the economic impacts of climate change on River systems: An application to hydropower and fisheries in a Himalayan River. (Mishra et al., 2015); Changes in observed climate extremes in global urban areas (Rohini et al., 2016); On the Variability and Increasing Trends of Heat Waves over India (Panda et al., 2017); Increasing heat waves and warm spells in India, observed from a multi aspect framework (Chen and Li, 2017); An Inter-comparison of Three Heat Wave Types in China during 1961–2010: Observed Basic Features and Linear Trends <em>(Pervin et al., 2020)</em>; Adapting to urban flooding: a case of two cities in South Asia (Gu et al., 2015); Risks of exposure and vulnerability to natural hazards at the city level: A global overview. Population Division Technical Paper No. 2015/2. New York: United Nations Department of Economic and Social Affairs</td>
</tr>
<tr>
<td><strong>Urban drought</strong></td>
<td>T and ET increase</td>
<td>South Asia</td>
<td>Multiple papers with multiple durations</td>
<td>Low</td>
<td>Medium</td>
<td>Medium</td>
<td><em>(Ali et al., 2014)</em>; Observed and projected urban extreme rainfall events in India</td>
</tr>
<tr>
<td><strong>Extreme rainfall events</strong> <em>(in urban areas)</em></td>
<td>Precipitation increase</td>
<td>India; Philippines</td>
<td>1901–2010 1951–2010 (Cinco et al., 2014)</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
<td><em>(Ali et al., 2014)</em>; Observed and projected urban extreme rainfall events in India</td>
</tr>
<tr>
<td>Coastal urban flooding</td>
<td>Precipitation increase, SLR</td>
<td>Across Asia, specifically SE Asia</td>
<td>Multiple papers with multiple durations</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>(Dulal, 2019); Cities in Asia: how are they adapting to climate change?</td>
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<tr>
<td>Flood induced damages</td>
<td>Annual P increase</td>
<td>Northwest China (Xinjiang)</td>
<td>1980–2001</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>(Fengqing et al., 2005); Magnification of Flood Disasters and its Relation to Regional Precipitation and Local Human Activities since the 1980s in Xinjiang’, Northwestern China</td>
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<tr>
<td>Sea level rise (only for coastal cities)</td>
<td>T increase</td>
<td>Vietnam, Bangladesh</td>
<td>1993-2014, 1974-2004</td>
<td>High</td>
<td>Medium</td>
<td>Medium</td>
<td>(Brammer, 2014); (Hens et al., 2018) (Shahid et al., 2016); Climate variability and changes in the major cities of Bangladesh: observations’, possible impacts and adaptation</td>
</tr>
<tr>
<td>Permafrost thawing</td>
<td>T increase</td>
<td>North Asia</td>
<td>2007–2009</td>
<td>Medium</td>
<td>High</td>
<td>Medium</td>
<td>(Biskaborn et al., 2019); Permafrost is warming at a global scale (Shiklomanov et al., 2017b); Climate Change and Stability of Urban Infrastructure in Russian Permafrost Regions: Prognostic Assessment based on GCM Climate Projections (Shiklomanov et al., 2017a), Conquering the permafrost: urban infrastructure development in Norilsk’, Russia</td>
</tr>
<tr>
<td>Wildfire</td>
<td>Summer temperature and precipitation regime, droughts</td>
<td>North Asia</td>
<td>1970–1990</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
<td>(Brazhnik et al., 2017); Simulating changes in fires and ecology of the 21st century Eurasian boreal forests of Siberia (Schaphoff et al., 2016) ; Tammm Review: Observed and projected climate change impacts on Russia’s forests and its carbon balance</td>
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<tr>
<td>Biodiversity and habitat losses</td>
<td>Climate change and interaction with human disturbance</td>
<td>East Asia</td>
<td>1700-2000</td>
<td>high</td>
<td>high</td>
<td>high</td>
<td>(He et al., 2019); Moral hazard and adverse selection effects of cost-of-production crop insurance: evidence from the Philippines (Wan et al., 2019); Historical records reveal the distinctive associations of human disturbance and extreme climate change with local extinction of mammals</td>
</tr>
<tr>
<td>Primary production</td>
<td>ocean warming and stratification</td>
<td>Western Indian Ocean</td>
<td>1950-2012</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>(Roxy et al., 2016); A reduction in marine primary productivity driven by rapid warming over the tropical Indian Ocean</td>
</tr>
<tr>
<td></td>
<td>T increase</td>
<td>South Asia (India, Pakistan, Sri Lanka), East Asia (Japan, Hong Kong in China, S Korea), South East Asia (Thailand, Indonesia, Philippines), North Asia (Russia)</td>
<td>Multiple papers with multiple durations</td>
<td>High</td>
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<td><strong>Urban Heat Island Effect (UHI)</strong></td>
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<td>(Kotharkar et al., 2018); Urban Heat Island studies in South Asia: A critical review (Choi et al., 2014); Assessment of Surface Urban Heat Islands over Three Megacities in East Asia Using Land Surface Temperature Data Retrieved from COMS (Estoque et al., 2017); Effects of landscape composition and pattern on land surface temperature: An urban heat island study in the megacities of Southeast Asia (Santamouris, 2015); Analysing the heat island magnitude and characteristics in one hundred Asian and Australian cities and regions (Li et al., 2018a); Comparative Analysis of Urban Heat Island Intensities in Chinese’, Russian’, and DPRK Regions across the Transnational Urban Agglomeration of the Tumen River in Northeast Asia (Ranagalage et al., 2017); An Urban Heat Island Study of the Colombo Metropolitan Area’, Sri Lanka’, Based on Landsat Data (1997–2017) (Hong et al., 2019); Analysing 56 years (1962-2017) of UHI variation in Seoul, Korea, using surface observation, UHI is reinforced by heat waves.</td>
<td></td>
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<td><strong>Dust storms</strong></td>
<td>T increase, P decrease</td>
<td>West Asia, Iran, Persian Gulf Countries</td>
<td>Multiple papers with multiple durations</td>
<td>High</td>
<td>High</td>
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<td>(Alizadeh-Choobari et al., 2016); Temporal variations in the frequency and concentration of dust events over Iran based on surface observations (Nabavi et al., 2016); Climatology of dust distribution over West Asia from homogenised remote sensing data (Yu et al., 2015): Variability of Suitable Habitat of Western Winter-Spring Cohort for Neon Flying Squid in the Northwest Pacific under Anomalous Environments (Kelley et al., 2015): Climate change in the Fertile Crescent and implications of the recent Syrian drought</td>
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</table>
SM10.2 Sand and Dust Storms Occurrence Frequency

West Asia Region, especially Tigris-Euphrates alluvial plain, has been recognised as one of the most important dust source areas in the world (Cao et al., 2015). As a result, six main clusters were recognised as dust source areas. Three clusters situated in Tigris–Euphrates plain were identified as severe Sand and Dust Storms (SDS) sources. Another cluster in Sistan plain is also a potential source area (Cao et al., 2015). The main persistent sources of dust storms (in Central Asia) are located in the large “dust belt” that extends from west to east over the southern deserts, north of Caspian Sea deserts, south of Balkhash Lake, and Aral Sea region (Indoitu et al., 2012). Dust storm variability and trends in frequency on decadal timescales has been reviewed by Middleton (2019) in three dust belt settlements with more than fifty years long meteorological records in Mauritania (Nouakchott), Iran (Zabol) and China (Minqin). The inhabitants of each of these settlements have experienced a decline in dust storms in recent decades, since the late 1980s at Nouakchott, since 2004 at Zabol, and since the late 1970s at Minqin. Iran is mostly arid or semi-arid, with deserts making up at least 25 million hectares (100,000 square miles) of the country’s area (NASA, 2018). Due to the severity of the condition in Sistan-Baluchestan allocated 115 million euros from the National Development Fund (Iran) to fight sand and dust storms in the region (Tajrishi, 2019). Southwest regions of Iran, due to dry environmental and climatic conditions, have been identified as one of the five major regions in the world. In recent years, large parts of Iran have been affected by suspended particles from the dust storms (Ghasem et al., 2012). There are some 20 million hectares of sand and dust storm hotspots in the country and some are in a critical condition (Tajrishi, 2019). Sand and dust storms have been striking the southwestern province for over 10 years. The numbers of dusty days in southern province of Khuzestan have increased by day-and-a-half over a 30-year period per annum on average. The number of dusty days is different in different seasons, but on average over a 30-year period sand and dust storms hit the area 63 days annually (Sabzehzari, 2019). In Iran, five regions of frequent dust events are identified. In the order of importance, these areas are the Khuzestan Plain, the coastal plain of the Persian Gulf, west of Iran, Tabas and Sistan (Alizadeh Choobari et al., 2016). Iran is experiencing unprecedented climate-related problems such as drying of lakes and rivers, dust storms, record-breaking temperatures, droughts, and floods (Vaghefi et al., 2019). The dust storm event can be considered as severe if it lasts 3–12 h, storms with wind speed 10–14 m/s and meteorological visibility in the range of 500–1000 m. The extremely severe dust storms last more than 12 h, with the wind speed exceeding 15 m/s; the dust storms with meteorological visibility less than 50 m are considered as very severe regardless to duration and wind speed (Orlovsky et al., 2013). Deserts and semi-arid areas are prone to dust storms, which can drive impacts on health and several other sectors (Tong et al., 2017). The evolution of dust under climate change is uncertain (Mirzabaev et al., 2019), and there is a lack of evidence and agreement of a change in their frequency or intensity so far in general (WGI AR5).

SM10.2.1 Cause of Sand and Dust Storms

There are three key factors responsible for the generation of sand and dust storms – strong wind, lack of vegetation and absence of rainfall (EcoMENA, 2020). Both climatic and human variables have been important but overall the balance of research conclusions indicates natural processes (precipitation totals, wind strength) have had greater impact than human action, in the latter case both in the form of mismanagement (abandoned farmland, water management schemes) and attempts to reduce wind erosion (afforestation projects). Understanding the drivers of change in dust storm dynamics at the local scale is increasingly important for efforts to mitigate dust storm hazards as climate change projections suggest that the global dry land area is likely to expand in the twenty-first century, along with an associated increase in the risk of drought and dust emissions (Middleton, 2019).

It seems that it is closely related to the heating surface and the occurrence of local dry instabilities. Analyses of data showed that dust amounts (or volumes) in all the stations have two climactic peaks, first between 1982 and 1990 and second between 2005 and 2008 periods. These peaks can be related to a variety of factors including anthropogenic factors such as war, agricultural activities, dam construction, and widespread droughts (Ghasem et al., 2012).

SM10.2.2 Sand and Dust Storms harmfulness

According to EcoMENA sand and dust storms cause significant negative impacts on society, economy and environment at local, regional and global scale (EcoMENA, 2020). Sand and Dust Storm (SDS) have significant socio-economic impacts on human health, agriculture, industry, transportation, water and air quality.
Sand and dust storms: In West Asia, the frequency of dust events has increased slightly in some areas (eastern Saudi Arabia and southeast Iraq), and increased markedly in other emerging areas (northwest Iraq and east Syria) from 1980 to present (Nabavi et al., 2016). The marked dust increase during the first decade of the 21st Century has been associated to drought conditions in the Fertile Crescent (Yu et al., 2016) likely amplified by anthropogenic warming (Kelley et al., 2015). In terms of long-term frequency of dust events, observational analyses show an overall rising trend of the frequency of Iran’s dust events in recent years, predominantly attributed to increasingly frequent dust outbreaks in Iraq due to human intervention (Alizadeh-Choobari et al., 2016). The northwest of Iraq and east of Syria are identified as emerging dusty areas, whereas east of Saudi Arabia and southeast of Iraq are identified as permanent dusty areas, including both dust sources and affected areas (Nabavi et al., 2016). Southwest of Iran and Persian Gulf countries were determined as main receptors of summertime dust storms in West Asia (Nabavi et al., 2016). Dust storms in central Iran are a natural hazard, and Tigris-Euphrates alluvial plain has been recognised as the main dust source in this area (Dastorani and Jafari, 2019). Results showed that there was a direct relationship between dust event and drought and years having intensive drought (Dastorani and Jafari, 2019). The most important point in a powerful dust storm brought winds to Tehran, which killed 5 and injured 82 people in the capital of Iran, was the lack of an early warning system (Fatemi et al., 2015). The seasonality of the numbers of dusty days (NDD) in Iran shows the highest frequency for summer followed by the spring and autumn seasons. The popular Mann–Kendall and the bootstrap MK test to consider serial correlation are then applied for Trend assessment. Results showed both negative (across the north and northwestern regions) and positive trend (across south and south eastern regions) in the annual and seasonal NDD time series (Modarres and Sadeghi, 2018). According to the statistical calculations, most storms occurred in the spring and summer. The lowest number of dust events occurred in the fall and winter particularly in December and January, when there are high possibilities of rainfall occurrence and dynamical instability conditions in the north and west of the region. The results illustrated that the highest amounts of hourly dust occurred in the afternoon and the lowest amounts occurred at 00UTC (3.30 am local times) (Ghasem et al., 2012). Major concerns in Asia are associated particularly with droughts and floods in all regions, heat extremes in South and East Asia, sand and dust storms in West Asia and Central Asia (IPCC). Throughout Iran, the frequency of dust events strengthens in spring, peaks in summer and significantly weakens in autumn and winter, with the least observed frequency in winter (Alizadeh-Choobari et al., 2016). The past decade, West Asia has witnessed more frequent and intensified dust storms affecting Iran and Persian Gulf countries (Nabavi et al., 2016).

The UNCCD supports countries in the mitigation of SDS impacts and anthropogenic dust sources by advocating the following three pillars approach: 1- Early warning systems; 2- Preparedness and resilience; 3- Anthropogenic source mitigation (UNCCD, 2019). As Iran reminded in COP14, the rich body of traditional and modern knowledge on SDS hot spots could help create a stronger knowledge base regional initiatives (UNCCD, 2019).
**SM10.2.4 Projections**

Compared to the period of 1980–2004, in the period of 2025–2049, Iran is *likely* to experience more extended periods of extreme maximum temperatures in the southern part of the country, more extended periods of dry (for ≥120 days: precipitation <2mm, Tmax ≥30°C) as well as wet (for ≤3 days: total precipitation ≥110mm) conditions, and higher frequency of floods (Vaghefi et al., 2019).

**SM10.2.5 Precipitation changes – region**

The slope of precipitation, in West Asia region showed that during the period of 2016-2045 in January, February, July and August, precipitation would increase and decrease in other months of the year (Ahmadi et al., 2018). The Precipitation season in West Asia region with the Mann-Kendall method also shows that the prevailing trend is decreasing throughout the year (Ahmadi et al., 2018). Precipitation depicts minor positive trends, except for spring when precipitation is decreasing (Haag et al., 2019).

**SM10.2.6 Temperature changes – region**

Temperatures in Central Asia have risen significantly within the last decades whereas mean precipitation remains almost unchanged (Haag et al., 2019). However, climatic trends can vary greatly between different sub-regions, across altitudinal levels, and within seasons (Haag et al., 2019). The results show a strong increase in temperature, almost uniform across the topographically complex study site, with particular maxima in winter and spring (Haag et al., 2019).
### Table SM10.2: Summary of observed and projected impacts of climate change to agriculture and food systems in Asia based on post IPCC-AR5 studies

<table>
<thead>
<tr>
<th>Region</th>
<th>Country</th>
<th>Agriculture Sector</th>
<th>Observed Impacts</th>
<th>Projected Impacts</th>
<th>Scale of analysis</th>
<th>Study</th>
</tr>
</thead>
<tbody>
<tr>
<td>East Asia</td>
<td>China</td>
<td>Crops</td>
<td>Economic loss of $595-858 million for the corn and soybean sectors from 2000 to 2009</td>
<td>Projected yield decline of 3-12% and 7-19% for corn and soybean, respectively by 2100</td>
<td>National</td>
<td>Chen et al. (2016)</td>
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<tr>
<td>China</td>
<td>Crops</td>
<td></td>
<td>1°C increase in annual average temperature could reduce grain output by 1.74% and 1.19% in North and South China, respectively (or a national reduction of 1.45%)</td>
<td>Increase in total annual precipitation of 100 mm could increase grain output by 3.0% in North China but a reduction by 0.59% in South China (an overall increase in national grain output by 1.31%)</td>
<td>National (North and South China)</td>
<td>Holst et al. (2013)</td>
</tr>
<tr>
<td>China</td>
<td>Crops</td>
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<td>Increase in net crop revenue per hectare between 79 USD/ha and USD207 for the 2050s and from USD140 to 355 USD for the 2080s</td>
<td>Potential advantage for the development of Chinese agriculture for the provinces of the Northeast, Northwest, and North regions</td>
<td>National with regional differentiation</td>
<td>Chen et al. (2013)</td>
</tr>
<tr>
<td>China</td>
<td>Crops</td>
<td></td>
<td></td>
<td>Increased precipitation can lead to a loss of net crop revenue per hectare, especially for the provinces of the Southwest, Northwest, North and Northeast regions</td>
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<tr>
<td>China</td>
<td>Crops</td>
<td></td>
<td>17% decrease in Northeast Region maize production by 2030 (from 624 million to 518 million bushels) with temperature increases of 1.32°C and 30% increase in precipitation from the 2008 levels</td>
<td>22% increase in Southwest Maize production (from 216 million bushels to 263 million bushels) by 2030 considering the same temperature and precipitation scenarios</td>
<td>Subnational - Northeast and Southwest Regions of China</td>
<td>Li et al. (2014)</td>
</tr>
<tr>
<td>China</td>
<td>Crops</td>
<td></td>
<td></td>
<td>China's rice export will increase by 2.7% as rising rice exports to Republic of Korea overweight the export decrease to other countries, and import would decrease by 0.04%, which leads to a slight increase in rice self-sufficiency</td>
<td>National</td>
<td>Zhang et al. (2019)</td>
</tr>
<tr>
<td>Region</td>
<td>Country</td>
<td>Agriculture Sector</td>
<td>Observed Impacts</td>
<td>Projected Impacts</td>
<td>Scale of analysis</td>
<td>Study</td>
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<tr>
<td>China</td>
<td>Crops</td>
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<td>With RCP 4.5, the yield of following crops are projected to increase by 2030, with respect to the 2000s: 0.52% for rice; 0.16% for maize; 0.17% for wheat; and 0.1% for soybean.</td>
<td>China (6 regions)</td>
<td>Zhuo et al. (2014)</td>
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<tr>
<td>China</td>
<td>Crops</td>
<td></td>
<td>Vulnerability of spring wheat production is expected to significantly increase considering increasing temperature under the RCP4.5 and RCP 8.5 scenarios.</td>
<td>Mongolia Region of China</td>
<td>Dong et al. (2018)</td>
<td></td>
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<tr>
<td>Republic of Korea</td>
<td>Crops</td>
<td></td>
<td>The following crops are expected to decrease by the end of the 21st century: rice, by 25% or more; maize, by 10%-20%; summer potatoes, by more than 30%.</td>
<td>National</td>
<td>(Ministry of Environment, 2020)</td>
<td></td>
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<tr>
<td>Republic of Korea</td>
<td>Crops</td>
<td></td>
<td>Rice yield is expected to decrease by 12.95% (RCP 4.5) and 16.1% (RCP 8.5) in 2050; and 14.7% (RCP 4.5) and 23.6% (RCP 8.5) in 2080.</td>
<td>Republic of Korea (Central region)</td>
<td>Yoon and Choi (2020)</td>
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<tr>
<td>Republic of Korea</td>
<td>Crops</td>
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<td>Rice yield is expected to decrease by 15.85% (RCP 4.5) and 14.3% (RCP 8.5) in 2050; and 17.45% (RCP 4.5) and 17.1% (RCP 8.5) in 2080.</td>
<td>Republic of Korea (Southern region)</td>
<td>Yoon and Choi (2020)</td>
<td></td>
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<tr>
<td>South Asia</td>
<td>Pakistan</td>
<td>Crops</td>
<td>Farmers are experiencing changes in crop yields and crop diseases as a result of climate extremes particularly floods and droughts</td>
<td>Provincial (Khyber Pakhtunkhwa province)</td>
<td>Fahad and Wang (2018)</td>
<td></td>
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<td>Nepal</td>
<td>Crops</td>
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<td>Loss of agricultural productivity brought about by climate change has adverse impact to the overall national economy</td>
<td>National</td>
<td>Chalise et al. (2017)</td>
<td></td>
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<tr>
<td>India</td>
<td>Crops</td>
<td></td>
<td>Aggregate decline in food grain production for rice, wheat, pulses and coarse serials in 10 large food grain producing states by 2.30% and 8.62% for the entire country for 2030 and 2050, respectively, with substantial variations in terms of the specific crop, the region (state) and the time period</td>
<td>National/Subnational</td>
<td>Dasgupta et al. (2013)</td>
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<tr>
<td>India</td>
<td>Crops</td>
<td></td>
<td>Crop yields of wheat, barley and maize will all increase under both the RCP4.5 and RCP8.5 scenarios for the period 2021–2050 with the most significant growth of crop yield projected for wheat followed by barley and maize</td>
<td>Rajasthan state in India</td>
<td>Dubey and Sharma (2018)</td>
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<td>Region</td>
<td>Country</td>
<td>Agriculture Sector</td>
<td>Observed Impacts</td>
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<tr>
<td>India</td>
<td>Crops</td>
<td></td>
<td>Yield reduction in rice production varies from less than 10% to more than 30% depending on the study area and model assumptions based on review of literature.</td>
<td>Reduction in rice yield varies between less than 10% to more than 30% depending on the study area and model assumptions based on review of literature.</td>
<td>Different parts of India</td>
<td>Balasubramanian et al. (2017)</td>
</tr>
<tr>
<td>India</td>
<td>Crops</td>
<td></td>
<td>Reduction in maize yield by as much as 25%, 40%, and 70% under a rise of temperature by 1, 2, and 4°C, respectively, although maize varieties that combined drought and heat tolerance have the potential to offset some of the negative impacts.</td>
<td>Rice yields could potentially increase in the northern states but could decline by 5.0% in the 2030s, 14.5% in the 2050s, and 17.0% in the 2080s in the southern states.</td>
<td>Hyderabad, India</td>
<td>Tesfaye et al. (2018)</td>
</tr>
<tr>
<td>India</td>
<td>Crops</td>
<td></td>
<td>45 improved varieties are adopted in India and that in each state high resistant and tolerant varieties are cultivated providing some degree of varietal resilience</td>
<td></td>
<td></td>
<td>Pradel et al. (2019)</td>
</tr>
<tr>
<td>Bangladesh</td>
<td>Crops</td>
<td></td>
<td>Temperature increase could reduce national rice and wheat production by as much as 12.1% and 12.4%, respectively.</td>
<td></td>
<td>National (16 sub-regions of Bangladesh)</td>
<td>Ruane et al. (2013)</td>
</tr>
<tr>
<td>Bangladesh</td>
<td>Crops</td>
<td></td>
<td>Overall rice production could decline by about 17% and wheat production by 61% compared with a baseline situation without accounting for the potential impacts of CO2 fertilization.</td>
<td></td>
<td>National</td>
<td>Asian Development Bank (2014)</td>
</tr>
<tr>
<td>Bhutan</td>
<td>Crops</td>
<td></td>
<td>Rice yields could decrease by 6.7% in mid-latitude and 12.6% in low altitude by 2050.</td>
<td></td>
<td>National</td>
<td>Asian Development Bank (2014)</td>
</tr>
<tr>
<td>Sri Lanka</td>
<td>Crops</td>
<td></td>
<td>Rice yields could decline by 3.6% to 19.8% by 2050 across seasons and climatic zones.</td>
<td></td>
<td>National</td>
<td>Asian Development Bank (2014)</td>
</tr>
<tr>
<td>Sri Lanka</td>
<td>Crops</td>
<td></td>
<td>The future distributions of suitable tea (Camellia sinensis) growing areas revealed a decline of approximately 10.5%, 17%, and 8% in total 'optimal', 'medium', and 'marginal' suitability areas respectively, implying that climate would have a negative effect on the habitat suitability of tea in Sri Lanka by 2050 and 2070.</td>
<td></td>
<td>National</td>
<td>Jayasinghe et al. (2019)</td>
</tr>
<tr>
<td>South Asian countries</td>
<td>Crops</td>
<td></td>
<td>Reduction in crop productivity in all South Asian countries by 2040 with India likely to be the most affected.</td>
<td></td>
<td>South Asia</td>
<td>Cai et al. (2016)</td>
</tr>
<tr>
<td>Region</td>
<td>Country</td>
<td>Agriculture Sector</td>
<td>Observed Impacts</td>
<td>Projected Impacts</td>
<td>Scale of analysis</td>
<td>Study</td>
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<tr>
<td>Southeast Asia</td>
<td>Southeast Asian countries</td>
<td>Crops</td>
<td>Reduction on rice yields under climate change will be largest in Cambodia with a decrease of approximately 45% in the 2080s under RCP 8.5, relative to the baseline period 1991–2000 without adequate adaptation</td>
<td>Improved irrigation considering CO2 fertilisation will largely increase rice yields by up to 8.2–42.7%, with the greatest increases in yields in Cambodia and Thailand in the 2080s under RCP 8.5 compared to a scenario without irrigation</td>
<td>Southeast Asia</td>
<td>Chun et al. (2016)</td>
</tr>
<tr>
<td>Vietnam</td>
<td>Crops</td>
<td></td>
<td>Net household revenue is from agriculture is projected to decline at 17.7% and 21.2% in 2050 and 2100 respectively using B2 scenarios under the without adaptation model and by 0.37% and 0.20% in 2050 and 2100, respectively under the with adaptation model</td>
<td></td>
<td>Subnational (Northwestern Vietnam)</td>
<td>Huong et al. (2019)</td>
</tr>
<tr>
<td>Vietnam</td>
<td>Crops</td>
<td></td>
<td>Yields in rice decline by 5.5 – 8.5% annually on average depending on the emissions scenario.</td>
<td></td>
<td>Can Tho, Vietnam</td>
<td>Kontgis et al. (2019)</td>
</tr>
<tr>
<td>Cambodia</td>
<td>Crops</td>
<td></td>
<td>Yields in lowland rice decreased by 4% for every degree increase from an average annual baseline temperature of 28 °C</td>
<td></td>
<td>National</td>
<td>Poulton et al. (2016)</td>
</tr>
<tr>
<td>Thailand</td>
<td>Crops</td>
<td></td>
<td>Yield losses due to past climate trends (1984–2013) in the range of &lt; 50 kg/ha per decade (3% of actual average yields) with large variation in the impacts of climate trends on rice yields across the 10 provinces studied</td>
<td>Yield reduction likely to be more serious in the future if the observed trends of temperatures and precipitation continue</td>
<td>Subnational (Mun River Basin, Northeast Thailand)</td>
<td>Prabnakorn et al. (2018)</td>
</tr>
<tr>
<td>Region</td>
<td>Country</td>
<td>Agriculture Sector</td>
<td>Observed Impacts</td>
<td>Projected Impacts</td>
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<tr>
<td>Thailand</td>
<td>Crops</td>
<td></td>
<td>Potential reduction on the yield of Thai Jasmine rice by 14% and 10% under RCP4.5 and RCP8.5 scenarios, respectively, by 2080s.</td>
<td>Positive impact on rice yields especially in rain-fed areas, by +2.6% (RCP8.5: 2080–2099) to +22.7% (RCP6.0: 2080–2099). Rice yields tend to increase significantly by +0.7% (RCP8.5: 2060–2079) to +18.8% (RCP6.0: 2080–2099), with the exception of 2080–2099 under RCP8.5, which results in a decline of rice yield by –8.4%.</td>
<td>Subnational (Songkhram River Basin)</td>
<td>Boonwichai et al. (2019)</td>
</tr>
<tr>
<td>Thailand</td>
<td>Crops</td>
<td></td>
<td>The total yield losses due to past climate trends are rather low, in the range of b50 kg/ha per decade (3% of actual average yields)</td>
<td></td>
<td>National</td>
<td>Prabnakorn et al. (2018)</td>
</tr>
<tr>
<td>Philippines</td>
<td>Crops</td>
<td></td>
<td>A 1 °C increase in minimum temperature during summer decreases yield by 64 kg/ha; rice yield diminishes by 36 kg/ha for every 1% increase in the share of wet days.</td>
<td></td>
<td>National</td>
<td>Bordey et al. (2013)</td>
</tr>
<tr>
<td>Asia</td>
<td>29 Asian countries</td>
<td>Crops</td>
<td>A warming of 1.5°C (without carbon fertilisation) may reduce the total annual net revenue across all the 29 countries by 13 % or a total of US$92.6 billion with most of the countries projected to lose net crop revenue except for Afghanistan, Brunei Darussalam, North Korea, Japan, Kyrgyzstan, Republic of Korea, and Tajikistan.</td>
<td>At 3°C warming without carbon fertilisation, overall damages will reach to US$195 billion or a 28% loss of annual net revenue with 11 countries predicted to lose more than 30% of their crop revenue, namely, Bhutan, Cambodia, India, Kazakhstan, Laos, Mongolia, Myanmar, Nepal, Pakistan, Thailand, and Turkmenistan. With carbon fertilisation, aggregate damages in the 1.5°C warming scenario is predicted to be offset leading to a small gain of US$18 billion (+3%)</td>
<td>Mendelsohn (2014)</td>
<td></td>
</tr>
<tr>
<td>Region</td>
<td>Country</td>
<td>Agriculture Sector</td>
<td>Observed Impacts</td>
<td>Projected Impacts</td>
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<tr>
<td>Central Asia</td>
<td>Afghanistan, Uzbekistan, Turkmenistan, Tajikistan</td>
<td>Crops</td>
<td>The advanced irrigation modes (e.g., sprinkle and drip) can improve irrigation efficiency and raise unit water benefit from 0.15 US$/m³ to 0.24 US$/m³. Irrigation mode with efficiency of about 0.61 is an effective option in adaption to changed water availabilities, which is beneficial for pursuing balance between water and land relationships.</td>
<td>At 3.0 °C warming scenario with carbon fertilisation, a 12% loss in crop net revenue is predicted for Asia with an aggregate value of US$84 billion per year and with only Afghanistan, North Korea, Japan, and Tajikistan gaining in net revenue. In all scenarios, India is the overall loser which accounts for two thirds of the lost net revenue in Asia in both 1.5 °C and 3.0 °C warming scenarios without carbon fertilisation.</td>
<td></td>
<td>Sun et al. (2019)</td>
</tr>
<tr>
<td>Southeast Asia</td>
<td></td>
<td>Livestock</td>
<td>Climate has a significant impact on farmer’s livestock choice. Climate change would increase the probability of raising livestock. The total value of livestock owned per livestock farm will shrink 9%-10%</td>
<td></td>
<td></td>
<td>Ou and Mendelsohn (2017)</td>
</tr>
<tr>
<td>North Asia</td>
<td>Mongolia</td>
<td>Livestock</td>
<td>Very severe livestock-induced rangeland degradation is overstated in Mongolia (1-18% of land area), with most rangelands slightly (33-53%) or moderately (25-40%) degraded.</td>
<td></td>
<td></td>
<td>Jamsranjav et al. (2018)</td>
</tr>
<tr>
<td>Southeast Asia</td>
<td>Philippines, Thailand, Malaysia, Indonesia</td>
<td>Fisheries</td>
<td></td>
<td>.</td>
<td></td>
<td>Nong (2019)</td>
</tr>
<tr>
<td>Region</td>
<td>Country</td>
<td>Agriculture Sector</td>
<td>Observed Impacts</td>
<td>Projected Impacts</td>
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<tr>
<td>South Asia</td>
<td>Nepal</td>
<td>Fisheries</td>
<td>Fishery suitability in the Trishuli River would be greater than 70% of optimal under both RCP 4.5 and RCP 8.5</td>
<td>Trishuli River, Nepal</td>
<td>Mishra et al. (2018)</td>
<td></td>
</tr>
<tr>
<td>South Asia</td>
<td>Bangladesh and India</td>
<td>Fisheries</td>
<td>Fishers’ experience shows that intensity of coastal cyclone is gradually increasing, which causes severe physical and economical damage. Incorporation of local knowledge in governmental policy formulation and public support to improve human skill are essential for the adaptive management.</td>
<td>Meghna River, Bangladesh and West Bengal, India</td>
<td>Jahan et al. (2015)</td>
<td></td>
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<tr>
<td>East Asia</td>
<td>Korea</td>
<td>Fisheries</td>
<td>The strengthened Tsushima warm current in the Korea Strait/the Tsushima Strait and the Sea of Japan, driven by global warming, and the subsequent confinement of the relatively cold water masses within the Yellow Sea will decrease larval anchovy biomass in the Yellow Sea, but will increase it in the Korea Strait/the Tsushima Strait and the Japan Sea by 2030.</td>
<td>Korea Strait /the Tsushima Strait and the Sea of Japan</td>
<td>Jung et al. (2016)</td>
<td></td>
</tr>
<tr>
<td>Asia</td>
<td></td>
<td>Fisheries</td>
<td>Asia has a significant contribution to the world inland capture fisheries production of $11.5 \times 10^6$ t that is c. 69%.</td>
<td>Philippines, Indonesia, and Lower Mekong, Vietnam</td>
<td>Amarasinghe and De Silva (2015)</td>
<td></td>
</tr>
<tr>
<td>South and Southeast Asia</td>
<td></td>
<td>Fisheries</td>
<td>Climate change is predicted to decrease fish productive potential in South and Southeast Asia by 2050</td>
<td>Global</td>
<td>Barange et al. (2014)</td>
<td></td>
</tr>
<tr>
<td>East Asia</td>
<td>China and Korea</td>
<td>Fisheries</td>
<td>The subsequent shrinkage of habitat range to the southwest was the major cause of the sudden decline of filefish (<em>Thamnacanites modestus</em>) catch in the northern east China sea. Shift in water temperature and currents were also identified in the NECS in early 1990s.</td>
<td></td>
<td>Jung and Cha (2013)</td>
<td></td>
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<tr>
<td>Region</td>
<td>Country</td>
<td>Agriculture Sector</td>
<td>Observed Impacts</td>
<td>Projected Impacts</td>
<td>Scale of analysis</td>
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<tr>
<td>Southeast Asia</td>
<td>Vietnam</td>
<td>Fisheries and aquaculture</td>
<td>Four manifestations of climate change occurrence in Tam Giang lagoon: an increasing number of intensive storms, extreme temperatures, floods, and sea level rise. Climate change strongly affects aquaculture households but in some cases climate change also has brought benefits for fishing groups.</td>
<td>The absolute level of vulnerability is high in a long-term period of RCP8.5 in which exposure becomes severe, whereas the relative vulnerability is similar among farming species and regions. Specifically, vulnerability is at the highest level in seaweed, such as laver and sea mustard, while fish, shrimp, and abalone are relatively less vulnerable to climate change.</td>
<td>Tam Giang-Cau Hai Lagoon, Thua Thien Hue, Vietnam</td>
<td>d’Amour et al. (2017)</td>
</tr>
<tr>
<td>East Asia</td>
<td>Korea</td>
<td>Aquaculture</td>
<td></td>
<td></td>
<td>North Korea and Republic of Korea</td>
<td>Kim et al. (2019)</td>
</tr>
<tr>
<td>East Asia</td>
<td>China and Japan</td>
<td>Aquaculture</td>
<td>Arctic Oscillation (AO) and East Asian monsoon (EAM) strongly influenced the aquaculture areas on the Dalian Coast, China through their effects on temperature during winter. Conversely, ocean conditions and suitable areas in Funka Bay, Japan changed rapidly relative to oceanic and atmospheric circulation.</td>
<td></td>
<td>Dalian, China and Funka Bay, Japan</td>
<td>Liu et al. (2014)</td>
</tr>
<tr>
<td>Southeast Asia</td>
<td>Vietnam</td>
<td>Aquaculture</td>
<td>Declined in the rice crops areas in Ben Tre with 23.4%, and 31.5% in the coastal districts due to the conversion of freshwater rice fields into brackish shrimp ponds.</td>
<td>It is estimated that a 1 m rise in the current sea level would clear 45.2% of the remaining mangrove forests, 60.9% of the current areas planted with rice, 65% of the aquaculture ponds and 46% of the entire province would be under the water.</td>
<td>Ben Tre, Mekong Delta, Vietnam</td>
<td>Veettil et al. (2019)</td>
</tr>
<tr>
<td>Asia</td>
<td>Aquaculture</td>
<td>Aquaculture</td>
<td>Climatic factors increase aquaculture production, whereas energy sources and growth</td>
<td></td>
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<td>Bhuiyan et al. (2018)</td>
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</tbody>
</table>
SM10.4 Line of Sight City Wise Risks and Adaptation

Table SM10.3: Risks and key adaptation options in selected cities across Asia

<table>
<thead>
<tr>
<th>City</th>
<th>Key risks</th>
<th>Adaptation progress</th>
<th>Adaptation effectiveness</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Permafrost thaw</td>
<td>Floods</td>
<td>Drought, water scarcity</td>
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<tr>
<td>Salekhard</td>
<td>(Streletskiy, 2019)</td>
<td>NE</td>
<td>NE</td>
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<td></td>
<td>(Shiklomanov et al., 2017b)</td>
<td></td>
<td>(Streletskiy, 2019)</td>
</tr>
<tr>
<td>Location</td>
<td>Year 1</td>
<td>Year 2</td>
<td>Year 3</td>
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<tr>
<td>Guangzhou</td>
<td>(Jevrejeva et al., 2016)</td>
<td>(Huang et al., 2018)</td>
<td>(Zhang et al., 2017)</td>
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<td></td>
<td>(Ma et al., 2018)</td>
<td>(Hu et al., 2019)</td>
<td>(Liu et al., 2019)</td>
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<tr>
<td>Shanghai</td>
<td>(Yuan et al., 2017a)</td>
<td>(Chen et al., 2018)</td>
<td>(Xian et al., 2018)</td>
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<td></td>
<td>(Du et al., 2020)</td>
<td>(Wang et al., 2020)</td>
<td>(Chen and Frauenfeld, 2016)</td>
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<td></td>
<td>(Yuan and Lu, 2015)</td>
<td>(Chen and Frauenfeld, 2016)</td>
<td>(Yuan et al., 2017b)</td>
</tr>
<tr>
<td></td>
<td>(Yuan et al., 2017b)</td>
<td>(Chen and Frauenfeld, 2016)</td>
<td>(Yuan et al., 2017b)</td>
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<td></td>
<td>(Xian et al., 2018)</td>
<td>(Yan et al., 2016)</td>
<td>(Yin et al., 2020)</td>
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<td>(Chen et al., 2017)</td>
<td>(Filho et al., 2019)</td>
<td>(Du et al., 2020)</td>
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<td>(Xia et al., 2017)</td>
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<td>(Xia et al., 2017)</td>
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<td>(Du et al., 2020)</td>
<td>(Du et al., 2020)</td>
<td>(Du et al., 2020)</td>
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<tr>
<td>Location</td>
<td>Source 1</td>
<td>Source 2</td>
<td>Source 3</td>
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<tr>
<td>Jakarta</td>
<td>(Hallegatte et al., 2013) (Takagi et al., 2016) (Gu et al., 2015) (Muis et al., 2015) (Jan van Oldenborgh et al., 2015)</td>
<td>(Siswanto et al., 2016) (Liu et al., 2015)</td>
<td>(Estoque et al., 2017) (Darmanto et al., 2019)</td>
</tr>
</tbody>
</table>
SM10.5 Evidence on Effectiveness of Ecosystem-based Adaptation ‘EbA’ using Four Commonly used EbA Options

See Figure 10.10 for final assessment.

Table SM10.4: Evidence on effectiveness of ecosystem-based adaptation using four commonly used EbA options. Effectiveness is examined through four framings: potential to reduce risk (e.g., reduced exposure to hazard; reduced risk); benefits to ecosystems (through improved ecosystem health, high biodiversity); economic benefits (e.g., improved incomes, fewer man-days lost, better livelihoods); and human wellbeing outcomes (e.g., health, quality of living etc.). Blue shading denotes high score on effectiveness indicator (dark blue); medium effectiveness (medium shading); and low effectiveness (light blue shading). White cells denote no assessment due to inadequate literature. Each cell also has evidence (robust/medium/low) and agreement mentioned (high/medium/low).

<table>
<thead>
<tr>
<th>Ho Chi Minh City</th>
<th>Risk reduction potential</th>
<th>Ecosystem benefits</th>
<th>Economic/livelihood benefits</th>
<th>Human wellbeing benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extreme heat, urban heat island effects</td>
<td>Robust</td>
<td>Medium</td>
<td>Reduces UHI, provide thermal comfort (Zhang et al., 2014; Jim, 2015; Koc et al., 2018; Aram et al., 2019; Lai et al., 2019) Increasing urban green cover is more effective than increasing urban albedo (i.e. building reflectivity through cool roofs, green facades) to mitigate UHI, improve urban microclimates (Yuan et al., 2017a) Too much UGC can reduce ventilation, trapping heat and leading to temperature increases (Yuan et al., 2017a)</td>
<td>Medium</td>
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<tr>
<td>Urban parks and green spaces</td>
<td>Robust</td>
<td>Medium</td>
<td>Effectively mitigate urban flooding caused by high-frequency precipitation events, with additional economic, ecological, and social benefits. (Mao et al., 2017; Xu et al., 2017; Yau et al., 2017; Li et al., 2018b; Mei et al., 2018; Huang et al., 2020) Less effective at helping cope with pluvial flooding caused by extreme precipitation events over a short period of time (Huang et al., 2020)</td>
<td>Robust</td>
</tr>
<tr>
<td>Floods</td>
<td>Robust</td>
<td>Medium</td>
<td>Effectively mitigate urban flooding caused by high-frequency precipitation events, with additional economic, ecological, and social benefits. (Mao et al., 2017; Xu et al., 2017; Yau et al., 2017; Li et al., 2018b; Mei et al., 2018; Huang et al., 2020) Less effective at helping cope with pluvial flooding caused by extreme precipitation events over a short period of time (Huang et al., 2020)</td>
<td>Robust</td>
</tr>
<tr>
<td>Ecological stormwater management</td>
<td>Robust</td>
<td>Medium</td>
<td>Effectively mitigate urban flooding caused by high-frequency precipitation events, with additional economic, ecological, and social benefits. (Mao et al., 2017; Xu et al., 2017; Yau et al., 2017; Li et al., 2018b; Mei et al., 2018; Huang et al., 2020) Less effective at helping cope with pluvial flooding caused by extreme precipitation events over a short period of time (Huang et al., 2020)</td>
<td>Robust</td>
</tr>
</tbody>
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Global systematic review found no studies assessing wellbeing and health impacts (Venkataramanan et al., 2019)
<table>
<thead>
<tr>
<th>Sea Level Rise</th>
<th>Mangrove restoration</th>
<th>Food insecurity</th>
<th>Urban agriculture (UA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medium Medium</td>
<td>Medium Medium</td>
<td>Medium Low</td>
<td>Medium Medium</td>
</tr>
<tr>
<td>31% wave reduction; provide 50% protection from storms (Ferrario et al., 2014; Narayan et al., 2016)</td>
<td>Contribute to local biodiversity (flora and fauna) and sustain coastal fish (Lee et al., 2014)</td>
<td>Globally estimated to potentially produce 100–180 million tonnes food annually, avoid storm water runoff between 45 and 57 billion cubic meters annually (Clinton et al., 2018) but mixed evidence on UA and food security outcomes, especially in low-income countries (Badami and Ramankutty, 2015) UA reduces energy needs from enhanced rooftop insulation by growth substrate leading to savings of 2.4 billion kWh in China, 1 billion kWh in India (Clinton et al., 2018)</td>
<td>Improves local biodiversity, uptake of sustainable agriculture practices, increases environmental awareness (Thomaier et al., 2015; Zasada et al., 2020)</td>
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<tr>
<td></td>
<td></td>
<td>Medium Low</td>
<td>Medium Medium</td>
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<td></td>
<td>Uptake of organic farming, composting, and growing a large variety of plants and trees (Zasada et al., 2020) Can have negative impacts due to fertiliser use, polluted runoff, increased water demand (Ackerman et al., 2014) Mixed evidence on sustainability outcomes and potential for scaling (Weidner et al., 2019)</td>
<td>Positive economic impacts for urban farmers (Gasparatos, 2020)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Medium Medium</td>
<td>Medium Medium</td>
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<td>Improves quality of life, human wellbeing and health (Thomaier et al., 2015; Zasada et al., 2020)</td>
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