



FCRN **foodsource**

A free and evolving resource to empower informed discussion on sustainable food systems

Chapter 6.

Impacts of climatic and environmental change on food systems

Contents

Why should you read this chapter?	3
Key points	3
6.1 How do the climate and environment directly affect the conditions required for food production?	4
6.1.1 Land and soils	4
6.1.2 Sunlight	4
6.1.3 Water	5
6.1.4 Insects	6
6.2 What is the climate change context	7
6.2.1 The degree of warming is uncertain	7
6.2.2 Climate change can affect the food system as a whole	9
6.2.3 How climate change will affect food systems is uncertain	9
6.3 What impacts have already been observed?	11
6.3.1 Regional variation in climatic change impacts on food production	11
6.3.2 Observed positive and negative impacts	12
6.3.3 Impacts on terrestrial and aquatic livestock	12
6.4 How might climatic change affect food systems in the future?	13
6.4.1 Climate change is expected to undermine crop yields	13
6.4.2 Negative post-harvest impacts should also be expected	16
6.4.3 Increased water stress is expected in various regions	16
6.4.4 Climate change impacts on marine-sourced foods	18
6.5 What is the likely human impact?	19
6.5.1 Who and where will the negative impacts affect most?	19
6.5.2 What are the likely nutritional impacts?	20
6.5.3 What are the likely economic impacts on food security?	21
6.6 Conclusions	23
References	24
Credits	27

Why should you read this chapter?

Food systems are central to human well-being. We rely on them for nourishment, employment, livelihoods, culture and more. Reliable access to sufficient food is a foundation of human health, and of social and political stability. While the impacts of food systems on the environment are great, changes to the climate and the wider environment – to which food systems contribute – also have major implications for the functioning of food systems and all that they support.

Understanding this matters, because sustainable food systems in the future must not only maintain human well-being with fewer environmental impacts, but must also be able to cope to different environmental conditions to those experienced today.

This chapter provides an overview of the following:

- In what ways do food systems depend on the state of the environment and climate?
- How are these changing and what impacts of these changes on food systems have been observed so far?
- How will present and future changes affect food systems going forwards, and what will be the real-terms impacts of these effects for people?

Key points

- Food production depends on the availability of suitable land and soils, sunlight, water and pollinating insects, among other things; all of which are or will be affected in different ways by climatic and environmental change.
- There are many uncertainties surrounding how much and how fast global warming will take place, how this will translate into climatic changes in different locations, and consequently, how changes in climate will affect food systems.
- Climate change is likely to have a mixture of positive and negative impacts on different parts of the food system, depending on the interplay between gradual temperature increase, extreme weather events, the CO₂ fertilisation effect, changes in water availability, economic effects (e.g. trade), demographics and infrastructure.
- Negative impacts of climate change on crop production have already been observed – with some benefits also observed in high latitude regions. Impacts of climate change on terrestrial livestock have not been well-researched yet, but are expected to take place from heat and water stress on animals and animal feed.
- Separating the impacts of climate change on marine species from those of overfishing is difficult, but ocean acidification and sea temperature changes are likely to compound the negative effects of overfishing.
- Expectations of future crop yields depend strongly on modelling assumptions and the crop, but several models suggest that average crop yield decreases of more than 5% are more likely than not after 2050; and that in the tropics, negative yield impacts are very likely after the 2080s, regardless of which scenario is used.
- The challenge of meeting additional demands on food systems in the future from population growth and dietary change, will be exacerbated the effects of climate change on food production and will require adaptation action to reduce the level of impacts experienced.
- As well as production, post-harvest food system activities are also likely to be impacted by climate change. These impacts may include disruption or changes to infrastructure, transport, imports, exports, and sourcing, as well increased risks of spoilage, waste and food-borne diseases.
- While some developed countries in the Northern Hemisphere are likely to experience some positive impacts of climate change on production in the first half of this century, many globally traded staple crops are grown in areas that will experience negative impacts with implications on global food security – especially in lower income countries, those that import food, and on poor farmers.
- A number of major crops have been shown to lose nutritional quality – at least in relation to zinc, iron and protein levels – at higher atmospheric CO₂ levels, which may contribute to nutrient deficiencies in some countries, although these relationships are complex and uncertain.

6.1 How do the climate and environment directly affect the conditions required for food production?

This section considers the environmental conditions or factors required for food production, their link to the climate and the environment, and how they will therefore be affected by climatic and environmental change and degradation.

6.1.1 Land and soils

Requirements for food production:



Figure 1: Land: physical space, accessibility – Soils: sufficient soil organic matter, depth, drainage, aeration and appropriate pH.

Impacts of climatic and environmental change:

The availability of suitable agricultural land is almost synonymous with the availability of suitable soils. In addition to the impacts of soil degradation (see [Chapter 5](#)), as the climate changes, and as precipitation patterns alter, the suitability of soils for growing crops is likely to change. For example, drought can lead to dry exposed soils, and may lead to desertification, while extreme flooding can lead to waterlogging, causing anaerobic inhospitable soils.

6.1.2 Sunlight

Requirements for food production:



Figure 2: Sufficient daylight hours and sufficient light intensity to support crop growth.

Impacts of climatic and environmental change:

While daylight hours are outside of climatic and environmental control, the intensity of light reaching crop plants depends on air clarity and weather. Smog and particulate carbon from car and factory emissions is so thick in certain parts of the world (e.g. Bangladesh) that the reduction in sunlight reaching crops was sufficient to hinder their growth.

6.1.3 Water

Requirements for food production:



Figure 3: Green water (i.e. precipitation) and blue water (i.e. ground sources of water or aquifers). Sufficient volume for irrigation needs, and appropriate technology and infrastructure for irrigation.

Impacts of climatic and environmental change:

Water availability (of both green and blue water) depends on volume and frequency of rainfall, as well as on soil drainage, infrastructure and competing demands from non agricultural activities. Projected changes in precipitation, soil moisture, run-off and evaporation across the globe indicate that, at a very rough approximation, places that are currently wet are set to get wetter, while places that are currently dry are set to get drier (both on a climatic scale and in terms of extreme weather events such as droughts and flooding). Both drought and flooding are likely to have negative impacts on crop production, although there are likely to be some regions in which changes in precipitation may bring benefits for food production.

6.1.4 Insects

Requirements for food production:



Figure 4: Insects and other invertebrates for pollination, pest control and maintenance of the soil environment (e.g. aeration of the soil, or aiding with the breakdown of organic matter).

Impacts of climatic and environmental change:

Insect pollinators and other invertebrates providing a range of ecosystem services are known to be under threat from climate change and other environmental influences. Temperature, changing seasonal patterns, and increased or decreased rainfall can all have serious consequences for the animals which provide vital ecosystem services for agriculture. For example: Changing temperatures can affect the emergence times of insect larvae or adult forms, in some cases leading to a loss of synchronicity with the plants they pollinate (whether wild or cultivated), leading to crashes in the insect population, a phenomenon called phenological advancement. The ranges which the insects inhabit may shift as average temperatures rise, leading to changes in the insect communities of particular regions. It is thought that this may have a positive effect on some insect species at mid- to high-latitudes, as warming temperatures decrease their mortality and allow for northward range expansion. Extreme weather events, such as flooding, which are likely to increase in frequency, can also have adverse effects on invertebrates: for example, following severe flooding in the UK in 2007, it was predicted that soil compaction and a decrease in the earthworm population would lead to poorer yields in the following years.

6.2 What is the climate change context?

6.2.1 The degree of warming is uncertain

The degree of warming is uncertain – it depends on the scale of GHG reductions achieved. Even within the IPCC scenarios, uncertainty exists

- IPCC reports identify likely outcomes for different temperature increases resulting from current GHG emission trajectories. A common assumption is that a safe global warming limit is a 2°C rise in average global temperature, although this is subject to debate and uncertainty.
- The 2015 climate summit (COP21) in Paris, resulted in reaffirmation by nations that goal of 2°C remains, but with a strong signal of intent to limit the temperature increase to 1.5°C, in response to calls by vulnerable states (specifically low-lying island nations).
- The recent IPCC report calculates that GHG emissions reductions of between 40% and 70%, by 2050, will be needed for the 2°C scenario to be likely. Reducing emissions to zero by 2100 is likely needed to maintain temperatures within this limit.

The IPCC report calculates that in order to likely stay within the 1.5°C limit, GHG emissions will need to be reduced by 70-95% by 2050.

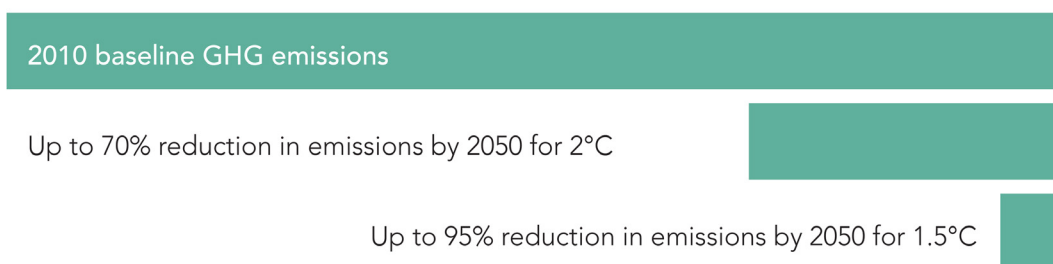


Figure 5: Emissions reductions required by 2050 in order to achieve a 2°C and 1.5°C target.

Source: FCRN. (2016).

This is considered to be a significant technical and socio-economic challenge.

IPCC terminology

The IPCC reports use specific terminology to state its level of confidence in its conclusions and the likelihood of stated outcomes. These are referred to at times throughout this chapter, so a brief explanation is included.

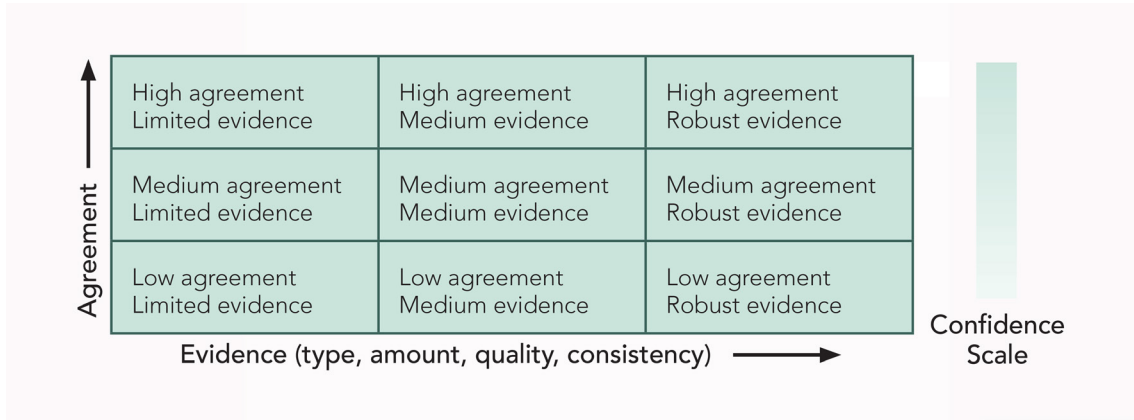


Figure 6: Confidence is expressed using five qualifiers: “very low”, “low”, “medium”, “high”, and “very high”.

Table 1. Likelihood Scale	
Term*	Likelihood of the Outcome
Virtually certain	99–100% probability
Very likely	90–100% probability
Likely	66–100% probability
About as likely as not	33–66% probability
Unlikely	0–33% probability
Very unlikely	0–10% probability
Exceptionally unlikely	0–1% probability

Credit: IPCC 2012

Figure 7: Likelihood is expressed using probability qualifiers.

Source: Adapted from Mastrandrea, et al. (2010).

There is a degree of uncertainty involved in scenario projections, and this mechanism provides a transparent way of understanding the ‘firmness’ of judgements about outcomes.

6.2.2 Climate change can affect the food system as a whole

Climatic change can impact all forms of agriculture and all stages of food systems

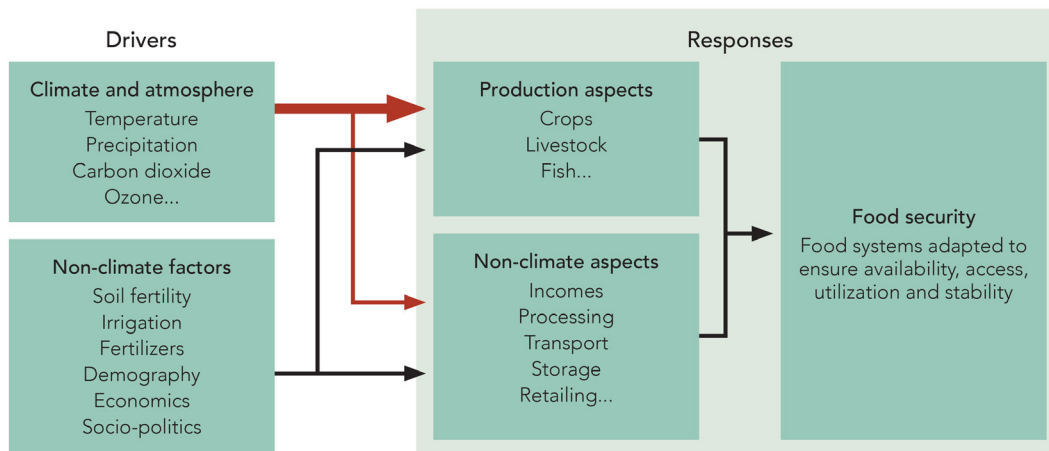


Figure 8: The relationship between climate and non-climate drivers and impacts on food security.

Source: FCRN. (2016).

Measuring direct impacts of climate change on food systems can be difficult since changes in agricultural practices may happen in response to temperature rise (such as increased irrigation), so altering the impact, together with a lack of a consistent baseline against which to measure change.

6.2.3 How climate change will affect food systems is uncertain

How climatic change will affect agriculture and food security is uncertain, and depends on many factors

There is considerable uncertainty, and impacts depend on the interplay between:

- Gradual temperature increase
- The CO₂ fertilisation effect (whereby higher ambient CO₂ concentrations in the atmosphere can stimulate increased plant growth and boost productivity, although the strength of this effect is unclear)
- Extreme events such as drought and flooding; temperature peaks
- Water
- Economics, demographics, infrastructure

Impacts will also depend on the degree of climatic change – i.e. it will vary between a 2°C and 1.5°C temperature increase. Scenarios, largely based on models, are used to provide plausible predictions and reduce uncertainty.

Figure 9: How climatic change will affect agriculture depends on many factors

Source: FCRN. (2016).

Impacts on agriculture and food security are uncertain, and depend on the interplay between many physical factors such as temperature, CO₂ levels, precipitation and extreme events, as well as social, demographic and economic factors, that influence people's ability to adapt to change and may also have an affect on future emissions.

Both positive and negative impacts are possible, depending on crop type and the interplay between variables

Can be positive :

- CO₂ fertilisation effect could stimulate plant growth, but crops differ in how they respond to CO₂ levels.
- Reduced frost (frost can damage or kill many crops).
- Precipitation (within limits, more rainfall is considered positive for agriculture).

Can be negative:

- Crops have different optimal temperatures for productivity; increases beyond this can have negative impacts, especially if there are peak temperature days at critical stages in a crop's growth cycle.
- Crops which require vernalisation – a process in which cold temperatures trigger flowering – including wheat, may suffer from increased temperatures.
- Extreme changes in precipitation (drought or flood).

Climate impacts on the yields and nutritional profile of different crops, are not fully understood. There are many variables, such as regional temperature changes, precipitation levels, and seasonal variability. While predictions can be and are made, these involve high levels of uncertainty.

For example, in warm dry regions, increased CO₂ could boost productivity in C3 plants, but this could be offset by reduced rainfall, higher temperatures or less predictable precipitation, resulting in droughts or floods.

Plants have different pathways for assimilating CO₂ (referred to as either C3 or C4) reflecting differences in the number of carbon atom molecules formed when CO₂ is first absorbed. The majority of plants are C3 (such as wheat, rice, and soy) and are believed to respond more productively to higher CO₂ levels than C4 crops (such as maize and sugar cane). For more information about the difference between C3 and C4 plants, including efforts to introduce carbon-concentrating mechanisms such as C4 into C3 plants, see the resources available at the [Cambridge CAPP](#) website. This variation in response to climate change is just one factor that needs to be considered, alongside changes in precipitation, air temperature increases, and impacts of extreme events such as droughts and floods. The strength of the CO₂ fertilisation effect is therefore uncertain and depends on other factors.

C3 plants

C3 plants are those whose method of photosynthesis is adapted to cooler and wetter climates. They represent the majority of plants globally and include rice, soybean, and wheat. C3 plants are less efficient at creating energy for growth than C4 type plants in hot and dry climates.

C4 plants

C4 plants are those whose method of photosynthesis is adapted to hotter and dryer climates. They represent only a small fraction of plants globally. Examples include some grasses, maize, sugar cane, millet, and sorghum. In hot and dry climates, it is more efficient at creating energy for growth than C3 plants

6.3 What impacts have already been observed?

6.3.1 Regional variation in climatic change impacts on food production

Impacts of climatic change on food production have varied between regions

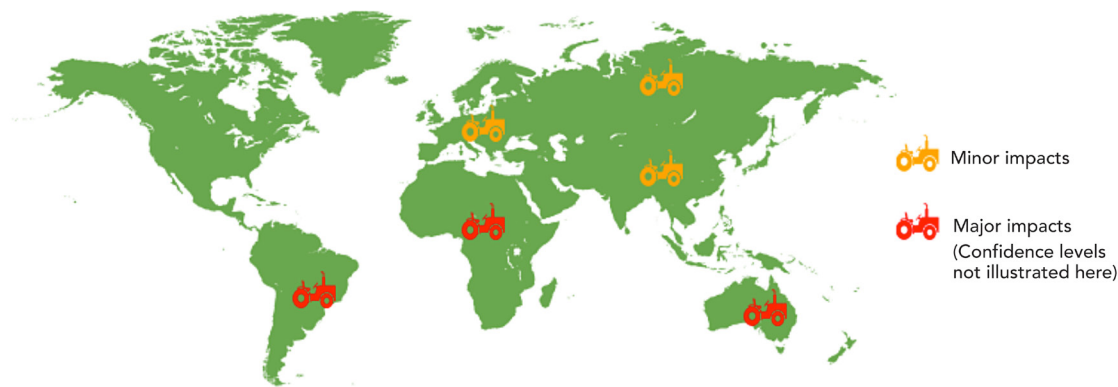


Figure 10: Regional impacts on food production from climate change.

Source: IPCC (2014).

Since the IPCC's Fourth Assessment report in 2007 (AR4), impacts of climatic change have been noted across the planet, but with significant regional variation. There is no scope in this chapter to discuss all of these impacts in detail, but the sections that follow describe the complexity of relationships between environmental changes and outcomes for food systems.

6.3.2 Observed positive and negative impacts

Some positive and negative impacts on crops have already been observed

The IPCC observed changes include:

- 'Medium confidence' of negative impacts on wheat and maize yields in many regions (including major producing regions).
- Small negative effect on yields for major producing regions of rice and soy.
- 'High confidence' that climatic change has benefited some crop yields in some high-latitude regions (e.g. North East China, UK).
- Early flowering and maturing in some crops (e.g. apples, grapes).
- Changes in the distribution of weeds and animal pests.

6.3.3 Impacts on terrestrial and aquatic livestock

Migration of some fish species has been observed, while research on livestock has been limited

Marine species

- Northern Atlantic: "high confidence" of a shift in population densities to northern ranges of habitats, away from southern ranges. This is associated with temperature increase.
- Ocean acidification – some negative impact on molluscs (i.e. their shells).
- Combined impact of overfishing and sea temperature changes, negatively impacting corals (and consequential impacts on marine ecosystems).
- It is difficult to separate the impacts of climatic change from those of over-fishing (see Chapter 5 for more on over-fishing).

Livestock

- Very little research to date on impacts of climate change on livestock production.
- Heat stress for livestock is considered to be a risk, but little research has been undertaken.
- Water stress may also affect animal feed production.
- Impacts will depend not just on the region and animal type and breed, but also the type of livestock production system.

6.4 How might climatic change affect food systems in the future?

6.4.1 Climate change is expected to undermine crop yields

Climate change is expected to undermine future crop yields, both in the short and long term

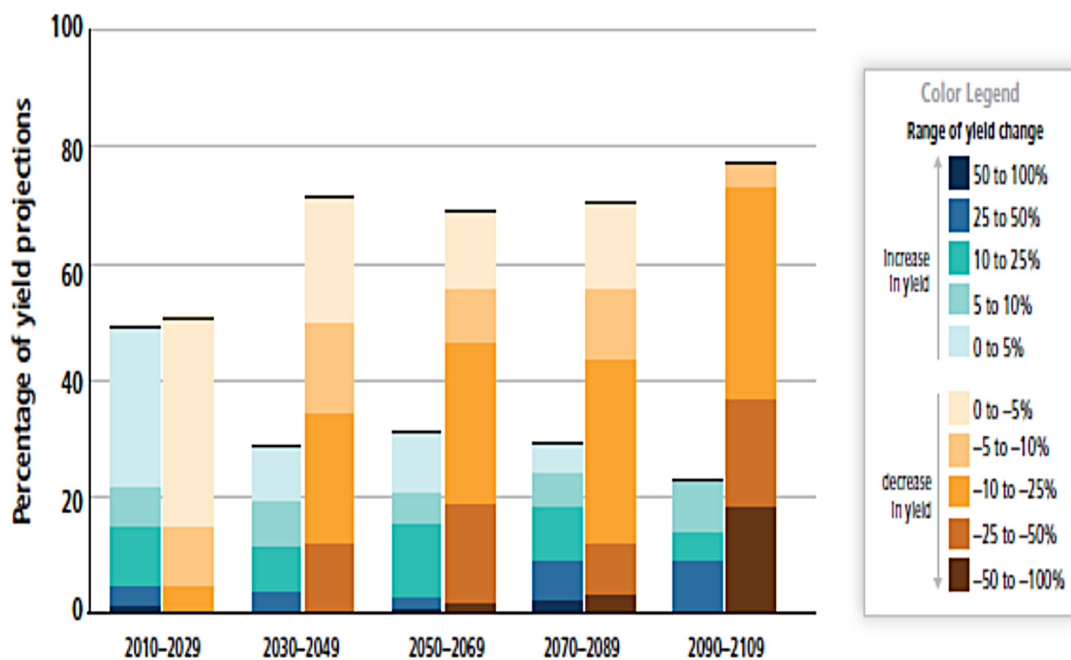


Figure 11: Future changes in yield resulting from climate change.

Source: Porter, et al. (2014).

Regional variability is considerable, though it is expected that negative impacts on average yields will become likely from the 2030s.

Negative impacts of more than 5% are more likely than not beyond 2050 and likely by the end of the century. From the 2080s onwards, negative yield impacts in the tropics are very likely, regardless of adaptation or emission scenario.

Studies included in the IPCC reports have used models to identify South Asia and southern Africa as two regions where, without adaptation, there would be very negative impacts on several important crops.

Shorter-term impacts on crop yields are significant because of a projected increase in demand for food in the next 20 years

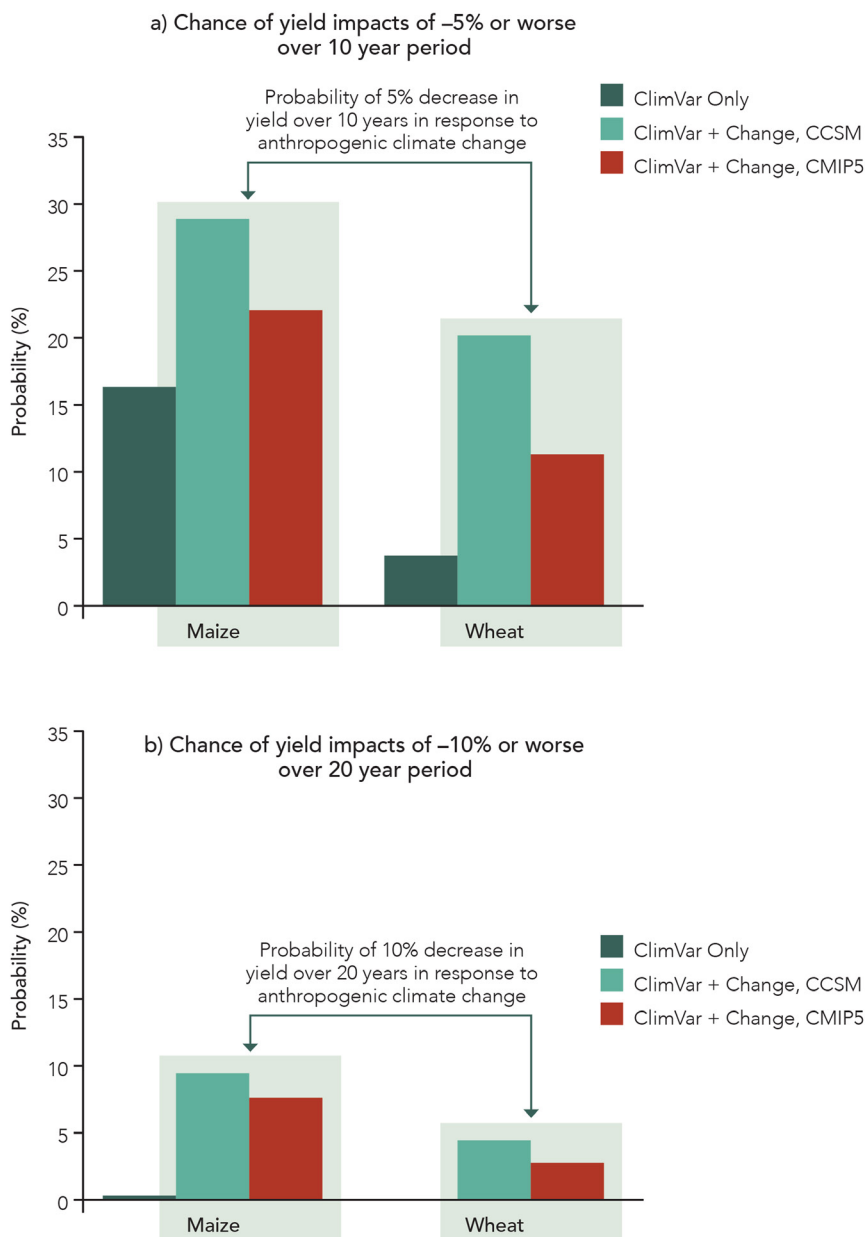


Figure 12: Likelihood of -5% and -10% impacts on maize and wheat yield from near-term climate change.

Source: Graphs produced by FCRN from data in Lobell and Tebaldi (2014).

Models predict an increase in the probability of negative yield impacts on key crops (wheat and maize). Two different climate change simulation models were applied, both predicting increased likelihood of crop impacts.

This is an important risk, given the expected increase in demand for food between now and 2050 (see Chapter 4 for more on predictions about future demand for food).

Increased risk of yield losses due to extreme events, but average yield impacts depend on the CO₂ fertilisation effect

See earlier in the chapter for a description of the CO₂ fertilisation effect.

Models have predicted that, with full CO₂ fertilisation, climatic change will not impact average yields so much as yield variability. There will be much greater risk of yield shocks (current 1-in-200 year shocks increase to more like 1-in-20). There may be a decline in nutritional quality too.

Without full CO₂ fertilisation, climatic change will impact yields and yield variability to a much greater extent. Yields that today are unprecedented, become frequent in modelling without CO₂ fertilisation included.

This shows the absolute need to adapt to climate change to ensure yields are maintained.

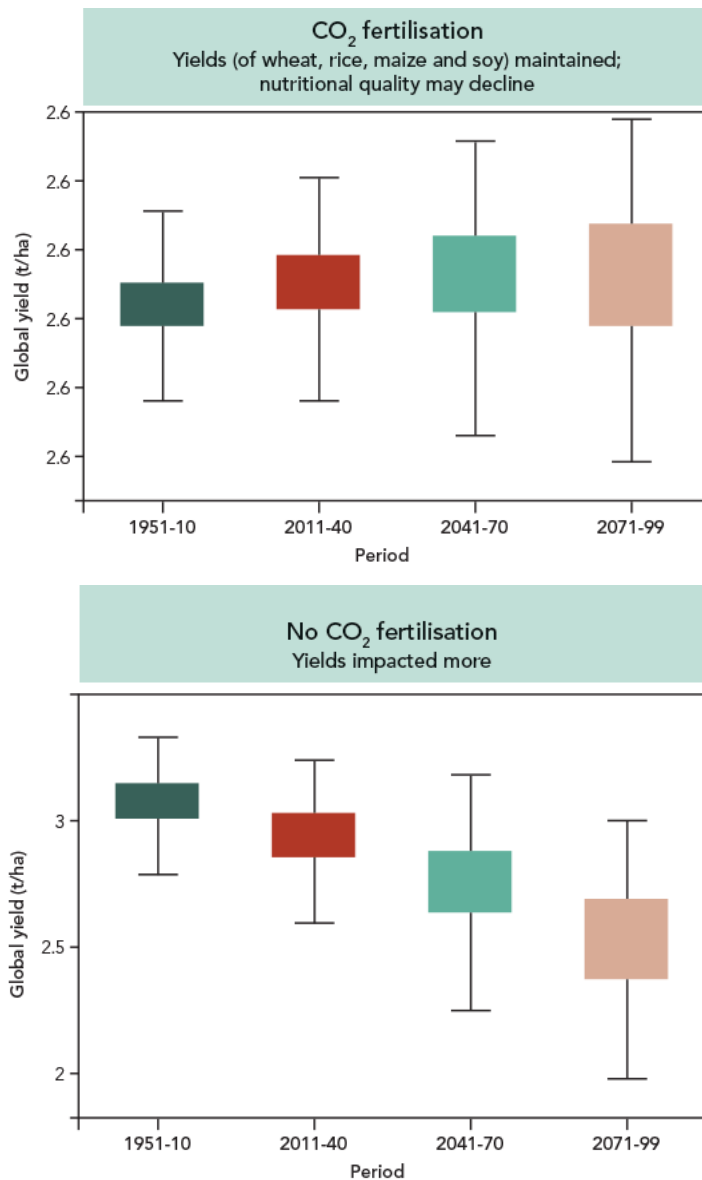


Figure 13: The importance of the CO₂ fertilisation effect in maintaining global yields in the face to climate change.

Source: Graphs produced by FCRN from data in Lobell and Tebaldi (2014).

6.4.2 Negative post-harvest impacts should also be expected

Post-harvest impacts on food systems must also be considered

Impacts may affect:

Food sourcing, processing and distribution:

- Disruptions to transport & stationary infrastructure.
- Unpredictability can lead to crop spoilage & waste.
- Food industry may need to change sourcing decisions.
- There may be changes in import dependence or export decisions.

Consumption:

- Food safety problems may increase as temperatures increase or humidity levels change, or because of change in the spread of pests and diseases.
- Increased use of refrigeration in response to higher temperatures may increase energy use and associated emissions.
- There may be changes in consumer demand (i.e. less demand for ‘cold weather’ dishes), which may affect food demand and cooking/refrigeration demand.

6.4.3 Increased water stress is expected in various regions

Climate change will affect water availability and patterns of water stress

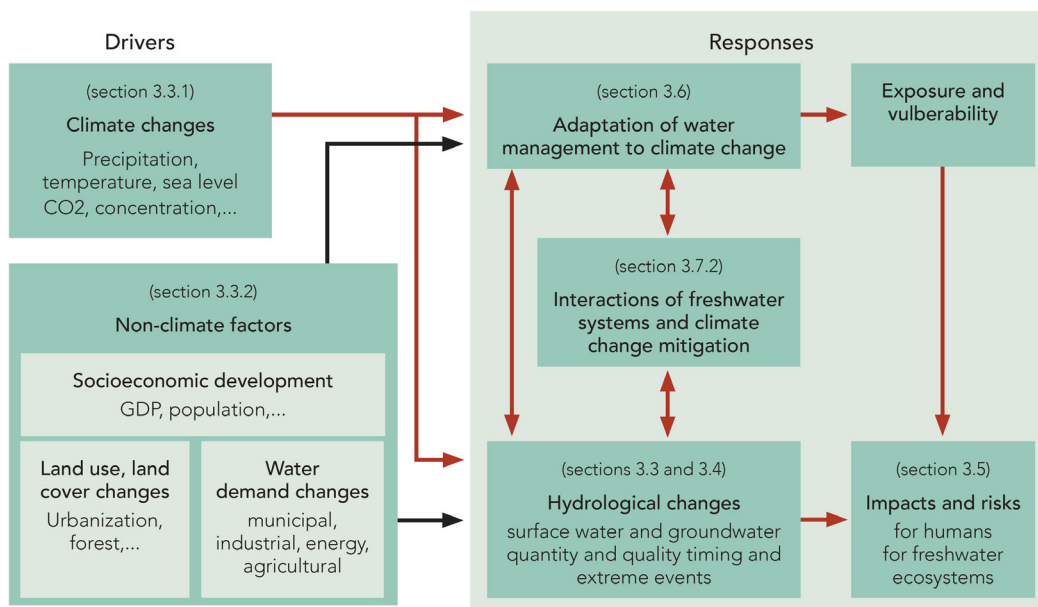


Figure 14: The influence of climate and non-climate drivers on water impacts and risks.

Source: FCRN (2016).

Water stress is influenced by the relationship between rainfall, existing groundwater stocks, and water extraction/replenishment rates. These will be influenced by climate change, which will alter precipitation patterns and the prevalence of extreme events, flooding and drought; and will also affect the demand for water for irrigation.

More than 40% of the global population will be living in water stressed regions by 2050

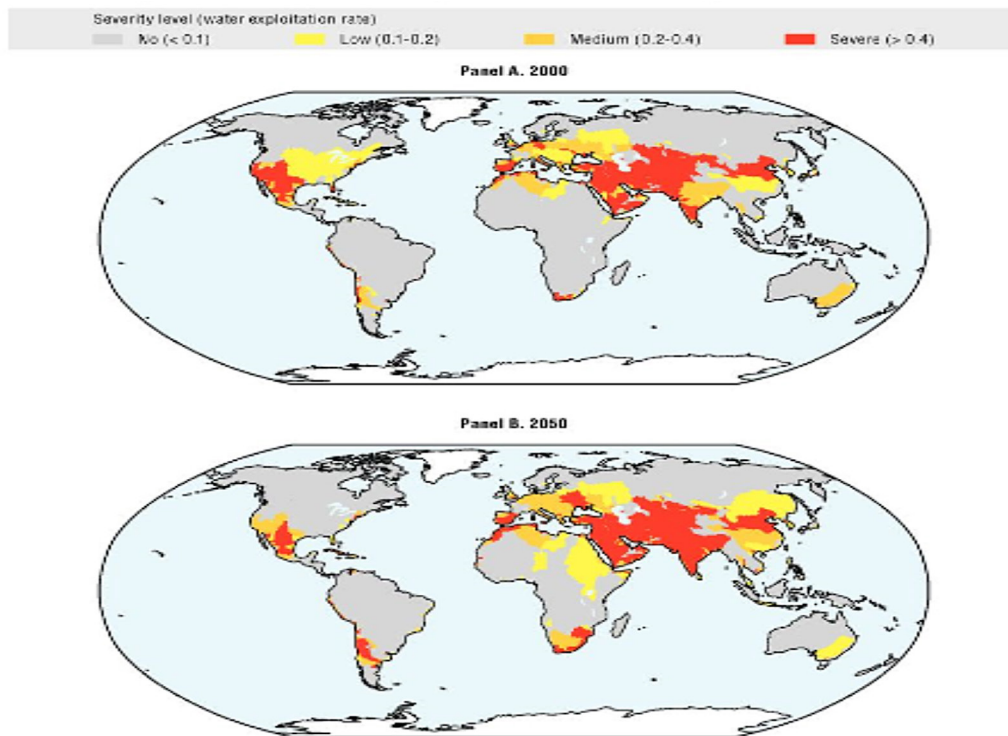


Figure 15: Projected water stress by river basin, 2000 versus 2050.

Source: OECD (2012).

Increased water stress is predicted by 2050, especially in river basins with high population densities and increasing water demand. This will include large areas of South Asia, the Middle East, China and North Africa. Over 40% of the world’s population will be living in water stressed river basins by 2050.

Other areas, such as the USA, are predicted to experience less water stress because precipitation is predicted to increase, and because of anticipated gains in the efficiency of water use.

The severity of water stress in high risk areas will depend on water management strategies, and there is need for more efficient water management in both agriculture and in other sectors.

6.4.4 Climate change impacts on marine-sourced foods

Sea temperature increases and acidification are likely to threaten marine-sourced foods

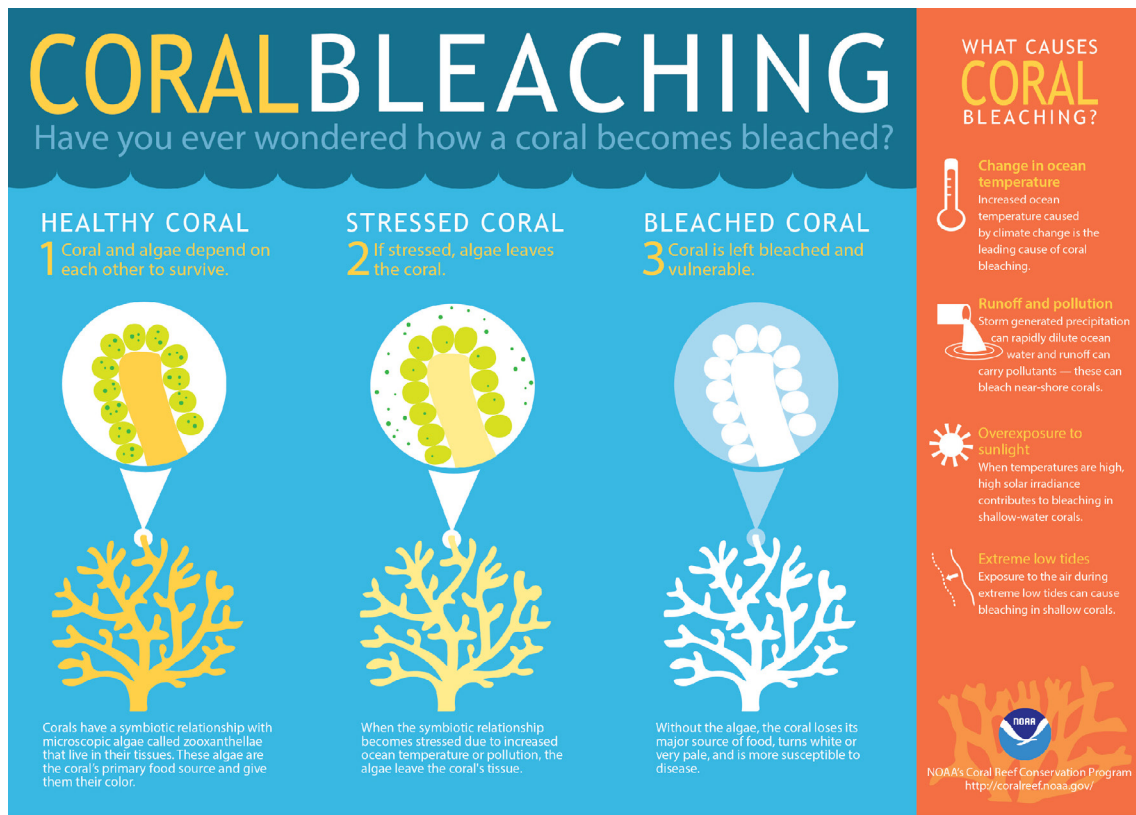


Figure 16: How coral bleaching takes place.

Source: Courtesy of NOAA's Coral Reef Conservation Programme.

Climate change impacts will be felt in marine systems as well as on land. One example of this is the degradation of coral reef systems by sea temperature rises; and by increased CO₂ concentrations, leading to ocean acidification. Temperature rises and acidification can lead to coral bleaching, whereby the symbiotic algae on which the coral depend are killed; in turn, affecting the organisms dependent on the coral for food and shelter, leading to a loss of biodiversity and damage to ecosystems.

Cesar, Burke and Pet-Soede (2003) estimated that globally, coral reef systems support US\$5.7 billion-worth of fishery activity (note that this economic estimation does not account for coral-reef dependent subsistence fishing). Climate change related coral reef degradation, therefore, has the potential for serious marine food system impacts.

6.5 What is the likely human impact?

6.5.1 Who and where will the negative impacts affect most?

Negative impacts by 2050 will impact poor people more

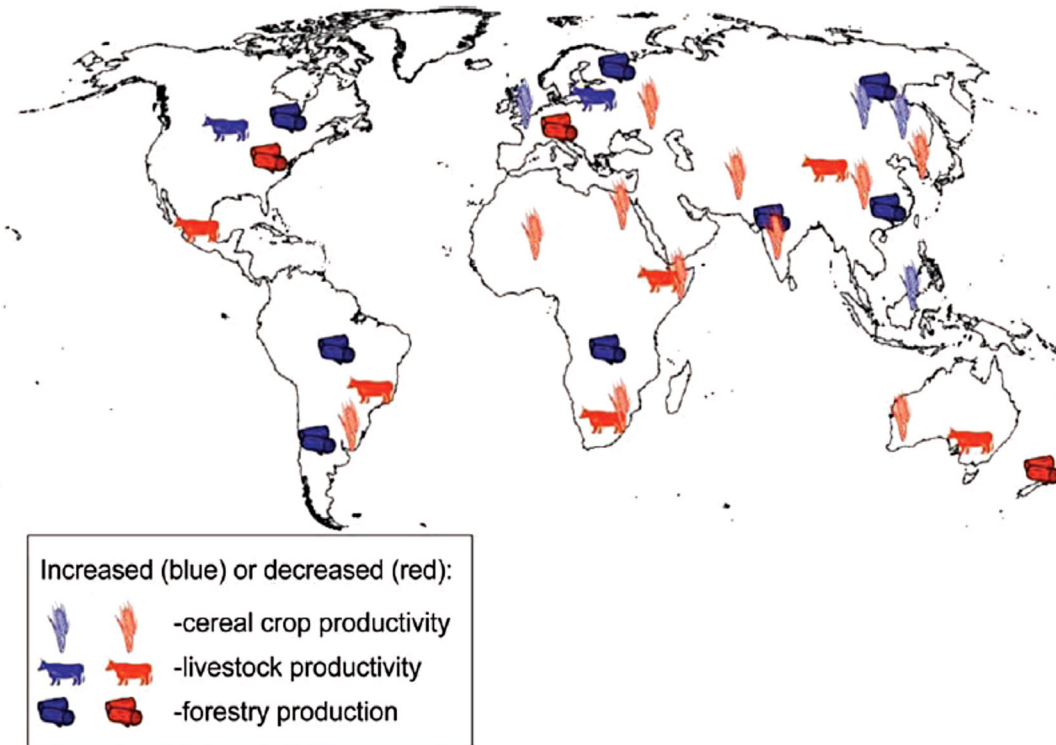


Figure 16: Projected regional impacts of climate change on livestock and forestry in 2050 (assuming no adaptation).

Source: Easterling, *et al.* (2007).

Some major global crop and livestock producing regions will experience negative impacts on productivity.

Based on expert judgement from lead authors of the IPCC reports, in 2007, most of the negative agricultural impact up to 2050 will affect poorer regions. Developed countries, typically in northern hemispheres, are expected to experience some positive impact, at least in the earlier half of the twenty first century. However, from a global food production perspective, many of the staple foods (cereals, grains, etc.) that all populations rely on, and that are traded globally, are produced in areas that may experience negative impacts. Increased climatic variability may be more damaging than gradual changes in temperature, per se.

How these impacts affect food security will depend on socio-economic factors and on the policies put in place to adapt to climate change.

6.5.2 What are the likely nutritional impacts?

Probable reduction in nutritional quality - will vary for different crops but the general trend is negative

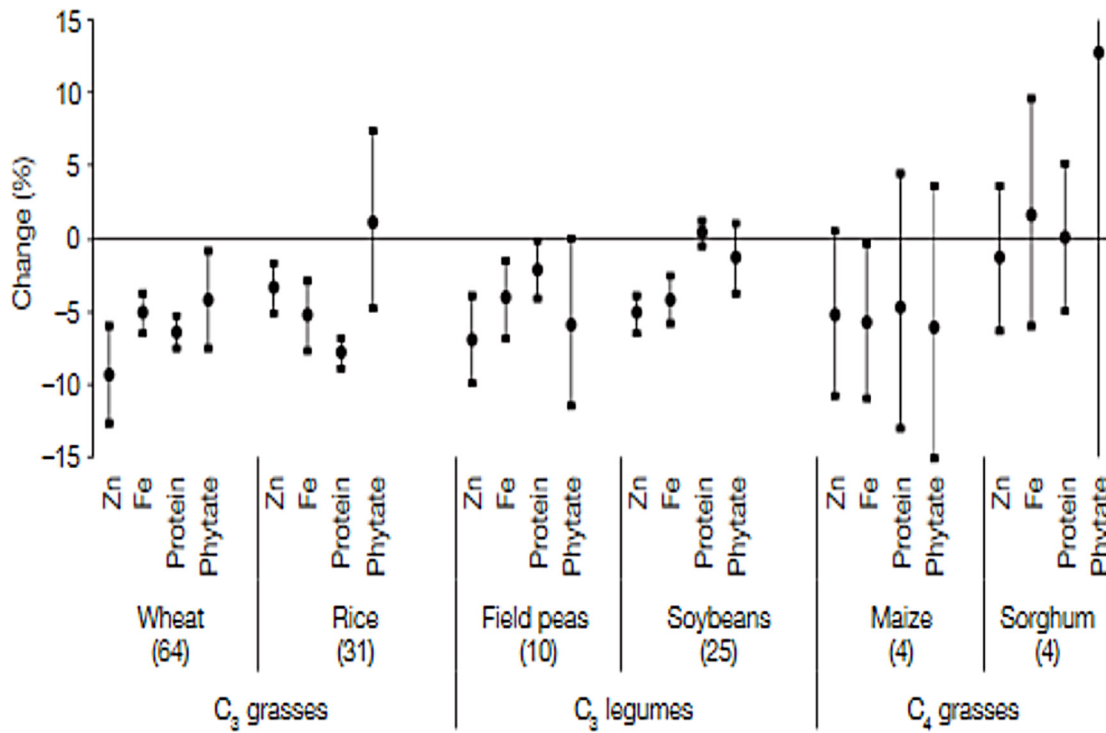


Figure 16: Percentage change in nutrients in crops at elevated levels of CO₂ (546 - 584 ppm) relative to ambient CO₂ levels (363 - 386 ppm).

Source: Myers, et al. (2014).

The study (whose results are shown above), tested changes in nutritional quality for a variety of crops, in field experiments, under conditions of increased atmospheric CO₂, finding reductions in nutrients in most cases. Some crops showed less negative (and in some cases, positive) changes, but the nutritional quality of key crops such as wheat, rice and legumes is expected to suffer as a result of climate change.

Nutritional impacts: high degree of uncertainty and complexity

Increased concentrations of CO₂ have been linked to reduced protein content in some crops (e.g. wheat) and decreases in zinc, sulphur, phosphorus, magnesium, and iron in wheat and barley.

But these relationships are very complex and uncertain, and are likely to vary by region, and by crop type.

6.5.3 What are the likely economic impacts on food security?

Supply and price volatility will impact food insecure regions and net food importers

Food security has been defined by the United Nations Food and Agriculture Organisation as follows:

“food security exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food which meets their dietary needs and food preferences for an active and healthy life.”

(see [Chapter 7](#) for more on food security).

How might climatic change impact food security?

- Countries who are net food importers are particularly vulnerable.
- Low-income economies that are net food importers could experience significant losses in food access through a double negative effect on:
 - reduced domestic agricultural production;
 - increased food prices on global markets.
- Any increases in climate extremes will exacerbate the vulnerability of all food-insecure people, including urban citizens and rural smallholders.
- With greater food insecurity, people may prioritise securing enough calories over accessing nutrient dense foods – with negative consequences for micronutrient deficiencies and childhood stunting.

Impacts of price increases will impact poorer regions more significantly

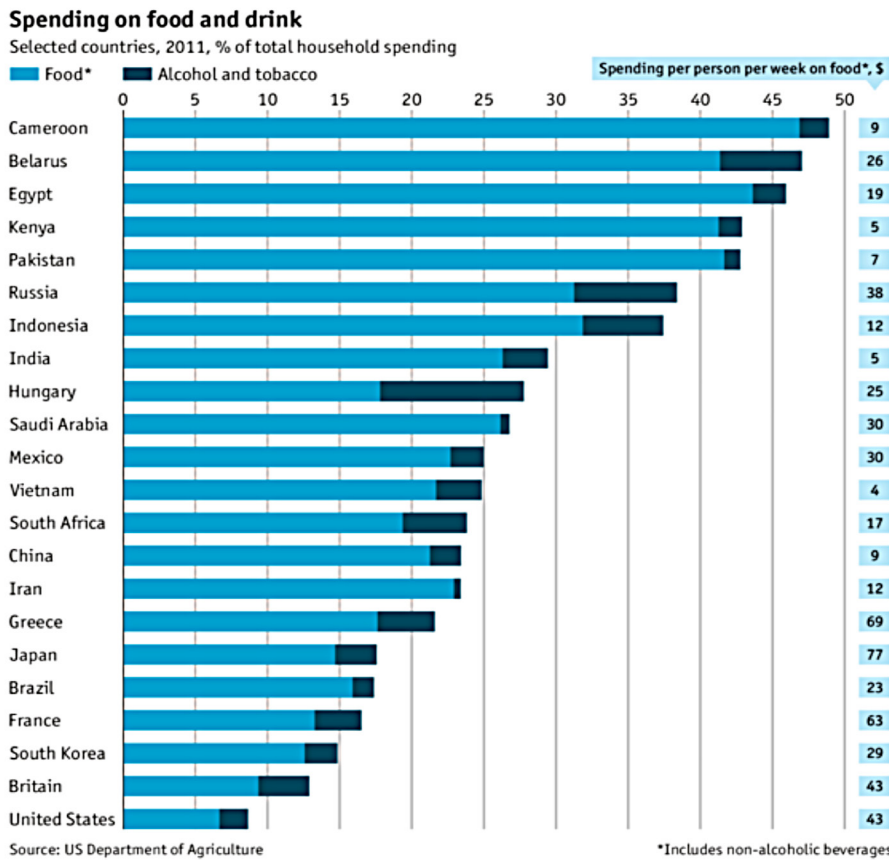


Figure 17: Poor people spend more of their budget on food. This means less for education and health, increasing overall vulnerability.

Source: Economist (2013).

The proportion of income that is spent on food varies widely across countries and within populations, and is linked to inequality of incomes. Populations who spend a high proportion of their income on food are more vulnerable to supply and price changes in food, but additionally have less disposable income to spend on, for example, education and health. They can also be more vulnerable to sanitation risks, lack of safe drinking water and related illnesses. This poverty trap exacerbates health outcomes; poorer populations are more food insecure and more vulnerable to connected health problems. For more on the impacts of poverty on health, in relation to food and nutrition, see [Chapter 7](#).

Higher food prices could be beneficial to net food producers but many of the world's poorest farmers are actually net food purchasers.

6.6 Conclusions

- Conditions that determine crop growth are intrinsically linked to the climate and the environment; changes are likely to impact on crop growth.
- Uncertainty exists about the predicted impacts of climatic change, although some positive and negative impacts are expected.
- The scale of impact depends on the degree to which climate changes.
- Some changes in crop production and fish migration have already been observed.
- Without mitigation or adaptation, the impacts on food production, overall, are expected to be negative, although regional differences will occur.
- Poorer countries will be affected most because:
 - Climate change will affect those regions most severely.
 - Poor people and lower-income nations are less able to adapt to changes in climate (e.g. by investing in the necessary infrastructure or training); afford higher food prices; or cope with price and supply volatility.

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