CLIMATE CHANGE IMPACT ON FOOD SECURITY

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To end of hunger and malnutrition and achieve food security and improve nutrition is at the heart of the sustainable development goals. At the same time, climate change is already impacting agriculture and food security, and will make the challenge of ending hunger and malnutrition even more difficult. The effects of climate change on our ecosystems are already severe and widespread, and ensuring food security in the face of climate change is the most daunting challenge facing humankind. While some of the problems associated with climate change are emerging gradually, action is urgently needed to build resilience in agricultural production systems. Despite tremendous progress in crop production, almost 800 million people are chronically undernourished, and 161 million under-five year olds are stunted (FAO, 2016).According to the United Nations (2015) report, there are still 836 million people in the world living in extreme poverty (less than USD1.25/day). At least 70% of the poor people live in rural areas, most of them depending partly or completely on agriculture for livelihood. It is estimated that 500 million smallholder farms in the developing world are supporting almost 2 billion people. In Asia and sub-Saharan Africa, these small farms produce about 80% of the food consumed (IFAD, 2011).

According to the IPCC's Fifth Assessment Report, changes in the climate over the last 30 years have already reduced global agricultural production by 1 – 5 % per decade relative to a baseline without climate change. Recent studies have indicated that a 2 degrees increase in global temperature will affect agricultural productivity, particularly in the tropical regions (Kirtman *et al*., 2013; Dinesh *et al*., 2015). Rise in global temperature is largely due to increased concentrations of greenhouse gases, which include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and chlorofluoro-carbons (CFCs). Over the past 200 years, the atmospheric concentration of carbon dioxide has increased by 35%, and is expected to double by the end of this century, i.e. 300 ppm the preindustrial era versus 401 ppm at present (Houghton et al. 1995; NOAA 2016).

Constraints to food security

Climate change and climate variability will have major implications for water availability, forest cover, biodiversity, crop production, and food security. Changes in rainfall pattern are of greater importance for agriculture than the annual changes in temperature, especially in regions where lack of rainfall may be a limiting factor for crop production. Uncertainties are greater when the implications of climate change on food

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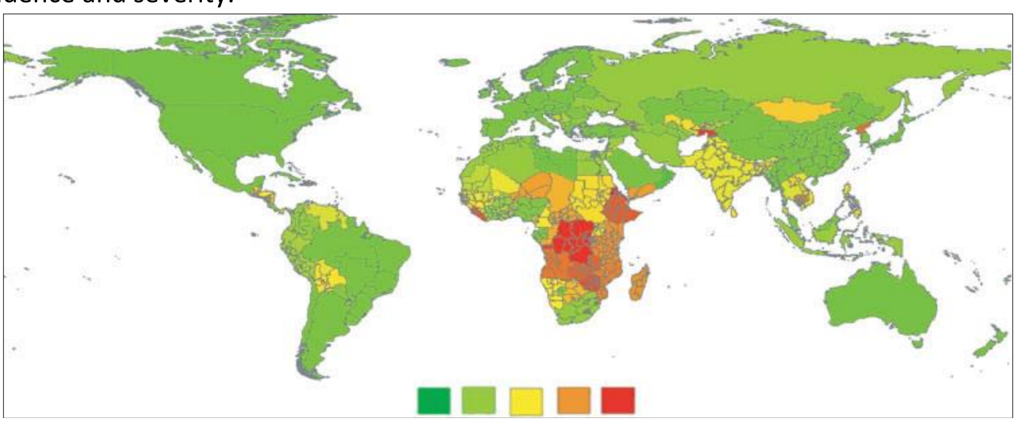
security are considered. Food security can be defined as ''when all people, at all times, have physical and economic access to sufficient, safe, and nutritious food to meet their dietary needs and food preferences for an active and healthy life'' (FAO, 2003). Issues such as education, poverty, poor market access, food price increase, unemployment and property rights are also cited as causes of food insecurity (Scholes & Biggs, 2004). These have resulted in many food security 'hotspots' around the world, particularly where multiple factors coincide (Fig. 1). Sub-Saharan African countries feature high in this list.

The water limitation is key to food security and is normally the rate-limiting factor for plant growth at lower latitudes, whereas irradiation is the key rate-limiting factor at many higher latitudes (Churkina & Running, 1998; Baldocchi & Valentini, 2004). There is no overall trend for amount of precipitation change, but there is clear historical evidence of changed distribution patterns both regionally and seasonally (Barnett *et al*., 2006). These changes will produce cropping changes which will have implications for food availability, directly or indirectly, through, for example, consequent changes in pathogen and pest incidence and severity.



Lowest concern   Highest concern

Fig 1. Identification of food insecurity hotspots based on hunger, food aid and dependence on agricultural gross domestic production statistics from FAOStat and WRI; 2001–2003. [Global Environmental Change and Food Systems (GECAFS), personal communication].

Climate change, pest associated losses and food security

To understand how best to control insect pests and diseases to improve food security in the context of climate change, plant protection professionals must work with societal change, defining its key processes and influencers to effect change. Insect pests and diseases could potentially deprive humanity of up to 82% of the attainable yield in the case of cotton and over 50% for other major crops (Oerke, 2006).Insects pests, one of the major constraint in food production, are also sensitive to climate change (Insect pests cause an estimated annual loss of 10-16% globally (Chakraborty and Newton, 2011), and the pest associated losses in India have been estimated to be 17.5% (Dhaliwal *et al*. 2010) valued at USD220 billion. The insect pest associated losses are likely to increase as a result of changes in crop diversity, cropping patterns, cropping intensity and climate change (Table

1). Pest associated losses have increased from an average of 7.2% during the pre-green revolution period to 23.3% during the post green revolution period in different crops in India (Dhaliwal *et al.*, 2010). Geographical distribution of tropical and subtropical insect pests will extend along with shifts in the areas of cultivation of their host plants, while the relative abundance of some insect species vulnerable to high temperatures in the temperate regions may decrease. High mobility and rapid population growth will increase the extent of losses due to insect pests.

Table 1. Pest associated losses in different crops during the pre- and post-green revolution in India.

Crop	Pre-green revolution (early 1960s)	Post-green revolution (early 2000s)	Changes in pest associated losses
Cotton	18.0	50.0	+ 32.0
Groundnut	5.0	15.0	+ 10.0
Other oilseeds	5.0	25.0	+ 20.0
Pulses	5.0	15.0	+ 10.0
Rice	10.0	25.0	+ 15.0
Maize	5.0	25.0	+ 20.0
Sorghum and millets	3.5	30.0	+ 26.5
Wheat	3.0	5.0	+ 2.0
Sugarcane	10.0	20.0	+ 10.0
Average	7.2	23.3	+ 16.1

Source: Dhaliwal *et al*., (2010).

Main Climate Changes of Importance for the Agriculture Sectors

The impact of climate change will vary across regions, crops and species. A large number of models and proto-cols have been designed to measure the effects of climate change for different species and in different disciplines. Long-term monitoring of population levels and insect behavior, particularly in identifiably sensitive regions, may provide some of the first indications of a biological response to climate change. There is a need for inter-disciplinary cooperation to measure the effects of climate change on the environment and food security. It will be important to keep ahead of undesirable pest adaptations, and consider global warming and climate change for planning research and development efforts for integrated pest management (IPM) in the future. The temperature increases associated with climatic changes could result in: change in geographical range of insect pests; increased overwintering and rapid population growth; changes in insect–host plant–natural enemy interactions; impact on arthropod diversity and extinction of species; changes in synchrony between insect pests and their crop hosts; introduction of alternative hosts as green bridges; changes in relative abundance and effectiveness of biocontrol agents; change in expression of resistance to insects in cultivars with temperature-sensitive genes; emergence of new pest problems and increased risk of invasion by migrant pests; and reduced efficacy of different components of insect-pest management.

Climate change and emerging pest problems in India

Several insect pests, that were important in the past or the minor pests, are likely to become more devastating with global warming and climate change (Sharma, 2013) (Fig 2).

Fig. 2. Pest outbreaks due to climate change (a = Pod borer, *Helicoverpa armigera* damage in pigeonpea following wet weather conditions in Sept – Oct, b = Mealy bug, *Ceroplastodes cajaninae* infestation in pigeonpea under prolonged hot and dry conditions, c = Beet armyworm, *Spodoptera exigua* damage in chickpea triggered by winter rains on Oct – Nov, and d = Pink stem borer, *Sesamia inferens* damage in sorghum due to hot and dry conditions during the post rainy season).

Many insect species, that will move to newer areas as invasive pests will also pose a major threat to crop production and food security, as they find more suitable climatic niches in the new areas. The invasive species are likely to cause more harm in the absence of natural enemies in the new habitats.

Table 2. Insect pests that have become or are likely to become serious pests due to climate change and changes in cropping patterns.

Insect pest	Scientific name	Crop(s)
American bollworm	*Helicoverpa armigera* (Hubner)	Cotton, chickpea, pigeonpea, sunflower, tomato, etc.
Beet armyworm	*Spodoptera exigua* (Hub.)	Chickpea in southern India
Spotted pod borer	*Maruca vitrata* (Geyer)	Pigeonpea, cowpea, lab-lab beans
Diamondback moth	*Plutella xylostella* (L.)	Cabbage, cauliflower
Pink stem borer	*Sesami ainferens* (Walk.)	Maize, sorghum, wheat
Whitefly	*Bemisia tabaci* (Gen.)	Cotton, tobacco
Brown planthopper	*Nilaparvata lugens* (Stal)	Rice
Green leafhopper	*Nephotettix* spp.	Rice

Insect pest	Scientific name	Crop(s)
Serpentine leaf miner	*Liriomyza trifolii* (Burg.)	Cotton, tomato, cucurbits, several other vegetables
Fruit fly	*Bactrocera* spp.	Fruits and vegetables
Mealy bugs	*Paracoccus marginatus* Williams &	Several field and horticultural Crops
	Granara de Willink	
	Phenococcus solenopsis (Tinsley)	
	Cerolastodes cajaninae (Mask.)	
Thrips	Several species	Groundnut, cotton, chillies, citrus, Pomegranate
Wheat aphid	*Macrosiphum miscanthi* (Takahashi)	Wheat, barley, oats
Pod sucking bugs	*Clavigralla*spp.	Pigeonpea
Gall midge	*Orseolia oryzae* (Wood-Mason)	Rice
Termites, white grubs	Several species	Many crops
Sugarcane aphid	*Ceratovacuna lanigera* (Zehnt.)	Sugarcane

Based on Prasad and Bambawale (2010), Fand et al., (2012) and Sharma (2013).

Climate change effects on geographic distribution of insect pests

Low temperatures are often more important than high temperatures in determining geographical distribution of insect pests. Increasing temperatures may result in a greater ability to overwinter in insect species limited by low temperatures at higher latitudes, extending their geographical range (EPA 1989; Hill and Dymock, 1989). Spatial shifts in distribution of crops under changing climatic conditions will also influence the distribution of insect pests in a geographical region (Parry and Carter, 1989). There are several examples of change in the geographic distribution of several insect species as a result of climate change (Table 3). However, whether or not an insect pest would move with a crop into a new habitat will depend on other environmental conditions such as the presence of overwintering sites, soil type and moisture. Populations of the corn earworm [*Heliothis zea* (Boddie)] in the North America might move to higher latitudes/altitudes, leading to greater damage in maize and other crops (EPA 1989). The cotton bollworm/ legume pod borers, *H. armigera* and *M. vitrata* will move to temperate regions in northern Europe (Fig. 3). *Helicoverpa armigera* has already reached Brazil as an invasive pest, and is likely to move to North America (Czepak *et al*., 2013).Distributions of spruce budworm *Choristoneura fumiferana* under distribution shifts may be good or bad, depending on the species and the regions concerned (Regniere *et al*., 2010).Fruit flies, *Bactrocera tryoni* (Froggatt), *Bactrocera cucurbitae* (Coquillett) and *Bactrocera latifrons* (Hendel), may be spread into colder areas due to increasing temperature (Prabhakar et al. 2012).For all the insect species, higher temperatures, below the species' upper threshold limit, will result in faster development, resulting in rapid increase of pest populations as the time to reproductive maturity is reduced. In addition to the direct effects of temperature changes on development rates, increases in food quality due to plant stress may result in dramatic increases in growth of insect pest populations, while the growth of certain insect pests may be adversely affected (Maffei *et al*., 2007).Climate change may increase the impact of pests by allowing their establishment in areas where they could previously not establish. Changes in temperature can result in changes in geographic ranges and facilitate overwintering. Some species could therefore extend their geographic range towards the pole and to higher altitudes (Porter *et al.*, 2014; Svobodová*et* et al., 2014). Climate change may also increase the impact of pests by allowing them to appear earlier in the season due to higher temperatures. Potential changes in temperature, rainfall and wind patterns associated with climate change are expected to have a dramatic effect on desert locust in Africa, the most dangerous of all migratory pests (Cressman, 2013)

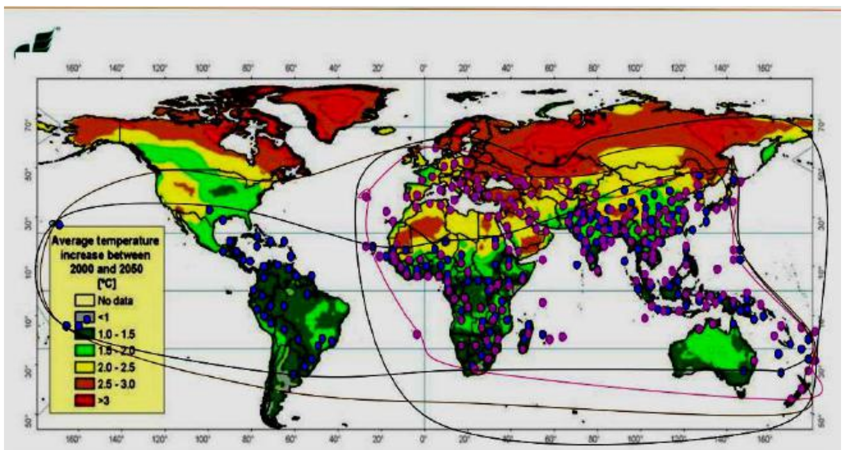


Fig 3. Likely changes in geographical distribution of cotton bollworm/legume pod borer, *Helicoverpa armigera (*red line: current, and black line likely distribution in future), and spotted pod borer, *Maruca vitrata* (blue line current, and brown line future distribution) (Sharma 2013).

Table 3. Examples of changes in geographic distribution of insect pests as a result of climate change.

Insect pest	Host plant/s	Impact on insects / behavioral Response	Reference
Corn earworm, *Helicoverpa zea* (Boddie)	Maize	Range expansion to higher altitudes and northern Europe and USA, and increased overwintering	Diffenbaugh *et al.* (2008)
European corn borer, *Ostrinia nubilalis* (Hub.)	Maize	Northward shifts with an additional generation per season Increased presence in southern	Porter *et al.* (1991)
Old world Bollworm *Helicoverpa armigera*		Europe and outbreaks	Cannon (1998)
Pod borers, *Helicoverpa Armigera* and *Maruca vitrata* (Geyer)	Cotton, pulses, vegetables	Expansion of geographic range in northern Asia and Europe	Sharma (2013)
Oak processionary moth, *Thaumetopoea processionea* (L.)		Northward range extension from southern Europe to Belgium, Netherlands and Denmark	Cannon (1998)
Non-migratory butterflies		Pole ward shift of geographic range	Parmesan and Yohe (2003)

Strategies for addressing climate change impacts on insect pests and diseases

While climate change impacts on insect pests on agricultural systems present challenges and have an element of uncertainty, there are possible strategies to address these impacts. The key components of an effective strategy to combat insect pests and diseases include

- ✓ **Capacity enhancement:** The capacity of regional, national, as well as local organizations to detect and respond to insect pests will need to be increased. These organizations will need to be supported with accurate information on pests and disease presence, level, impacts and the costs for control.
- ✓ **Coordination: Incest** pests and disease impacts are not constrained within national boundaries, and thus response strategies should develop approaches to coordinate at the regional and continental scales.
- ✓ **Data quality and quantity:** There are gaps in our current knowledge on pests and diseases, these gaps arise from a lack of data in some cases and poor data quality or non-comparable data in other cases. Streamlining and increasing data collection efforts will allow response strategies to be science-based.
- ✓ **Pre-emptive breeding:** Breeding for insect pest and disease resistant varieties is a key component of response strategies in the crop, livestock, and aquaculture sectors.
- ✓ **Resilience of production systems:** Overall increase in resilience of production systems will allow these to withstand shocks from increased incidence of insect pests and diseases.
- ✓ **Research and development:** Research and development to improve approaches for forecasting and predicting pests and disease outbreaks, as well as into mechanisms to manage these outbreaks are be crucial under climate change.

Finally, we need to adopt an integrated pest and disease management system that takes into consideration the change in pest spectrum, cropping patterns and effectiveness of different components of pest management for sustainable crop production.

Suggested Readings

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