

Aflatoxin: Economic & Health Impacts

How to assess public health interventions



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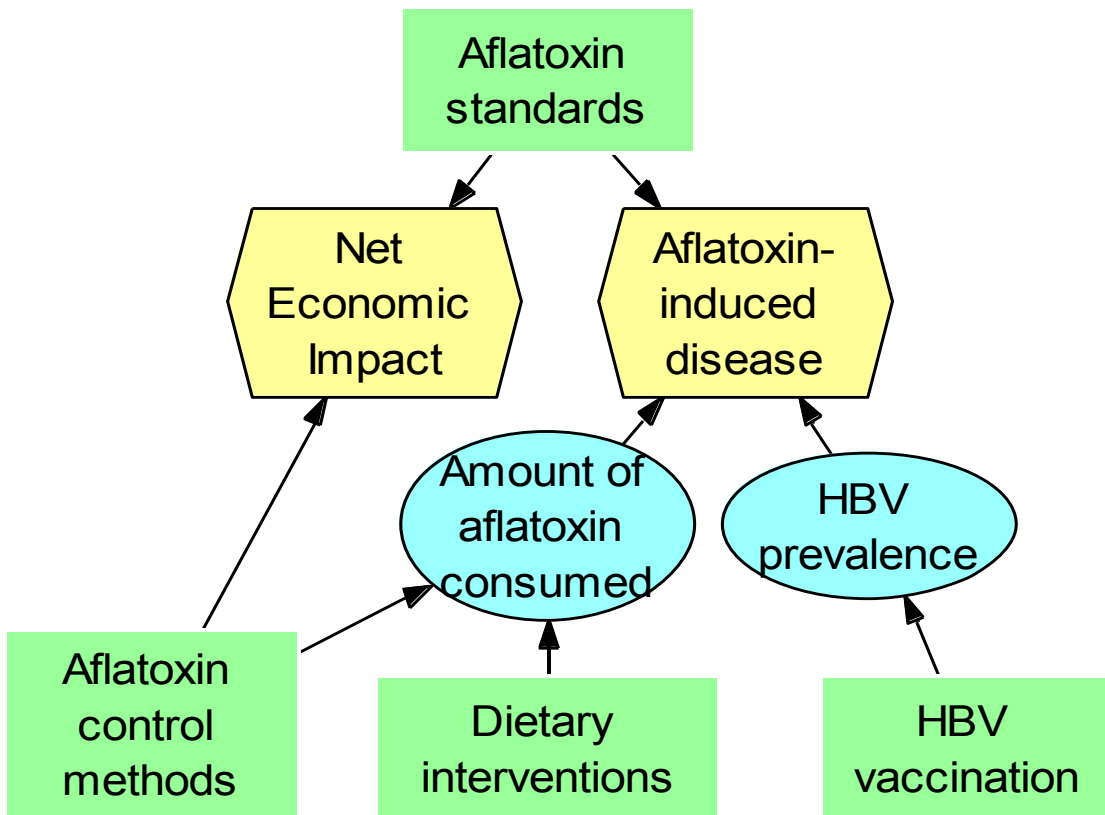
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Presentation Outline

- ◆ Motivating question: *How can we best reduce aflatoxin-induced illness & market loss through a combination of appropriate standards and interventions?*
- ◆ What is aflatoxin?
- ◆ Aflatoxin's health effects
- ◆ Impact of aflatoxin standards on trade & health
- ◆ Kenya: Case study
- ◆ Public health interventions & their global feasibility

Two approaches to reduce aflatoxin's economic & health risks worldwide

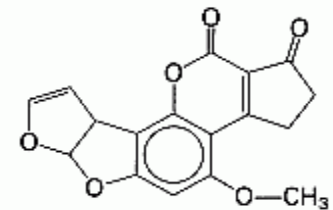


Top down...

vs. bottom up

Aflatoxin: Background

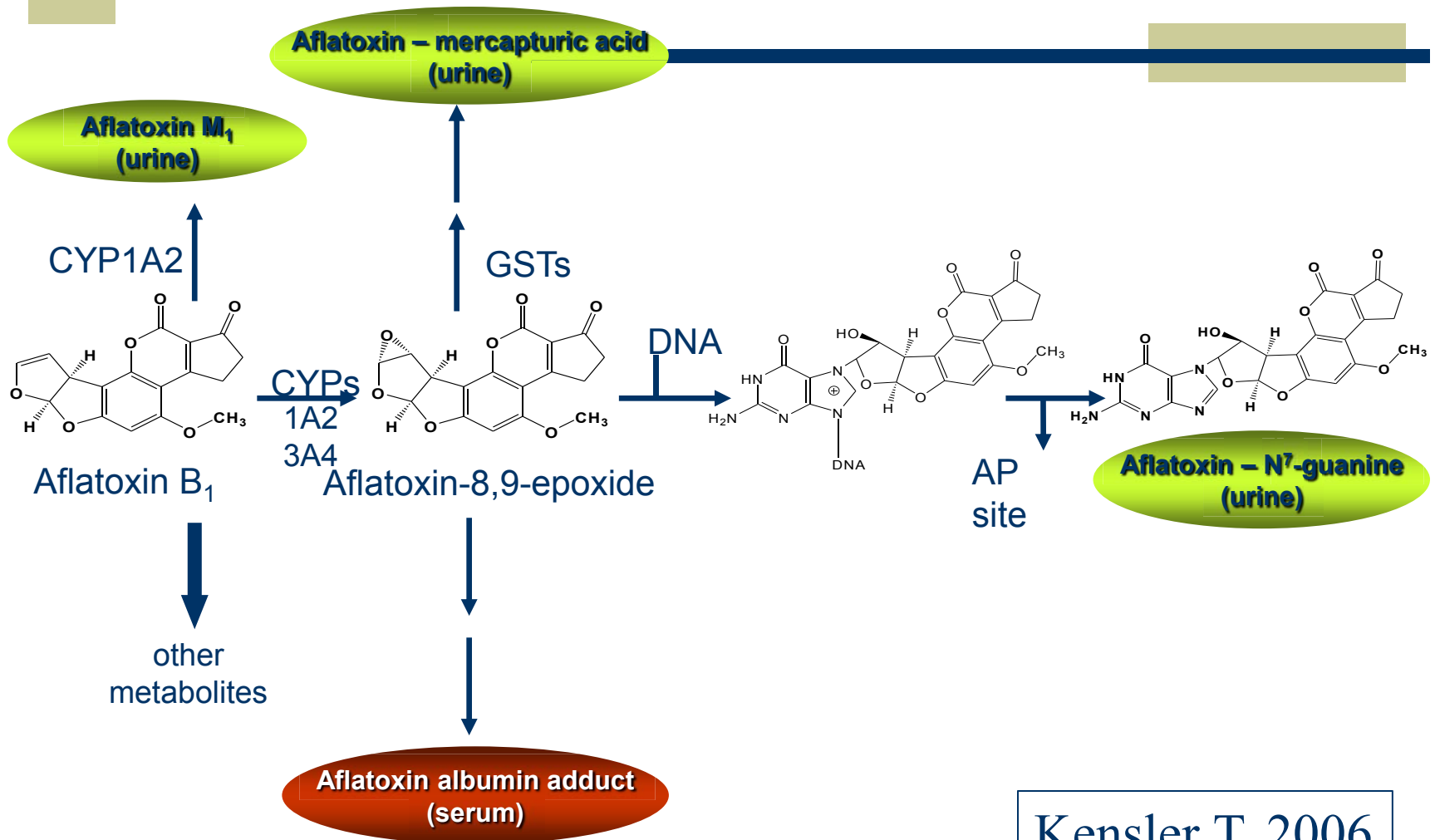
- ◆ Produced by fungi *Aspergillus flavus*, *A. parasiticus*
 - Corn, peanuts, tree nuts, cottonseed, spices
- ◆ Type 1 human liver carcinogen
 - Synergistic with hepatitis B (HBV): up to **60X** greater liver cancer risk
 - ~400 million people worldwide have chronic HBV infection
- ◆ Other effects: immune system disorders, stunting in children, acute aflatoxicosis



Aflatoxin B₁
(*Aspergillus flavus*)



Aflatoxin metabolism & DNA damage



We can't eliminate aflatoxin in food, so we regulate it

<i>Nation</i>	<i>Total aflatoxin standard in human food ($\mu\text{g}/\text{kg}$)</i>
Australia	5
China	20
European Union (EU)	4*
Guatemala	20
India	30
Kenya	20
USA	20

*applies to cereals & cereal products, nuts not subject to further processing, & dried fruit



3 questions relevant to these regulations



- **FOOD TRADE.** What is the global food export market loss at different aflatoxin standards?
 - Which nations are most at risk?

- **HEALTH.** How many additional global liver cancer cases attributable to aflatoxin occur at different aflatoxin standards?
 - Which nations are most at risk?

- **INTERVENTIONS.** How do global health and trade improve when we introduce vaccines, dietary supplements, or aflatoxin control methods?

Strict aflatoxin standards can have severe economic impacts

- ◆ **\$670 million** annual loss to African food exporters from attempting to meet EU aflatoxin standard (Otsuki et al. 2001)
- ◆ “A World Bank study has calculated that the European Union regulation on aflatoxins costs Africa \$670 million each year in exports of cereals, dried fruit and nuts. And what does it achieve? It may possibly save the life of one citizen of the European Union every two years... Surely a more reasonable balance can be found.”
 - -- *Kofi Annan, former UN Secretary General*
- ◆ “Milder” calculation: **\$450 million** annual loss to ALL food exporters if ALL nations harmonized to EU aflatoxin standard (Wu 2004)

Liver cancer risk calculations

- ◆ *Population cancer risk = Potency * Average aflatoxin intake*
- ◆ *Potency =*
*[Potency factor for HBV+ persons] * [% of HBV+ persons]*
*+ [Potency factor for HBV- persons] * [% of HBV- persons]*
 - *[% of HBV+ persons]:* prevalence data from WHO
 - **Individual cancer risk:** Calculate based on HBV status & aflatoxin intake
 - *Average aflatoxin intake:* FAO corn & peanut consumption data worldwide, & estimates of aflatoxin contamination

Key differences from JECFA 1998:

1. True HBV+ prevalence per nation (not 1% vs. 25%)
2. Nations export best food; keep worst at home

“Average individual’s” lifetime liver cancer risk: THEORETICAL

HCC RISK BY WORLD REGION	Individual’s lifetime risk, <i>no HBV infection</i> (in a million)		Individual’s lifetime risk, <i>chronic HBV infection</i> (in a million)	
	<i>20 µg/kg</i>	<i>4 µg/kg</i>	<i>20 µg/kg</i>	<i>4 µg/kg</i>
United States	3.5	1.8	120	55
EU	2.0	1.0	59	28
S. America	8.6	3.8	260	120
China	13	6.7	450	200
Africa	40	22	1400	650

How does aflatoxin compare to other risks in rich nations?

◆ Average U.S. citizen's lifetime death risk from:

- Bathtub drowning: 83 in a million
- **High school football:** **1.2 in a million**
- Motor vehicle accident: 10,500 in a million
- Homicide: 3,900 in a million
- Suicide: 7,600 in a million
- Bee, hornet, or wasp sting: 11 in a million
- **Lightning:** **23 in a million**
- **Shark attack:** **0.25 in a million**



Source: Harvard Center for Risk Analysis

But a low relative risk doesn't mean that we should not control aflatoxin

- ◆ ... if there is a cost-effective and feasible way to do so
- ◆ Though aflatoxin is a minor public health problem in rich, temperate-zone nations with low hepatitis rates, it is still a HUGE issue in Africa & Asia

The Republic of Kenya



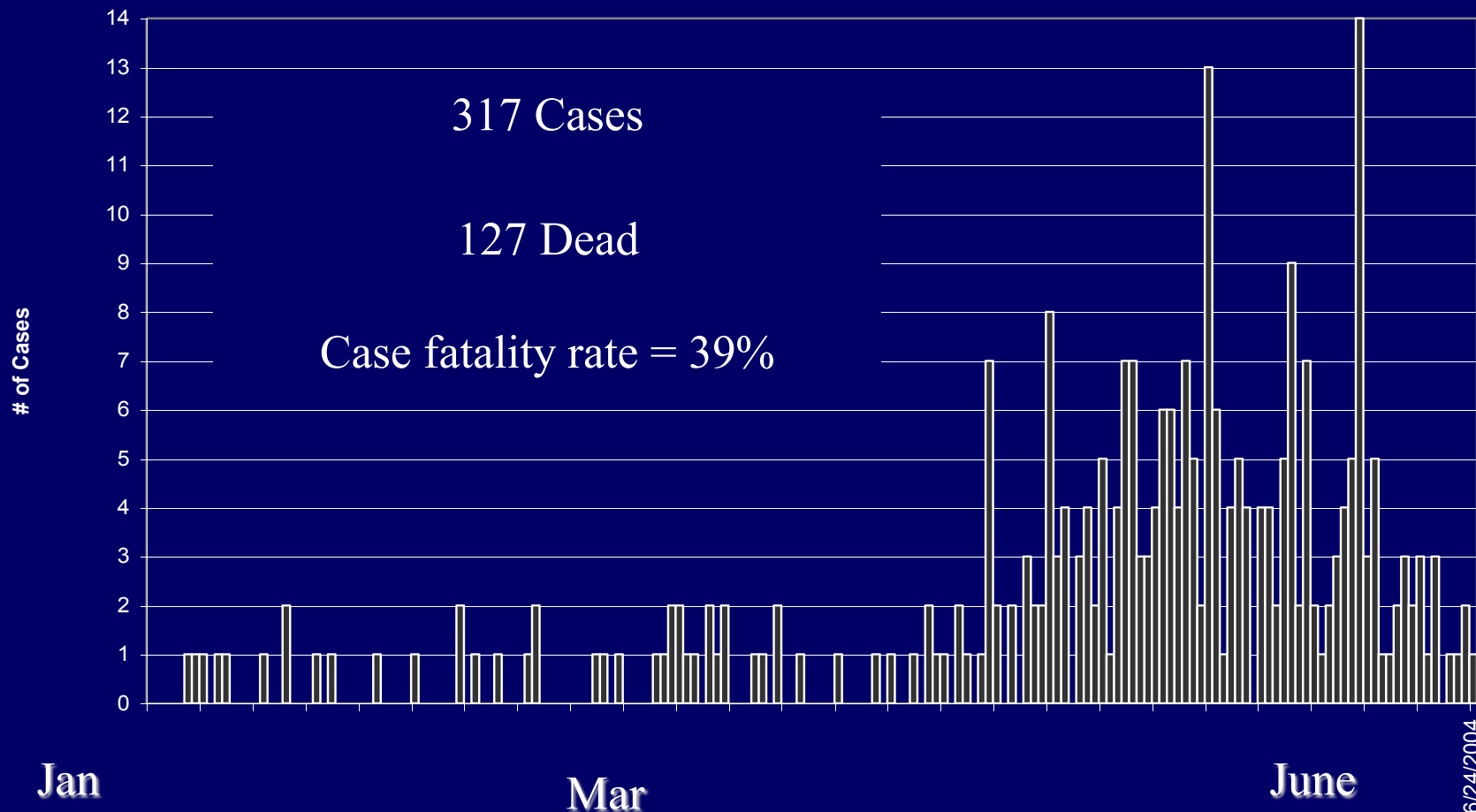
- ◆ 582,000 km²
- ◆ Population 32 M
 - 41% <15 yrs
- ◆ Maize is primary food staple
- ◆ Maize production is by small scale farmers
- ◆ Only ~ 20% suitable for rain-fed agriculture

◆ Source: David Wilson, UGA/Tifton

Outbreaks of Aflatoxicosis in Kenya are Seasonal (Peak in May)

Source: David Wilson, UGA/Tifton

Eastern and Central Province Aflatoxin Outbreak - Kenya 2004 (Updated 6/25/04)



E Azziz-Baumgartner, W Chege, A Bowen, K Gieseke, 2005

How the Outbreaks Unfolded

Symptoms of Aflatoxicosis

- ◆ High fever
- ◆ Gastrointestinal infections
 - Stomach pain
 - Vomiting
- ◆ Edema of the limbs
- ◆ Rapid progressive jaundice
- ◆ Swollen livers



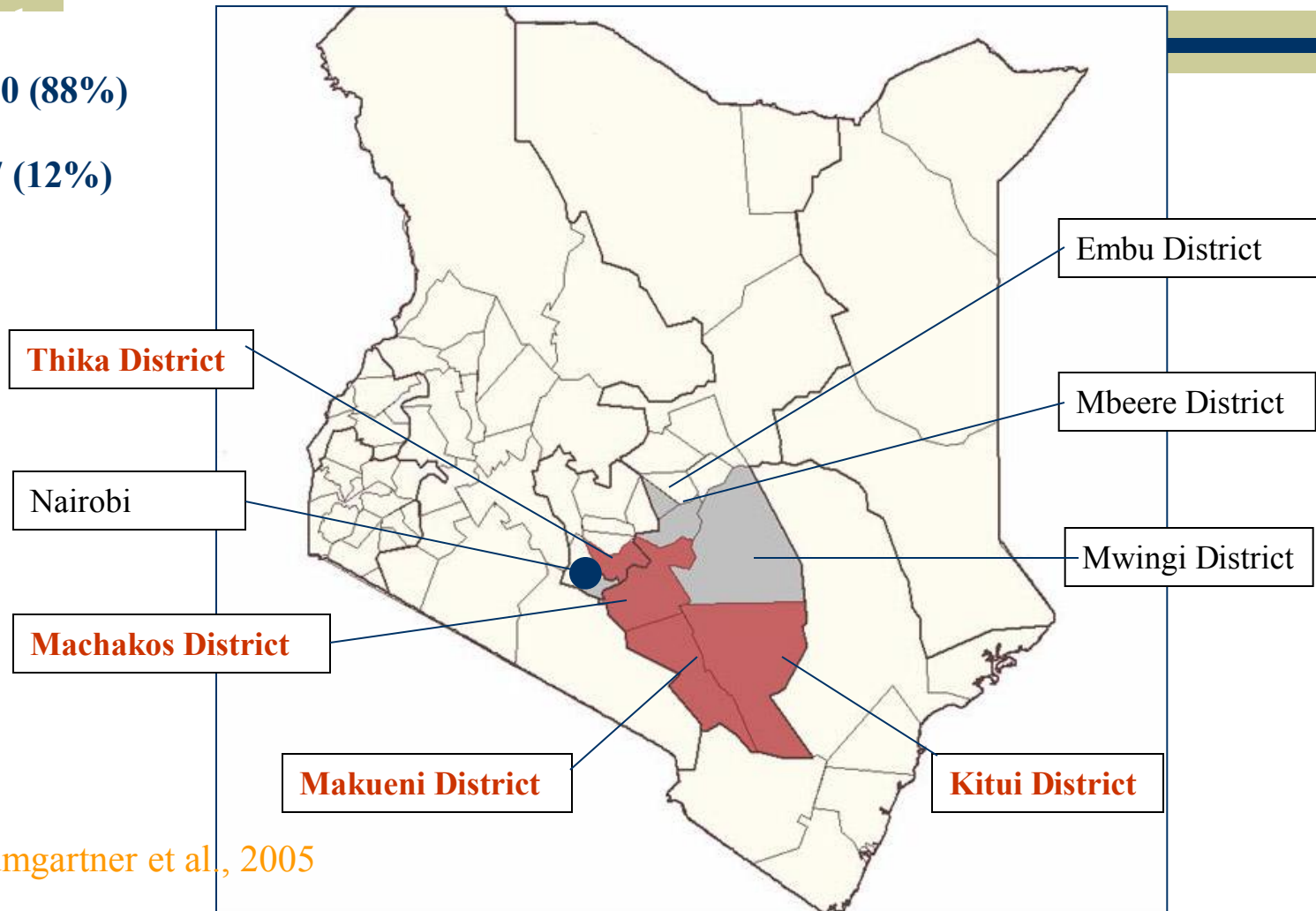
Jaundiced sclera

Tested negative for: Yellow fever, Rift Valley fever, dengue, hepatitis A, B, and C; West Nile virus; Chikungunya, and Bunyamwera

Source: David Wilson, UGA/Tifton

Regions with Severe Outbreaks of Aflatoxicosis in Kenya

Source: David Wilson, UGA/Tifton



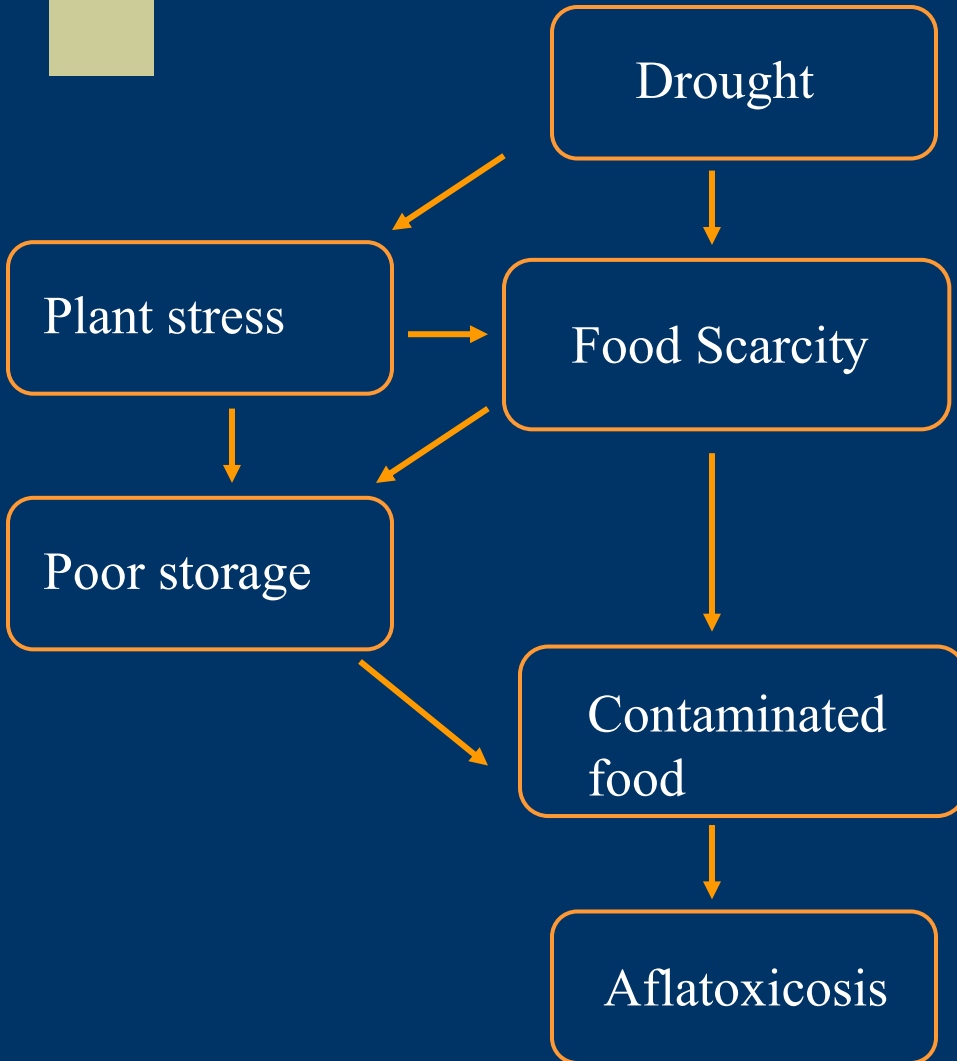
Azziz-Baumgartner et al., 2005

2004 Levels of Aflatoxin in Maize Samples Were Highly Variable

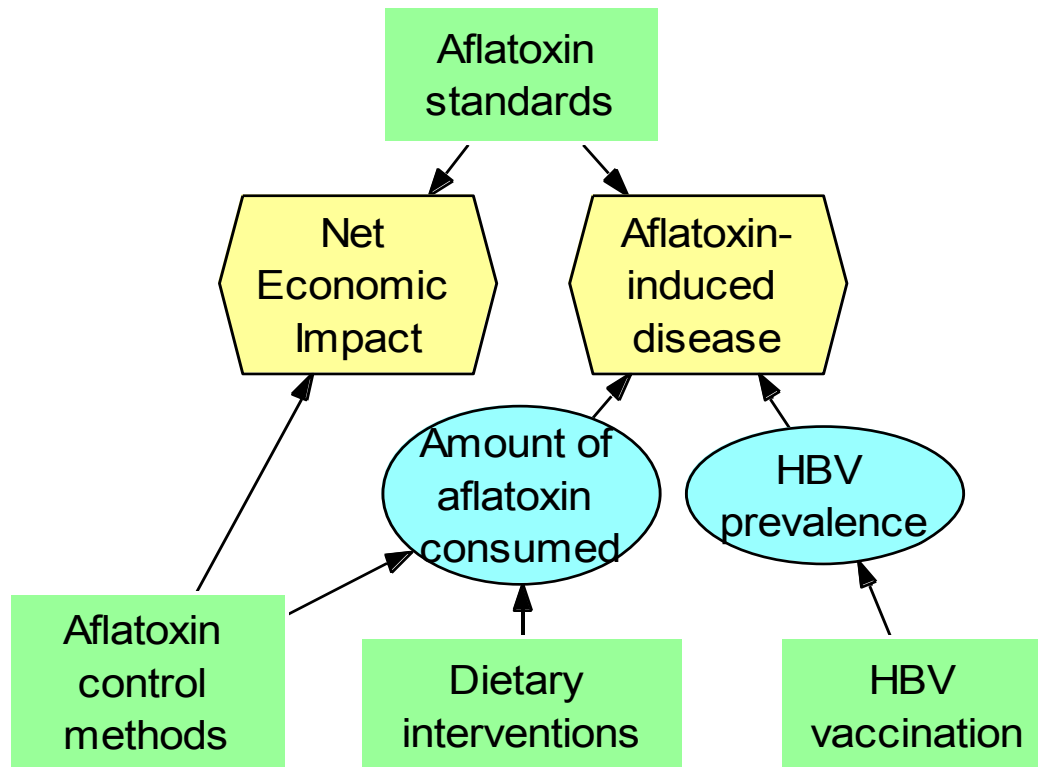
District	Maize Aflatoxin (ppb) Geometric Mean	Maize Aflatoxin (ppb) Range
Makueni	52.9	1 – 5,400
Kitui	35.2	1 – 25,000
Machakos	17.8	1 – 3,800
Thika	7.5	1 – 46,400
TOTAL	20.5	1 – 46,400

Hypothesis for 2004 & 2005 Outbreaks

Source: David Wilson, UGA/Tifton



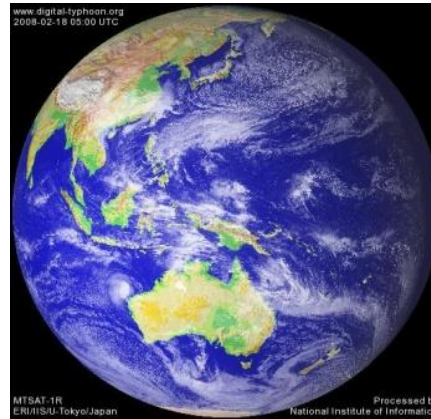
Public health interventions also affect health & economics of aflatoxin



Top down...

vs. bottom up

How feasible are public health interventions to combat aflatoxin?



Cost-effectiveness

Public compliance

Feasibility

3 categories of interventions to reduce aflatoxin's health risks

- ◆ Agricultural interventions
- ◆ Dietary interventions
- ◆ Clinical interventions



- ◆ These reduce aflatoxin risk in different ways
 - *Agricultural*: Farmers can reduce aflatoxin → reduce trade & health losses
 - *Dietary or clinical*: We can consume more aflatoxin & not significantly increase our liver cancer risk

How to analyze cost-effectiveness, compliance, feasibility of interventions

◆ **Cost-effectiveness:** very quantitative

- C_s = Societal cost of aflatoxin
- E_i = % efficacy of intervention's risk reduction
- A_i = Cost of applying intervention
- → Net benefit: $B = E_i * C_s - A_i$
- Compare B across interventions

◆ **Public compliance:** semi-quantitative

- How likely will people adopt or comply with intervention?
- Is it culturally appropriate?

◆ **Feasibility:** not very quantitative

- How supportive are policies, infrastructure, funding sources?



Agricultural interventions to reduce aflatoxin

◆ Preharvest

- Genetically enhance resistance
 - Transgenics
 - Conventional methods
- Good agronomic practices
- Biocontrol methods
- Chemical methods
 - Fungicides
 - Antioxidants



◆ Postharvest

- Physical methods
 - Sorting
 - Improved storage & transportation conditions
- Chemical methods
 - Ammoniation

Dietary / clinical interventions

- ◆ Binding agents
 - Novasil clay, chlorophyll, chlorophyllin
- ◆ Phase II enzyme inducers
 - E.g., sulforaphane found in cruciferous & other vegetables, triterpenoids, Oltipraz
- ◆ Inflammation reducers
 - E.g., NSAIDs, green tea polyphenols
- ◆ Hepatitis B vaccine



Items to consider in evaluating interventions

- ◆ How many people need to implement the intervention? (Just growers, or all consumers?)
- ◆ How many times a day, week, year, lifetime?
- ◆ What are global attitudes toward GMOs and vaccines (even those that can reduce health risk)?
- ◆ Can farmers afford upfront costs?
- ◆ Can we deliver vaccines / medicines / technologies where needed?
- ◆ Will people comply with prevention regimes?

Summary & final points

- ◆ We can control aflatoxin via top-down (policy) or bottom-up (intervention) methods
- ◆ Top-down methods work best for developed nations, where aflatoxin standards are enforced
 - Standards can be very costly to food exporting nations
- ◆ Bottom-up methods work best for developing nations, where much food doesn't enter regulatory oversight
 - Interventions can create a win-win situation