

Submission from the International Center for Tropical Agriculture (CIAT) on behalf of the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS), to UNFCCC SBSTA 42 on issues related to agriculture in response to SBSTA decision FCC/SBSTA/2014/L.14.

These are views on the assessment of risk and vulnerability of agricultural systems to different climate change scenarios at regional, national and local levels, including but not limited to pests and diseases FCC/SBSTA/2014/L.14 paragraph 3 (b).

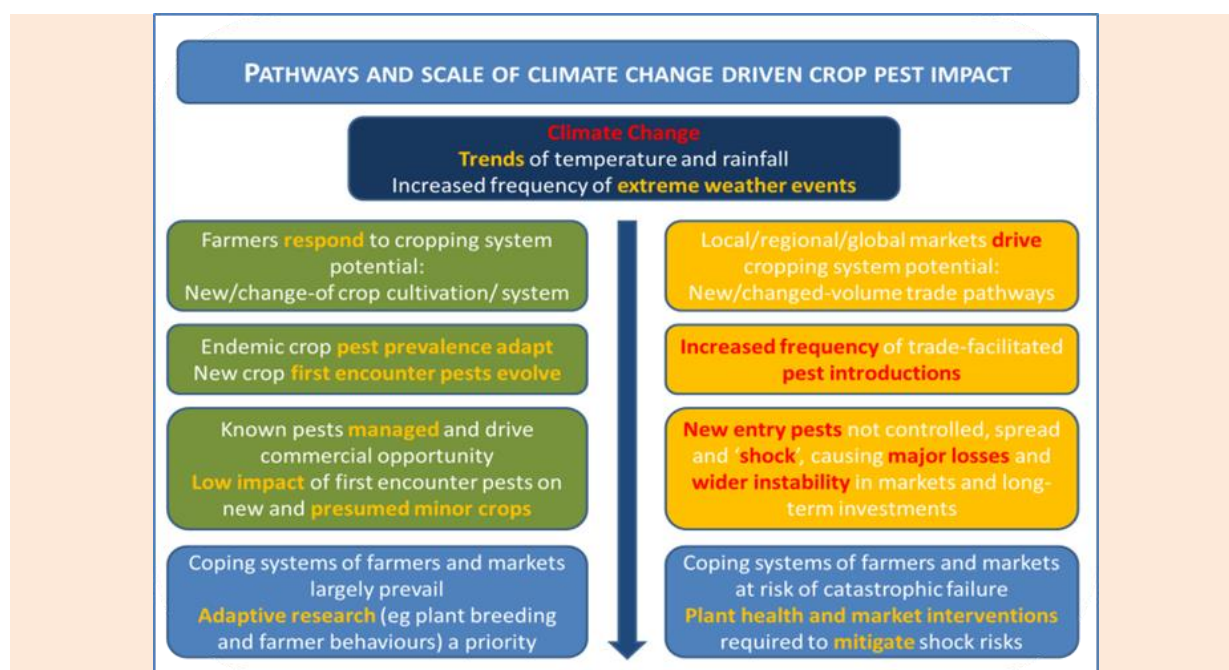
CROPS, CROP PESTS AND CLIMATE CHANGE – WHY AFRICA NEEDS TO BE BETTER PREPARED

A signature of a resilient agricultural system is where investments in prevention (anticipation, mitigation, preparedness and response) trumps curative action (firefighting).

SUMMARY

Ongoing investments in agriculture will not deliver for Africa until the destabilising nature of crop pest¹ events, especially shock outbreak events, are addressed. As a result of climate change, the prevalence of crop pests will change and the frequency of shock pest events will increase, putting agricultural systems at risk. The granularity of these changes, in terms of choices by farmers, cropping systems and markets, presents a critical challenge.

Two pathways to impact are described centred in farmer and market responses:



The following recommendations are put forward:

- **Recommendation 1:** *Build capacity of plant health organisations, as key partners at the front-line against crop pests, in support of food security, trade and policy implementation*

¹ The term pest is used throughout to cover any species, strain or biotype of plant, animal, or pathogenic agent, injurious to plants or plant products (FAO glossary definition) i.e. pests, diseases and LMOs.

- **Recommendation 2:** *Improve data gathering, centred on better understanding of critical metrics of crop pest impacts, extending beyond yield loss and encompassing economic and investment factors to improve prediction capabilities*
- **Recommendation 3:** *Enhance the understanding of risk behaviours of food chain stakeholders and their willingness to invest and adapt, to support increased adoption of technologies*
- **Recommendation 4:** *Improve fusion of disparate datasets and risk modelling of crop pest consequences for projections on farmer choices and cropping system at the landscape scale, informed by markets and policy*
- **Recommendation 5:** *Invest in pre-emptive crop pest resistance breeding against future high risk pests based on current and future geographic distributions in order to avoid the consequences of shock pest episodes*
- **Recommendation 6:** *Take cognizance of the boundary less nature of crop pests, and develop regional supra-governmental capabilities for the analysis and articulation of horizon scanning and crop pest risk concerns under climate change*

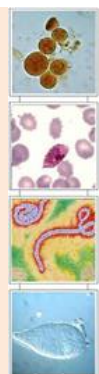
ADAPTATION TO CLIMATE CHANGE AND THE MITIGATION ON CROP PEST THREATS

At various levels the path towards adaptation to climate change and crop pest events identifies with challenges. The following set out a number of priority research areas and recommendations.

Plant health Services

- *Recommendation 1: Build capacity of plant health organisations, as key partners at the front-line against crop pests, in support of food security, trade and policy implementation*

It is to evident by the current failure to prevent major pest events that Africa needs much improved crop pest surveillance, along with capacity to identify crop pests. Awareness of pest lists, distribution and prevalence for a country is very low, and Africa continues to rely on external capability for crop pest identification, especially those that are new and of greatest risk. In building these capacities innovation is needed to embed costs with sustainable services. The role of industry and Non-Government Organisations (NGOs), as a partner to government, must be exploited more than is currently the case. A current example is with Maize Lethal Necrosis and the ongoing failure of industry and NGO (and the donors that give support to the NGOs) to work with governments to prevent the causal viruses moving with commercially traded seed.



The weakness of crop pest surveillance in African was identified as the number 1 risk from future diseases¹.

All first outbreak identifications of Banana Xanthomonas Wilt, Uganda Cassava Brown Streak Disease and Maize Lethal Necrosis were undertaken outside of Africa.

Data gathering

- *Recommendation 2: Improve data gathering, centred on better understanding of critical metrics of crop pest impacts, extending beyond yield loss and encompassing economic and investment factors to improve prediction capabilities*

Any capacity to predict is predicated on the inputting of reliable data, such as land-use, yield, yield loss, pest prevalence, agro-inputs, market values etc. Some of these data needs will, with increased accuracy, be captured by remote sensing technologies, based on increasingly routine satellite and other aerial imagery capture systems. Other data will have to be gathered by more prosaic practices and direct engagement with production chains. Significant innovation is required in all areas of information capture, noting that remote sensing and land-based mobile information sourcing are two highly dynamic areas of science. The opportunities to be exploited in these areas are highly compelling.

Risk acceptance and behaviours – farm to markets

- *Recommendation 3: Enhance the understanding of risk behaviours of food chain stakeholders and their willingness to invest and adapt, to support increased adoption of technologies*

Understanding the risk acceptance behaviours of stakeholders to a food value chain is profoundly linked with wealth-poverty and vulnerability. How severe and how frequent must a bad experience be suffered to induce change, and how attractive must an opportunity be to invest in and accept? Our experience on technology adoption attests to the difficulty in understanding the influencing required to promote positive, evidence-based, choices with stakeholders. In context of climate change the confounding of 'long' timeframes by which climate change impacts over the 'short' timeframe by which stakeholders make decision-making adds to the complexity. Understanding the innate rate of adaption with stakeholders is critical to predicting and planning.

Predictive modelling and analysis of risk

Recommendation 4: Improve fusion of disparate datasets and risk modelling of crop pest consequences for projections on farmer choices and cropping system at the landscape scale, informed by markets and policy

It is evident that we need to improve our ability to predict, with greater certainty, how markets and cropping systems will progress under climate change and other drivers (eg population and diet), and the crop pest prevalence and new entry/outbreak risks that these carry. Increased use of earth observations and models are required, which are iteratively truthed by highly granular farm and market level data. Modelling and crop Pest Risk Analysis need to be aligned to provide medium to long-term forecasts on market and landscape change. Such awareness is only meaningful if linked to contingency and response to mitigate crops against specific pest events in a timely way.

Pre-emptive plant breeding

Recommendation 5: Invest in pre-emptive crop pest resistance breeding against future high risk pests based on current and future geographic distributions in order to avoid the consequences of shock pest episodes

Predictions of what pest are likely to be a future threat must structure plant breeding programmes more than is currently the case. That a pest is absent from an area only by virtue of not having been introduced, or that a particular pest under a changed cropping system may emerge as a major threat can be anticipated. Pre-emptive breeding, as opposed to the current reactive approach, on crop pests must be seen as a sound investment if the consequences of shock pest episodes are to be avoided.

Supra-governmental body for cohesive and scaled action

Recommendation 6: Take cognizance of the boundary less nature of crop pests, and develop regional supra-governmental capabilities for the analysis and articulation of horizon scanning and crop pest risk concerns under climate change

A good example of global cooperation is in response to Fusarium Tropical Race 4 and the threat to Cavendish banana. This new race of Panama Disease, which wiped out Gros Michel and led to the global mono-culture and commercial cultivation of Cavendish, has long been recognised as a threat. However, the first outbreak in Southern Africa has galvanised a global effort involving FAO, governments, academia and industry.

The granularity of adaptive measures to climate change is paramount in providing context at the local scale such as with the farmer, the field and market. However, most of the threats are best conceived as regional, even continental, and require interventions at that scale. By example crop pests do not respect

boarders and therefore any intervention to prevent the country-to-country spread of a crop pest requires regional and global cooperation.

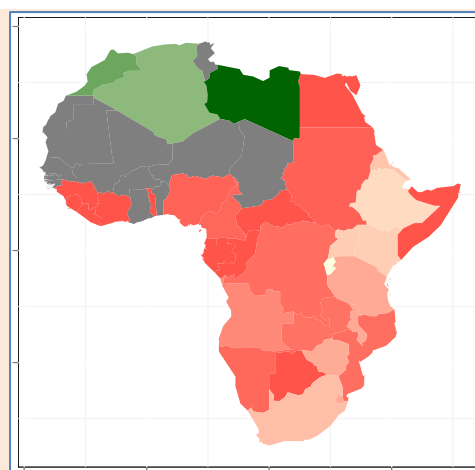
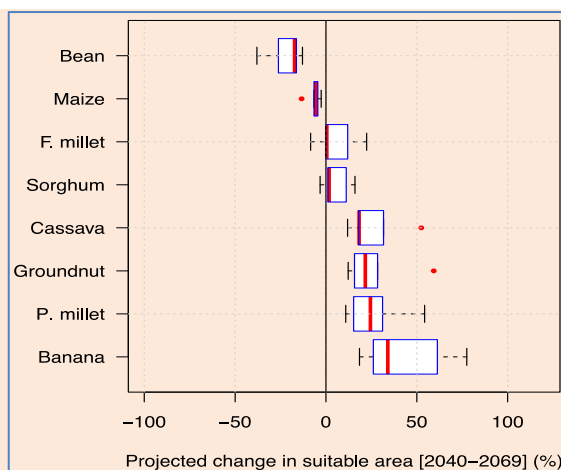
Africa has a number of supra-governmental bodies associated with agriculture, but none of these take on the task of horizon scanning and risk analysis. Such bodies would be ideally placed to be aligned to CAADP and provide high-level, evidence-based advice and guidance on research and policy priorities and could fast-track the legislative process.

FUTURED SYSTEMS

Assuming in the near future (10-20yrs) the potential of African agriculture is realised then we can expect much greater integration of local markets with regional and global markets. Population and dietary changes will have shaped this position and the transition will have taken place against the backdrop of climate change. The influences of these drivers are known to be most profound on Africa more than other continents.

Recent reports supported by DfIDⁱⁱ and OECDⁱⁱⁱ conclude that investment in African agriculture is a fast track to poverty reduction, and with a greater rate of return than other investment options.

The cropping systems of Africa will have evolved to these drivers. Many new trading pathways will have come to fruition at scales of village to global. Climate change will likewise have impacted on the productivity-potential of regions to support certain crops; whilst some crops will be favoured others will not be. We will have different crops and different proportions of crops. Some of the cultivars grown will be with enhanced traits to mitigate the stresses of climate change (eg drought and heat stress tolerances) and that allow the crop to persist in a system.



Projected changes in crops for Sub-Sahara Africa for 8 crops (left) and for beans at the continent level (right; green is positive and red negative)^{iv}

In parallel to these changes in the cropping system the natural environment will also have adapted with the fauna and flora of off-farm and in-field (weeds and field margin) environments acceding new climatic vegetative states. The ecosystem services, alongside the potential crop pest threat, provided by these environments stand to be markedly affected, yet the futured nature of these environments is largely unstudied. Some of the clearest examples of climate change on insects are with natural systems.



Fauna and flora of off-farm and in-field environments will change with changes in climate affecting ecosystem services and crop pests

To understand the underpinning biological and human processes that will determine the trade-offs and wins to be exploited in agriculture for Africa under climate change is critical. The real-life

hypothesis under test is to what extent climate change, and related shock events, will outpace the natural rate of change that farming and markets can absorb. In this space the off-setting of risk and capture of opportunity by technology, policy and other interventions is explored.

CROPS, CROP PESTS, CLIMATE CHANGE AND RISK

Crop pests already figure as a major factor in farm productivity. Various figures suggest that globally about one sixth of production is lost to pests in field, with further losses in storage. Our adaptations vary greatly depending on the familiarity and ability to control the pest, and if the crop is annual or perennial.



The Great Irish famine of the 19th Century was caused by potato blight (left), and today this remains a persistent but manageable pest. Coconut Lethal Yellowing Disease has over the past 10 years devastated coconut production in much of Mozambique, upwards into Tanzania and Kenya. No control is known and the perennial and long life nature of coconut makes such losses irreversible.

A vast majority of crop pests are familiar to farmers and present every-day challenges. Most can be managed, and it is often the farmers that manage these crop pests best that prosper. Occasionally, rare-event, shock outbreak pests occur; as new virulences (eg Uganda cassava brown streak virus) or introductions (eg Maize Lethal Necrosis viruses). These outbreak pests are unfamiliar to farmers, not easily managed, and, by consequence, with the potential to devastate large areas of production over short (1-5yr) periods of time.



In the past 20 years major pest outbreaks have afflicted Africa. From left to right: Banana Xanthomonas Wilt, Maize Lethal Necrosis Disease, Cassava Brown Streak Disease, Cassava Mosaic Disease

Climate change will progressively change what crops are grown where, shaped by the dynamic economics of local markets, imports and exports. Layered on this will be extreme weather events that are expected to increase under climate change and result in the shock of seasonal failed production. These outcomes directly identify with significant crop pest risk events:

- **Markets:** Changes in trade routes by volume and/or origin of procurement relate to increased risk in pest introduction. Whilst much of this change will be progressive with trends in climate change, shock weather events will result in short-term response market adaptation.

A recent study showed that plant pests are moving polewards at a rate of $2.7 \pm 0.8 \text{ km yr}^{-1}$; but with substantial variations associated with taxonomic groups. These new distributions most probably reflect the impact of climate change on pest establishment^v.

- **Cropping systems and environ:** Changes in the cropping system will see changes in pest prevalence simply due to changes in the proportions of crops grown. Changes in climate will equally favour, or otherwise, a pest; with increased or decreased potency resulting. Situations of incremental additional loss will be incurred as well as tipping points for invasive status. First encounter pests may also arise as an outcome of changes in the fauna and flora of off-farm and in-field environment associated with new crop entrants, or by maintaining a crop in a changed environment by breeding (eg tolerance to drought).

*Many of our major pests are example of first encounter events. For Africa these include *Phytophthora megakarya* on cocoa and both *Cassava Mosaic* and *Cassava Brown Streak Viruses* of cassava.*

- **Efficacy of pest control and food safety:** Associated with increased pests will be an increased reliance on pesticides. This situation is exacerbated by reliance under new regulations on a restricted list of approved bioactives that will drive rates of pesticide resistance. Accordingly, increased applications of pesticides, especially on leafy vegetables, will present a higher risk to food safety. The other major food safety issue associated with climate change is with mycotoxins, currently the main food safety issue in Africa. The extent to which mycotoxins present a changed risk will be dependent on the climate and weather. Extreme weather events may again present the main initiator of mycotoxin episodes.

These crop pest outcomes identify with the risk of uncertainty, driven by the economics of markets, the production potential of land, as influenced by climate change in terms of trends of temperature and rain and shock weather events. The extent to which stakeholders, from farm to market and including associated industries of processing, are impacted by these outcomes will largely depend on their risk behaviour, yet relatively few studies seek to inform adaptation through gaining an improved understanding of stakeholder decision-making.

Adoption of orange fleshed sweet potato and new disease resistant cultivars attests to farmers' innate risk aversion behaviours

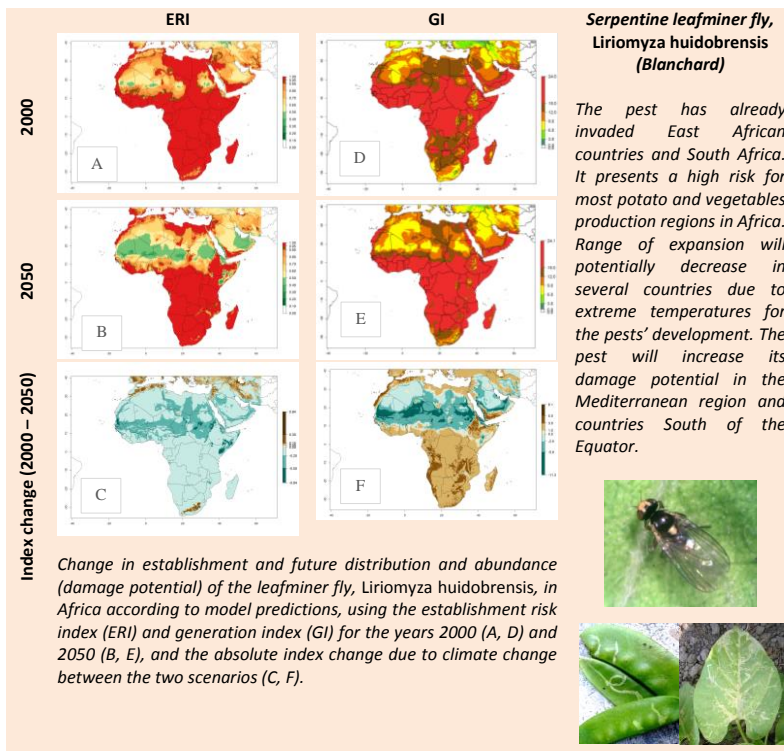
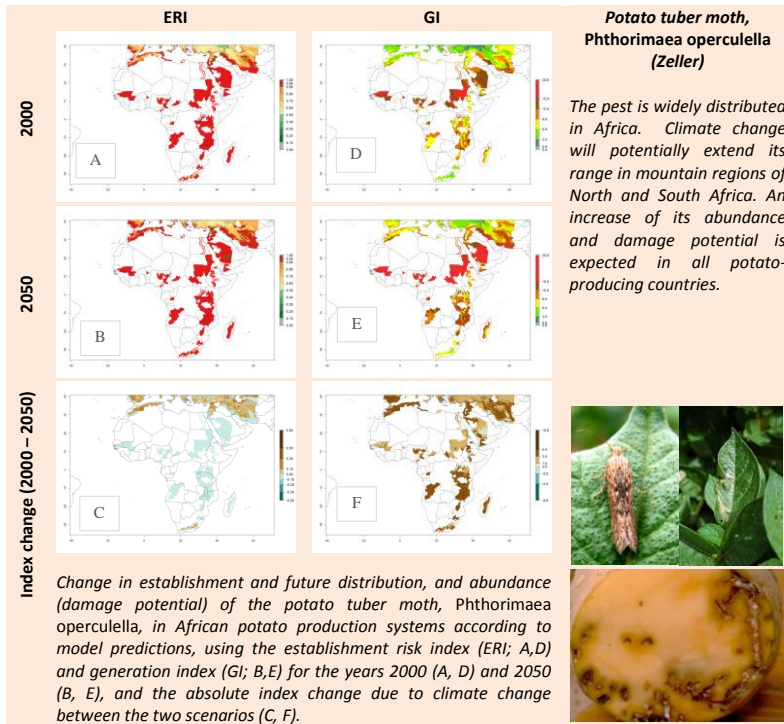
CONSEQUENCES AND LIKELIHOOD OF OUTCOMES

The above describes a two speed system of gradual 'progressive change' and rapid onset 'shock' events.

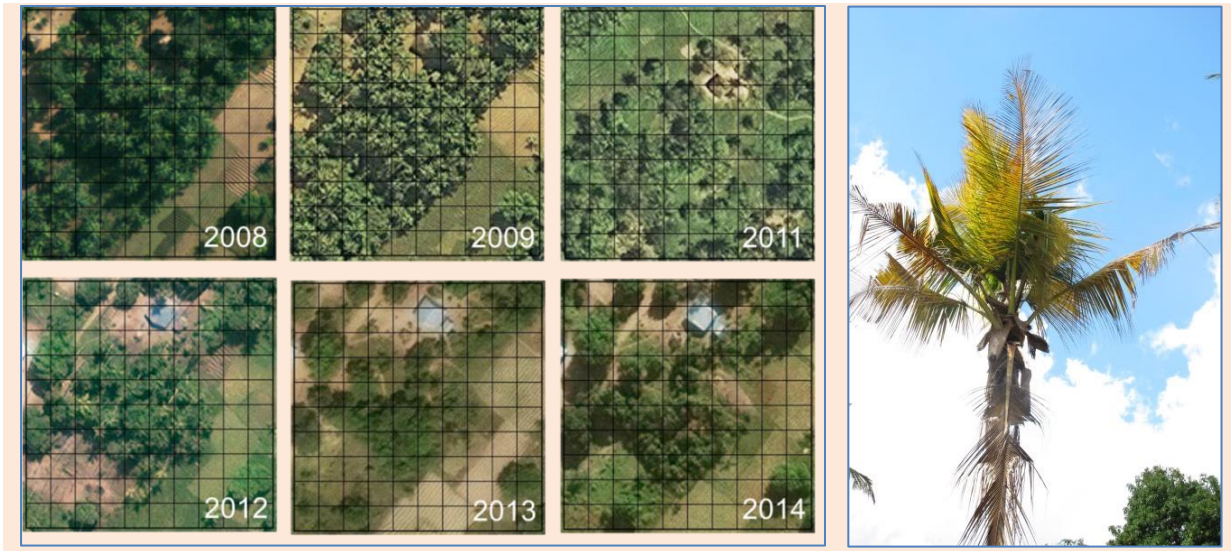
With progressive change an argument can be made that the economics of market forces and innate adaptiveness of farmers will respond to progressive climate change induced change, and that this can even differentiate between farmers and provide commercial advantage. In this scenario research is needed to anticipate market shifts and layer these with changes in land productivity, and then to understand the new agronomic and pest control practices that will best ensure sustainability. Ultimately, strategic and long-term investments in infrastructure, such as processing and access to markets, can then be made based on more sound evidence.

Some of the clearer climate change range expansion examples are with insects, including crop pests. The extent to which pest distribution and damage potential is to be altered by climate change in

Africa is currently being set out in a dedicated work on the ‘Pest Distribution and Risk Atlas for Africa’^{vi}. Two examples are given below for the potato tuber moth, *Phthorimaea operculella* (Zeller), and the serpentine leafminer fly, *Liriomyza huidobrensis* (Blanchard). In both cases it is shown that the range and damage potential caused by these already significant crop pests will increase with climate change. These models are based on temperature-based phenology models and simulated life table parameters of the pest, alongside metrics for estimating the risks for establishment and the number of generations per year, indicating the damage potential of the pest.



This logic for progressive change adaptation applies less with perennial crops, such as coffee, cocoa, and coconuts, where the fixed and long-term nature of the crop will limit adaptive choices. In these situations added pest burdens and direct climatic factors as associated with climate change will need to be endured. The example is given of Coconut Lethal Yellowing in Mozambique. With these cropping systems specific actions are being taken to allow transition to another crop^{vii}.



Satellite images showing progressive decline of coconut over time; associated with Coconut Lethal Yellowing and associated Oryctes beetle infestation. Limited knowledge exists on the epidemiology of Coconut Lethal Yellowing (right). The current epidemic in Mozambique has, in less than 10 years, raised smallholder and plantation coconut stands over areas of 100 sq kms. No control is known and, given the nature of coconut, success through breeding is unlikely in 10 even 20 years, and with farmers many years after that.

Shock events present a very different situation and stand to derail all farmers alike, regardless of education and skills, as controls are either not available or not known to the farmer. This major risk of crop pest outbreaks is not historic, as with the Irish famine and potato blight or Cassava Mosaic Disease in Africa, or in the future and dependent on climate change, or even in the current with Cassava Brown Streak Disease, Coconut Lethal Yellowing Disease or Maize Lethal Necrosis. It is with the next introduction of a new pest having epidemic potential that might be today, in a week's time, but with reasonable certainty within 5-years. A retrospective look at past epidemics tells us that for a new pest epidemic a 10-15yr timeframe will be required for a control practice to be developed and with farmers. In this intervening time, massive direct and indirect consequences ensue.



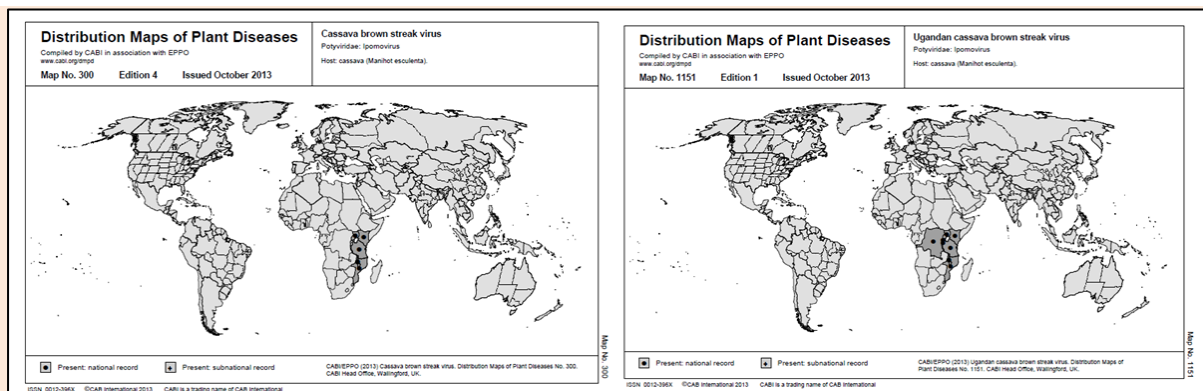
Banana Xanthomonas Wilt (left) has spread across the great lakes region since 2001. Although a simple husbandry control can control the disease, adoption of this practice by farmers' remains inconsistent. Losses over the past 10 years are estimated in the billions of US\$^{viii}.



The causal virus of Maize Lethal Necrosis (left) is believed to have been introduced to Kenya in 2011 from Asia^{ix}. All commercial and landrace cultivars appear susceptible and farmers describe the disease as a fire. The virus is seed borne and the disease is now formally reported in DR Congo and Rwanda, and unofficially known in many other countries of the region. A substantial research effort is now underway to develop resistance to this disease, but realistically a viable option for farmers is probably 5-10 years from now.

Many pest introduction events can be categorised as ‘pending’ as an outcome of trade, illegal human trafficking of plant material or bioterrorism. As argued above, climate change will serve to exacerbate the frequency and severity of such events, unless actions are taken to mitigate the risks. In the below we show one example of Cassava brown streak viruses to exemplify their geographic isolation to Sub-Sahara Africa and therefore the risk of future spread to other parts of Africa and regions of the world. Cassava mosaic viruses are similarly present in Africa and absent in South America and Asia. It is known that the cultivars of cassava grown in South America and Asia are susceptible to both Cassava brown streak and Cassava mosaic viruses. Many other examples of crop pest geographic isolation can also be pointed to that carry a high potential for damage if introduced into other regions of the world. Banana Xanthomonas Wilt is limited to Sub-Sahara Africa, whereas Frogskin disease (cassava) and Moko Disease (banana) are limited to Asia and South America. Fusarium Tropical Race 4 on banana has now spread to Mozambique and some North African and near-middle east countries from Asia, but is not reported for Latin America

Recent studies suggest that only 1 tenth of all pests have reached more than half the countries that cultivate their hosts. Whilst some pests, such as potato blight, are highly global in distribution others are strongly regionalised. This presents a truly massive potential for future losses^x.

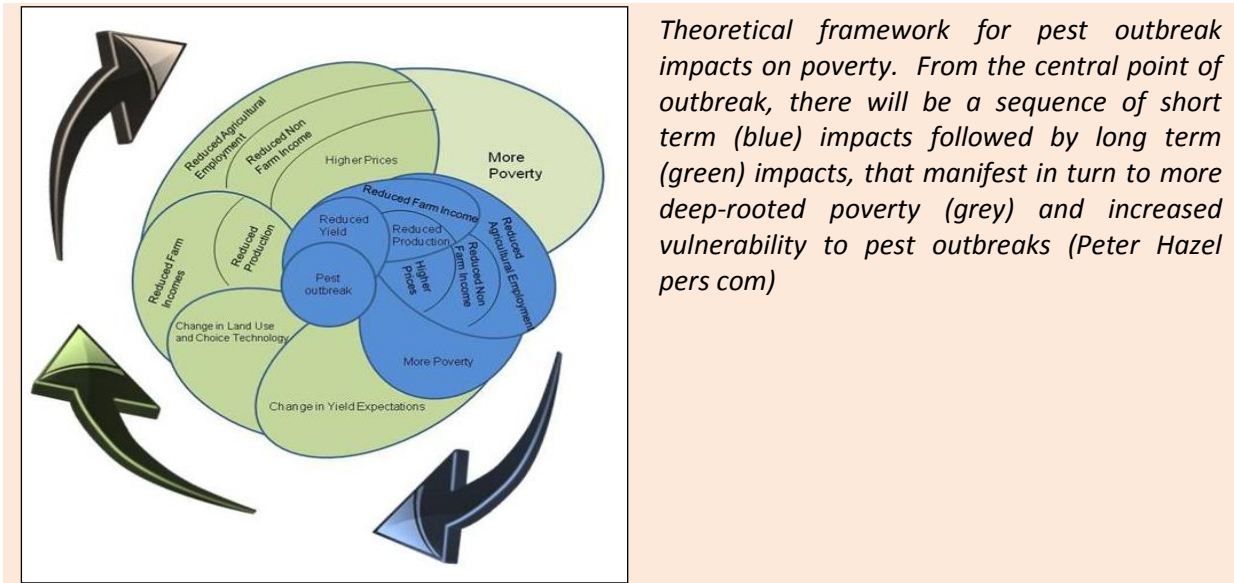


Distribution of Cassava brown streak virus (left) and Uganda cassava brown streak virus (right) is limited to Sub-Sahara Africa (CABI distribution maps).

The consequence of crop pests to a production value chain is hard to measure. It is not limited to the farmer, the in-year yield, and the next season of what to plant, but extends to consideration on

the willingness to invest on markets, processing and related infrastructure, and policy-making. In this context outbreak, more than every-day, pest events provide the major destabilising influences that hold back investment, and perpetuate poverty with the poorest and most vulnerable.

It is beyond the scope of this brief to give a detailed critique of crop pest costs, but it is to note that research mostly reports on losses of in-field or in-storage yield. Equating such losses to house-hold economic outcomes is largely not attempted. Similarly, wider impacts on long-term investments of infrastructure and policy development are not factored in. Yet broad statements on scaled losses for a region or country over time are frequently stated, but rarely convincing.



Example can already be pointed to where investments made towards adaptation to climate change are undermined by pest introductions (see below on drought tolerant maize in Tanzania and incursion of Maize Lethal Necrosis Disease).

Why the need for greater preparedness against crop pests – drought tolerant maize and Maize Lethal Necrosis Disease



“That year, for the first time, Joyce had planted a new kind of maize, bred to tolerate drought. When the drought came, most of her crops withered and died, but her maize was more productive than ever. She sold the surplus to buy beans and vegetables and other nutritious food for her family, and had money left over to pay her children’s school fees. That seed she said made the difference between hunger and prosperity”^{xi}.

This tells the situation how technology gave Joyce the edge over climate change and field productivity, and the edge in exploiting markets (possibly over her neighbours that remained with the old maize types), and how this translated to improved wellbeing. However, if not this year or

next, but soon, Maize Lethal Necrosis, a virus disease introduced to Kenya in 2011 and now spreading across Sub-Saharan Africa, stands to raise this new maize variety in the same way as the traditional types. Joyce will no longer be any more assured of a yield, or a yield surplus, than her neighbour, and we hope she has not invested too much on the finances that was yesterday. Whilst without questioning that such technologies carry the hopes of so many in Africa, we must ensure the investments by plant breeders and Joyce are not built on sand.

AUTHORSHIP AND ACKNOWLEDGEMENT

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