Research to Nourish Africa

UNIVERSITY OF LEEDS

Measuring, predicting and adapting to aflatoxin risk under climate variability and change

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Aflatoxin, Health & Trade

- Death (>200 people in Kenya)

Aflatoxins are highly toxic substances produced by the ubiquitous *Aspergillus* fungi in common staples

RELIEF

Spoilt maize threatens schools food programme

By LUCAS BARASA

A school-feeding programme for 40,000 pupils in some of Nairob's slums has been thrown into disarray by contaminated relief food.

Hundreds of bags of yellow maize and peas donated by the US government and supplied by the World Food Programme (WFP) have been seized after samples from one of the schools were found to be contaminated.

Investigations have been launched to establish how the food became poisonous and at what stage in the process of supply and storage.

Yesterday, the WFP said all its food was always tested for aflatoxin and moisture content, among other things, before being handed over to the Ministry of Education.

"WFP is confident that no aflatoxin is present in any of the food provided by the organisation to WFP supported programmes in Kenya."

It attributed the possible contamination to "poor storage conditions and inadequate handling, particularly during the rainy season, as well as mixing of

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BBC NEWS WORLD EDITION

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Killer maize sparks Kenya alarm

Several Kenyan politicians have urged the government to declare a national disaster following the death of more than 80 people from contaminated maize.

Twenty-eights bags of poisoned maize were impounded at a girls' school in eastern Kenya on Saturday.

MPs from drought-prone Makueni, Kitui, Mwingi and Machakos districts warned that unless all poisoned maize was seized quickly, more people would die.

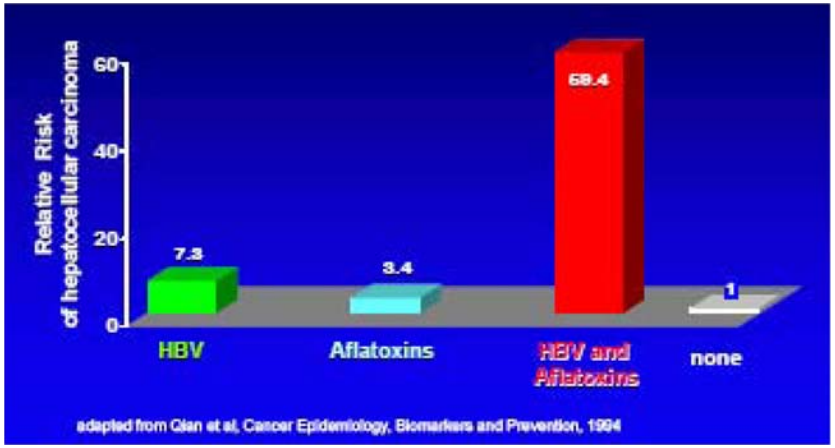
They also appealed for donations to set up a fund to help those affected.

"We demand action from the government since the lives of our people, especially in the arid areas, are at stake," Daudi Mwanzia, MP for Machakos town, said on the East African Standard newspaper website.

Health Minister Charity Ngilu was quoted last week as saying that 80% of locally available maize stocks were affected

Aflatoxin, Health & Trade

- Death (>200 people in Kenya)
- Synergistic with Hepatitis B Virus (HBV) to cause liver cancer
  - 30 times more potent in HBV+ people
  - 5-60 times higher cancer risk



Aflatoxin, Health & Trade

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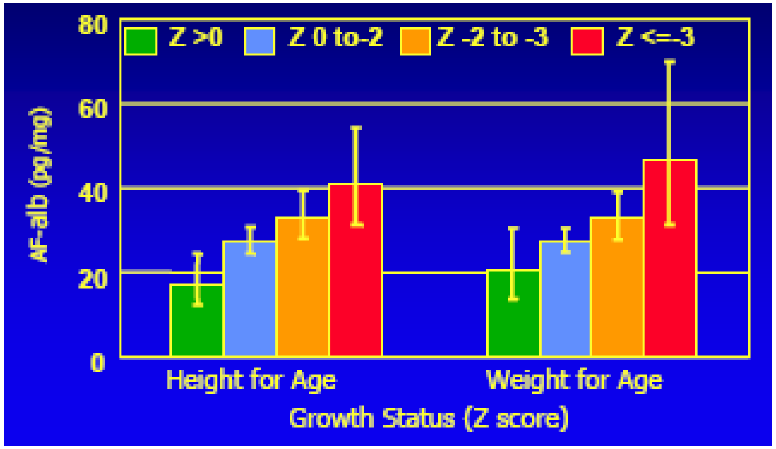

Aflatoxin Exposure Group	Mean AF-alb over 8 months Height increase (cm) Unadjusted	Adjusted[a]
lower quartile	4.9 (4.5,5.3)[*,c]	5.9 (5.2,6.6)
mid-lower quartile	4.4 (4.1,4.7)[**]	5.3 (4.8,5.9)
mid-upper quartile	4.1 (3.8,4.5)[**]	4.8 (4.4,5.2)
upper quartile	4.1 (3.8,4.5)[**]	4.2 (3.9,4.6)

Aflatoxin, Health & Trade

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- Impairs growth and development of children
- Suppress immune system – increased susceptibility to diseases, e.g., HIV, malaria?
- May impede uptake and utilization of micronutrients in human systems
- Associated with Kwashiorkor in children
- Animal productivity reduced – growth rate, embryo toxicity, feed efficiency, cancer, death……
- Trade impact -- >US$1.2 billion loss

Aflatoxin Contamination in West Africa

Primary products

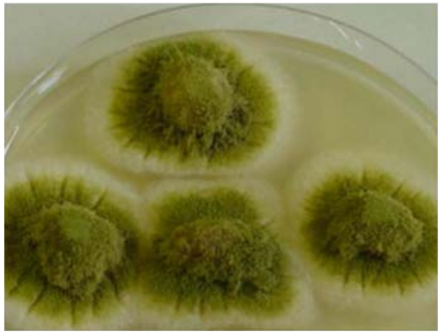
Maize: 4000 – Benin

Peanut: 216 – Ghana

Sorghum: 80 – Ghana

Millet: 200 – Nigeria

Tiger nuts: 120 – Nigeria



Food products

MTL = 20 ng/g

- Peanut paste: 3278 – Ghana
- Peanut sauce: 943 – Ghana
- Leaf sauce: 775 – Gambia
- Maize dough: 313 – Ghana
- Kenkey: 524 – Ghana
- Cashew paste: 366 – Ghana
- Peanut oil: 500 – Nigeria
- Yam flour: 7600 – Nigeria
- Local beer: 135 - Nigeria

Aflatoxin Exposure in West Africa

- Exposure to aflatoxin in sub-Saharan Africa is common and at high levels – important exposure occurs at the small subsistence farm level
- Exposure begins *in utero* and continues throughout life, with a reduced exposure during breastfeeding
- Exposure in young children is associated with impaired growth and development
- Undernutrition and growth faltering is an underlying cause of 50% of deaths in children <5 years age (Black et al., Lancet, 2003)

Prevention of Aflatoxin-related Health Effects in Developing Countries

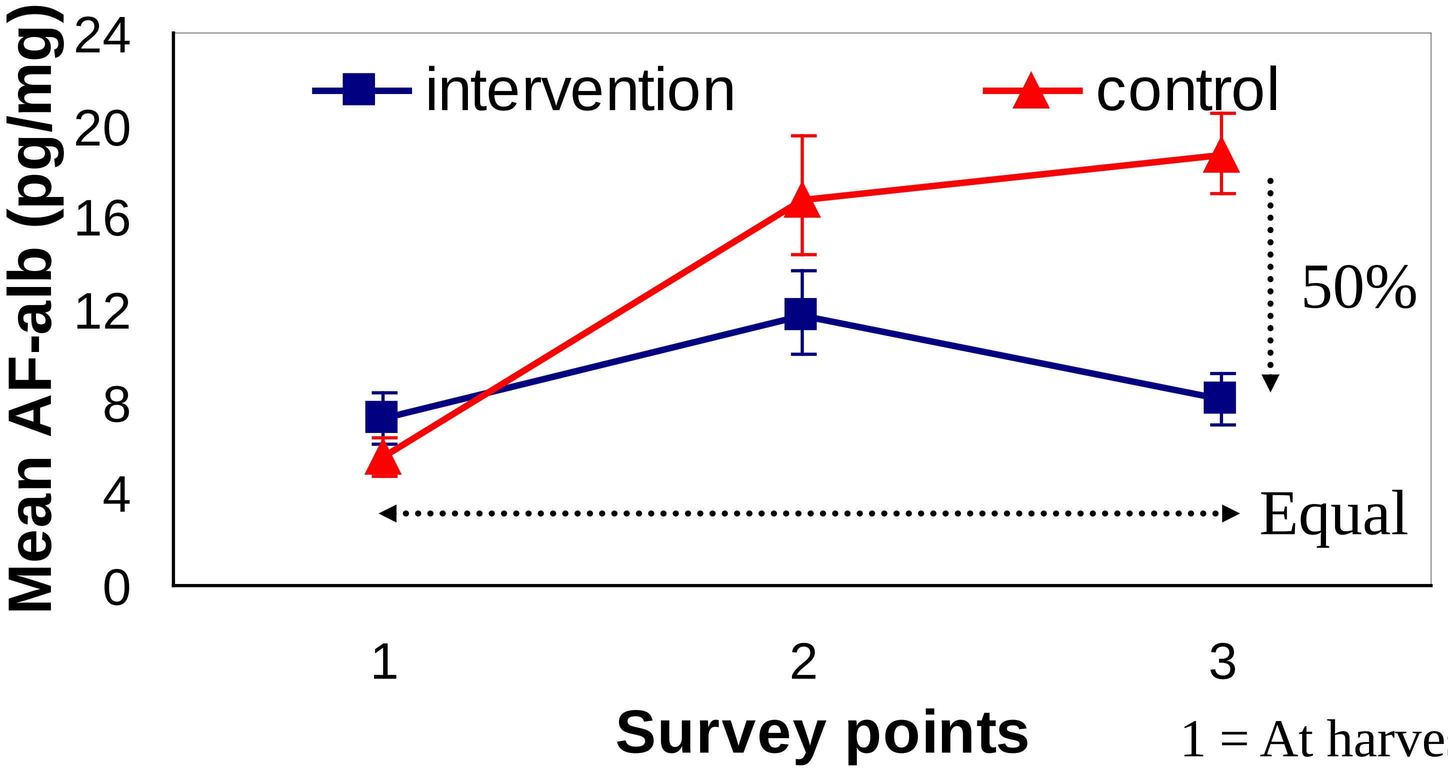
Aflatoxin Intervention

Awareness

- **Individual Level**
  - **Dietary Change**
    Risk: maize > sorghum > millet
  - **Enterosorption**
    e.g. Novasil clay
  - **Chemoprevention**
    e.g. oltipraz, cholorphyllin
- **Community Level**
  - **Pre-harvest**
    Crop resistance to fungal infection or aflatoxin biosynthesis
    Biocontrol e.g. nonaflatoxigenic strains
    Reduce crop stress- irrigation,
    Insecticides, fungicides
  - **Post-harvest**
    Improved drying, sorting, insect control and storage

(Adapted from Wild and Hall, Mutation Res., 2000)

Mean Levels of AF-alb are Reduced in Individuals Following Intervention



1 = At harvest
2 = 3 mo post-harvest
3 = 5 mo post-harvest

Turner et al., (2005) *The Lancet*, **365**, 1950-1956

Opportunities for Measuring and Adapting to Aflatoxin Risk

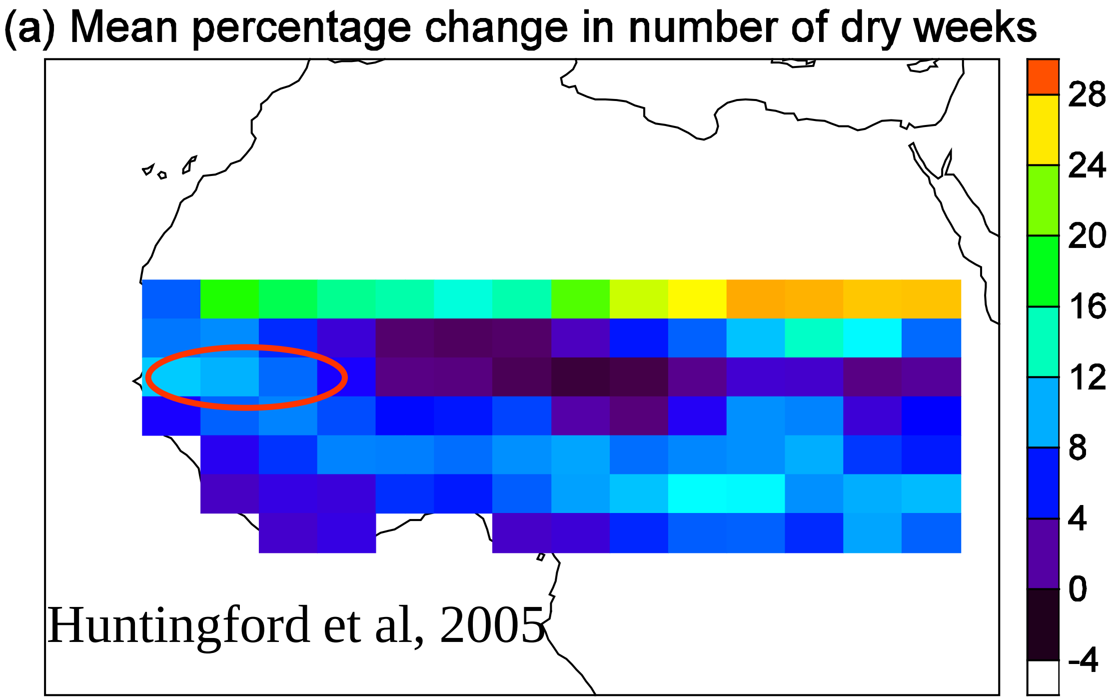
- The occurrence of aflatoxin on crops is strongly influenced by weather during and after the growing season
- Climate change is likely to lead to an increase in hot and dry spells => increased risk of aflatoxin contamination
- Crop yields can be predicted using climate model output and crop models

=> potential for a prediction system

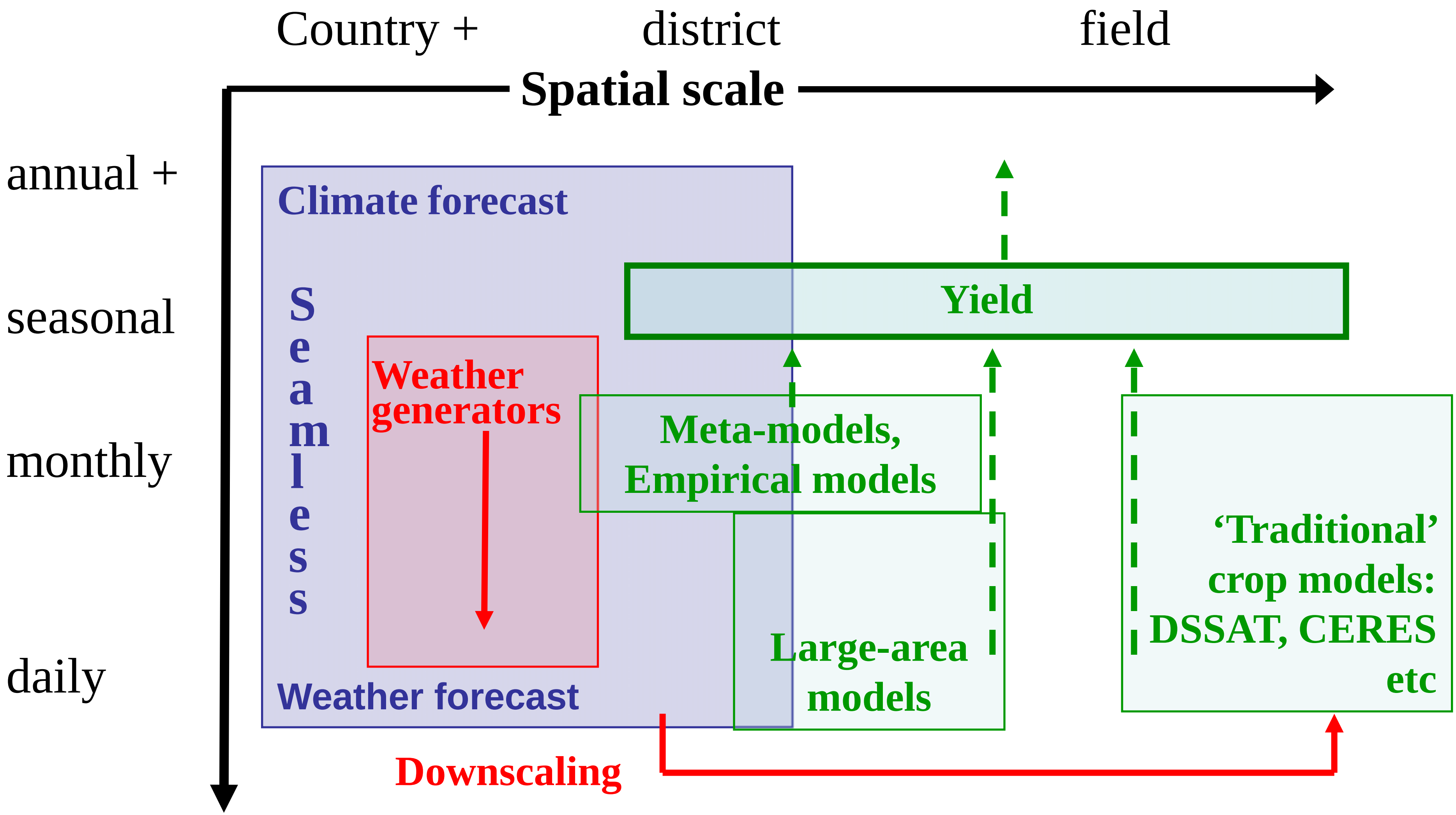
Climate Change is Likely to Lead to an Increase in Hot and Dry Spells

Change in occurrence of 7-day dry periods in July-Sept for range of models and SRES scenarios, 2081–2099.

Dry periods defined using drying 10% in current climate



Combining Crop and Climate Models



Crop Modelling Methods

- Empirical and semi-empirical methods
  - + Low input data requirement
  - + Can be valid over large areas
  - – May not be valid as climate, crop or management change

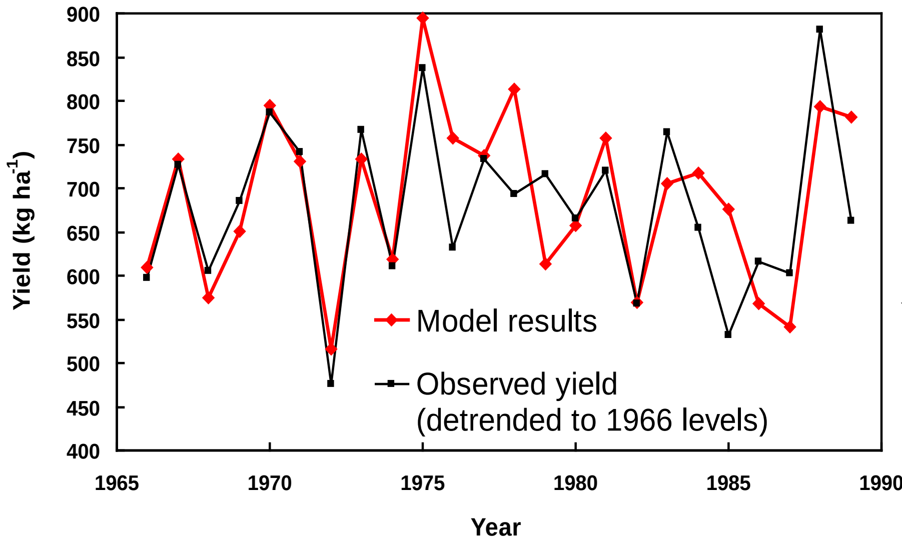
- Process-based
  - + Simulates nonlinearities and interactions
  - – Extensive calibration is often needed
  - – skill is highest at plot-level

=>

General Large Area Model for Annual Crops

Combines the benefits of empirical and process-based approaches

Model Results

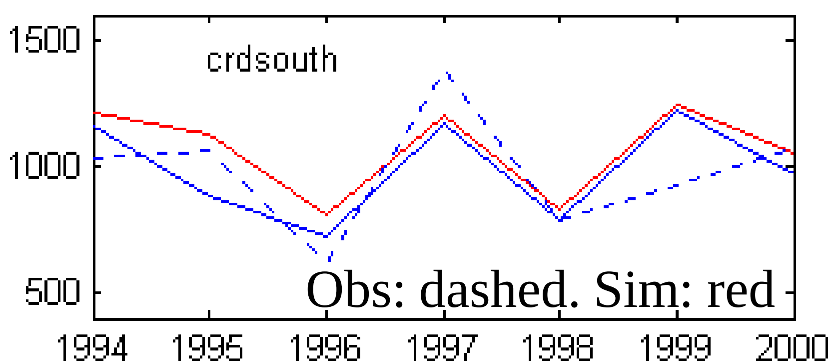


Challinor et al. (2004)

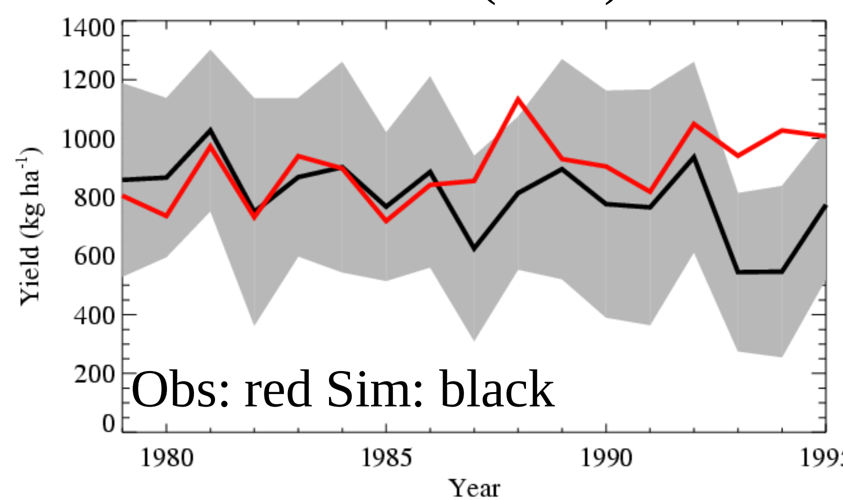
India

Africa
(The Gambia)

Chee-Kiat (2006)



Osborne (2004)



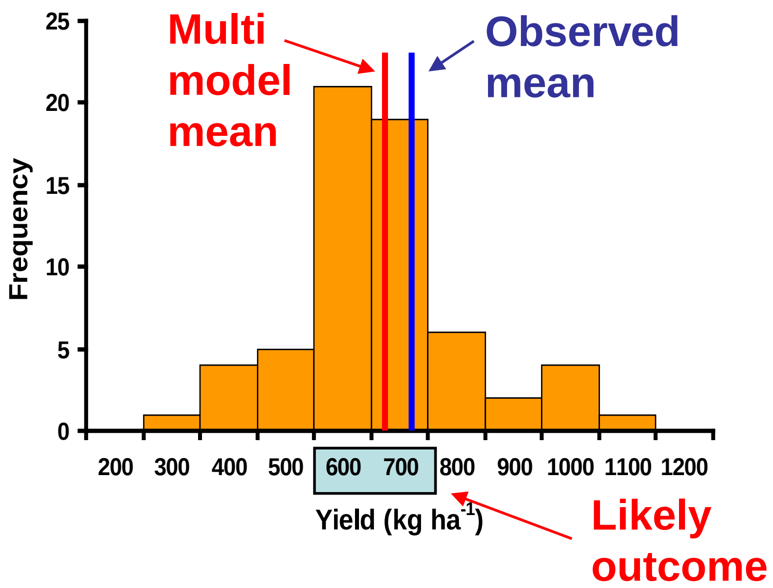
Seasonal Forecasting of Crop Yield using Climate Model Ensembles

- Multi-model ensemble: 7 climate models x 9 ensemble members

  Each ensemble member has slightly different (essentially imperceptible) initial atmospheric conditions => probabilistic simulation

- Run each ensemble member through GLAM to create an ensemble of crop yields

Probabilistic Forecasting of Crop Failure in India



- 63 ensemble members in total (orange bars)
- The number of ensemble members predicting yield below a given threshold is an indication of probability of occurrence

- Found high predictability in crop failure and yield
  - skilful forecast: Mean ensemble yield close to observed yield (almost 100%)
  - High probability: around 60% (40 out of 63 ensembles close to observed mean)

The AHRP-funded Project

- Multi-sectoral, multidisciplinary – agriculture, health and environment

The project will …..

- Build on success to date …
  - Seasonal prediction of crop yield
  - Probabilistic methods
  - Capturing importance of dry spells
- … to develop a forecasting tool - Short term
  - Seasonal timescales initially
- … and support adaptation – Long term
  - Seasonal timescale important for decision-making
  - Build capacity for long-term adaptation

Research Questions

1) Is the skill in seasonal weather forecasting in West Africa sufficient to predict the occurrence of high aflatoxin concentrations in groundnut? If so, what methods can be used to maximise the capacity for prediction?
2) Does the known link between weather and aflatoxin result in a robust demonstrable relationship between weather and aflatoxin levels, both in crops and in blood of exposed people?
3) What decisions, informed by seasonal forecasting, can be made before and during the season to minimise aflatoxin contamination?

Plan

- **Stage 1: population-based sampling frames across Senegal.**
- **Stage 2: combined crop (groundnut) and aflatoxin simulation.**
- **Stage 3: probabilistic seasonal forecasts of aflatoxin**
- **Stage 4: using seasonal forecasts to minimise aflatoxin contamination**

❖ **Pursue stages 1-3 under AHRP**

❖ **Stage 4 is long-term**

Stage 1: Population based sampling

- Sites: *Dinguiraye* in the Peanut Basin, rainfed production, high aflatoxin risk area; *Fanaye* in the Senegal River valley zone, irrigated cultivation started recently.
- Villages: 3 villages per site, 15 households per village
- Crop sampling for aflatoxin contamination: Sep/Oct 2009 (harvest), Mar/Apr 2010 (storage). 180 samples – 6 villages x 15 households x 2 visits
- Population sampling for aflatoxin exposure: Blood from 15 husband/wife pairs per village, Sep/Oct 2009 (low exposure), Mar/Apr 2010 (high exposure). 360 samples: 30 subjects x 6 villages x 2 visits
- Ethical approval from Ministry of Health – confidentiality, declared interests, and long-term consequences

Stage 2: Combined Crop & Aflatoxin Simulation

- The GLAM crop model will be extended to simulate end-of-season aflatoxin levels. Temperature and soil moisture as parameters (e.g. Chauhan et al., 2008).
- A post-harvest model (temperature and humidity) will be developed to account for increases in aflatoxin during storage (e.g. Pitt, 1995).
- Climate data for model development available from existing model simulations for forecast -- ensembles from the EU DEMETER project, gridded observations (e.g. CRU) and reanalyses (e.g. ERA40).
- Aflatoxin data for model development and evaluation from published and unpublished sources (e.g., WHO evaluation of global burden of disease), including present study.

Stage 3: Probabilistic Seasonal Forecast of Aflatoxin

- Seasonal weather forecast ensembles will be used with GLAM to assess the predictability of aflatoxin in crops with 3-6 month lead times.
- The crop model will be run with daily output data from
  - new state-of-the-art community climate model, EC-Earth (shares atmospheric and ocean model components with the operational seasonal forecast system of the European Centre for Medium Range Weather Forecasts (ECMWF)
  - Other ensembles (e.g. EU DEMETER, AMMA and ENSEMBLES projects
- Two types of probabilistic assessment of aflatoxin
  - Deterministic skill: Ensemble mean aflatoxin contamination will be compared to the measured values
  - Probabilistic skill: Ensemble spread will be used to assess the uncertainty associated with the simulations, to calculate the chance of aflatoxin being above identified critical thresholds (20 and 4 ppb).

Stage 3: Probabilistic Seasonal Forecast of Aflatoxin

- Predictability and uncertainty will be assessed by using the blood biomarker to study the links between weather and aflatoxin concentrations in crops and in people.
- Statistical analyses of the climate ensembles, the observed aflatoxin in groundnut and in humans, and the simulated contamination of groundnut, will reveal for the first time the extent to which the following factors limit the predictability of aflatoxin in the human bloodstream
  - inherent uncertainty in climate
  - the simulation of aflatoxin in crops pre- and post-harvest
  - the link between aflatoxin levels in crops and aflatoxin in the blood stream.

Stage 4: Using Seasonal Forecast to Minimize Aflatoxin Contamination

- Model simulations will be carried out for all forecast ensemble members and for several management interventions (e.g. sowing date, irrigation) and the impact on crop aflatoxin will be studied.
- Both the ensemble mean and spread will be used
  - Mean will be used to identify the most effective strategies based on deterministic forecasting
  - Spread will measure uncertainty.
- Both fixed changes in management (e.g. earlier sowing every year) and adaptive strategies informed by the forecasts will be investigated.

Project Outputs

- Seasonal forecasting system for aflatoxin in West Africa that predicts likely contamination of the groundnut crop
- Assessment of human health effects through the analysis of aflatoxins in human blood samples.
- Preliminary assessments of the economic impacts of contamination of groundnut, using the threshold method (stage 3).
- Decision support system for the groundnut export industry to plan exports to appropriate markets
- Ex-ante economic impact of various aflatoxin threshold and management scenarios over a longer timeframes

Outcomes and Policy Impacts

- Opportunities to link crop and climate models to models of the consequences of aflatoxin contamination (cancer, morbidity and mortality, and trade) in response to climate change.
- Linking the prediction systems to disease burden (one of the goals of WHO)
- Geographical comparison of aflatoxin levels and short-term health outcomes associated with aflatoxin exposure
- Assessment of the efficacy of short-term interventions and adaptive strategies aimed at reducing negative impacts.
- Seasonal forecasts will provide lead times to policy makers and export industry to put in place coping strategies to manage aflatoxin contamination.

Thank you