*Journal of Earth Science & Climate Change*

# Climate Change, Mycotoxins and Food Safety

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# Climate change videos

http://www.youtube.com/watch?v=RHrFBOUl6-8

http://www.bbc.co.uk/news/science-environment-24149439

# A. Introduction



*Aspergillus flavus* = aflatoxins

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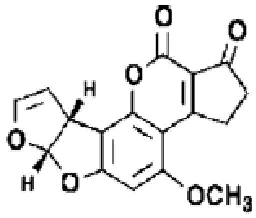
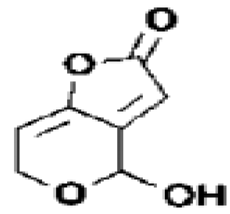
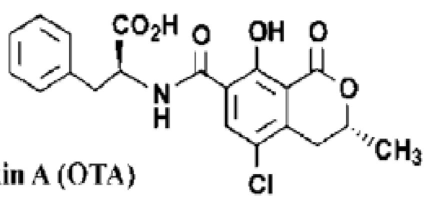
# Chemical Structures



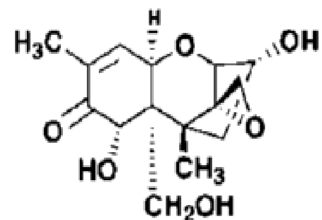

Aflatoxin $B_1$ ($AFB_1$)

Patulin




Ochratoxin A (OTA)




Deoxynivalenol (DON)

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# Mycotoxin Diseases

| Disease | Crop | Fungus |
|---|---|---|
| Alimentary toxic | | |
| Aleukia | Cereals | *Fusarium* |
| Balkan Nephropathy | Grains | *Penicillium* |
| Hepatocarcinoma | Peanuts | *A. flavus* |
| Deaths | Maize | *A. flavus* |

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# How Do They Occur?

## Biology

## Environment

## Harvest

## Storage

# Gives

# MYCOTOXINS

↓ ↓

←

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# First Paper on Climate Change and Mycotoxins

Food Research International 43 (2010) 1902–1914

Contents lists available at ScienceDirect

Food Research International

journal homepage: www.elsevier.com/locate/foodres

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## How will climate change affect mycotoxins in food?

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A R T I C L E  I N F O

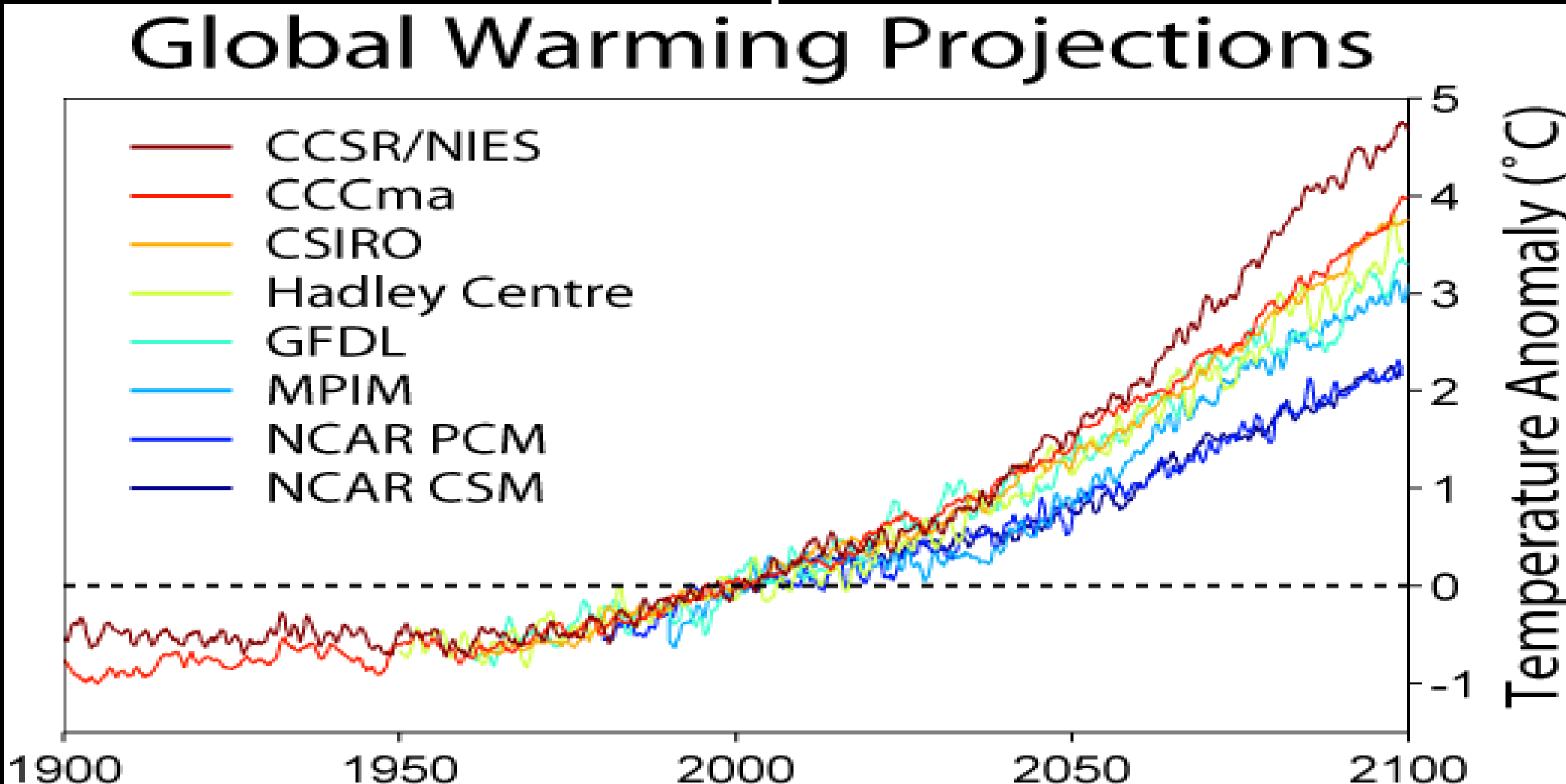
*Article history:*
Received 8 April 2009
Accepted 10 July 2009

*Keywords:*
Mycotoxins
Climate change
Fungi
Aflatoxins
Deoxynivalenol
Ochratoxin A
Temperature
Water activity

A B S T R A C T

This invited review and opinion piece, assesses the impact of climate change on mycotoxins in food: only one paper and an abstract referred directly from a substantial literature search and then only in relation to Europe. Climate change is an accepted probability by most scientists. Favourable temperature and water activity are crucial for mycotoxigenic fungi and mycotoxin production. Fungal diseases of crops provide relevant information for pre-harvest mycotoxin contamination. However, the mycotoxin issue also involves post-harvest scenarios. There are no data on how mycotoxins affect competing organisms in crop ecosystems. In general, if the temperature increases in cool or temperate climates, the relevant countries may become more liable to aflatoxins. Tropical countries may become too inhospitable for conventional fungal growth and mycotoxin production. Could this lead to the extinction of thermotolerant *Aspergillus flavus*? Currently cold regions may become liable to temperate problems concerning ochratoxin A, patulin and *Fusarium* toxins (e.g. deoxynivalenol). Regions which can afford to control the environment of storage facilities may be able to avoid post-harvest problems but at high additional cost. There appears to be a lack of awareness of the issue in some non-European countries. The era will provide numerous challenges for mycotoxicologists.

# B. Intergovernmental Panel on Climate Change Report



# 1. A Warmer Planet – Virtually Definite

Increased yields


Decreased yields


Increased insects

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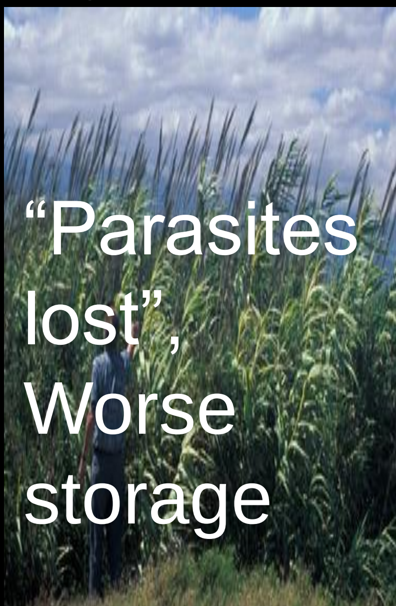
# Mycotoxin Effect

Increased Mycotoxins




Decreased mycotoxins


Increased mycotoxins

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# More crop/more mycotoxin

Current production = 1000 kg with 1mg toxin

Changed production = 2000 kg

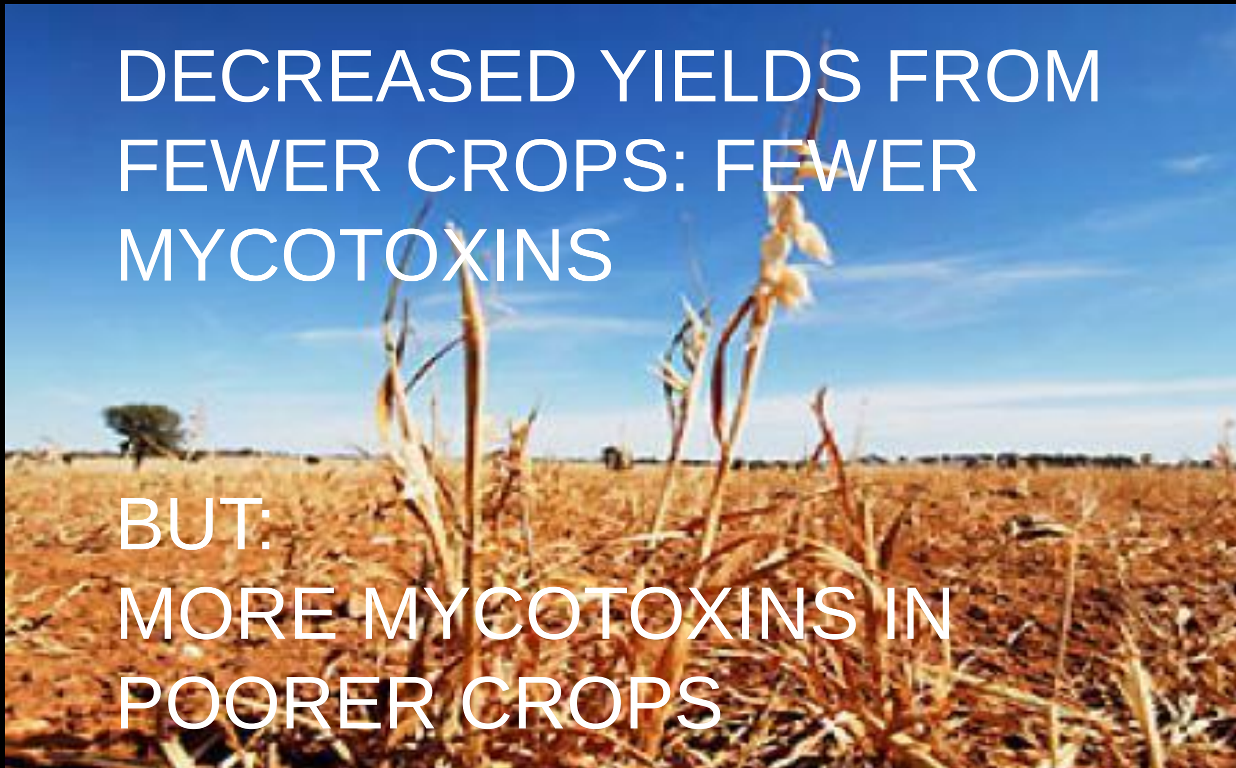
1. Quality same = 2mg toxin
2. Quality worse = > 2mg toxin
3. Quality better = a. >1<2 mg toxin

   b. 0 - 1 mg toxin

# Hence...

- 3b is the only scenario where less mycotoxin obtained from more crop.
- A very specific statement would be needed explaining how 3b might occur.
- I recommend a general statement: “more mycotoxin is “likely” from more crop”.

# 2. Heat Waves – Very Likely



# 3. Precipitation

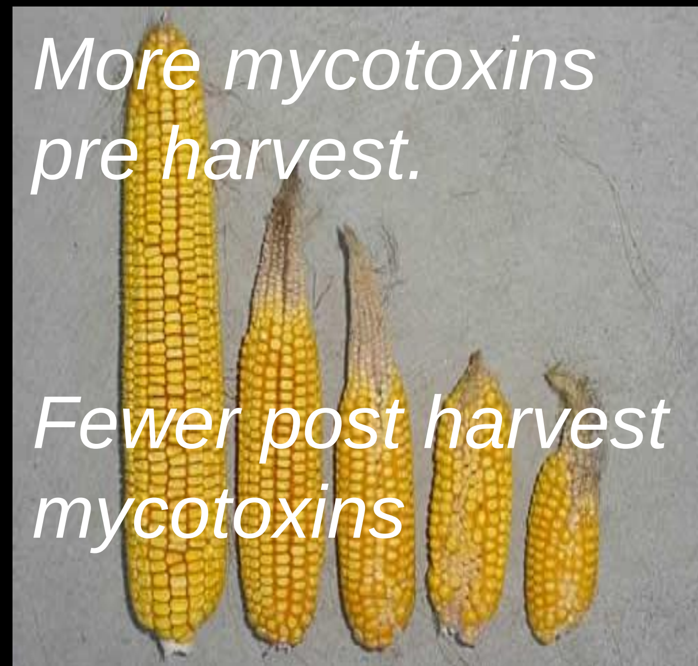
## Heavy – very likely


## Drought - likely

# Mycotoxin Effect

Heavy – very likely


Drought - likely



# Asian Climate Change

- Freshwater availability to decrease 2050
- Coastal areas greatest risk from more flooding.
- Weather alterations affect “runoff” and water availability.

# By the 2080s

- Floods every year due to sea level rise.
- Largest affect in densely populated, low-lying megadeltas.
- Small islands are especially vulnerable.

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# Mycotoxin Consequences in Regions


## Asia

- Fewer total crops fewer total mycotoxins.
- More ingress of fungi, storage major problem all from flooding.
- Compounded malnutrition  effects.

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# Africa 2020

- More mycotoxins in current cooler areas.
- Fewer mycotoxins in current hot regions.
- Storage better (hot and dry).
- But basic survival main problem.

# Europe

- Problems move South to North, e.g. *A. flavus* in Hungary.
- More aflatoxin, OTA, fumonisins in sub mediteranean.
- Less patulin and *Alternaria* toxins in current temperate.
- Tropical mycotoxin problems?

# Australia/New Zealand 2030

- Too hot/dry for crops per se.
- Can cope as a developed country.
- Fewer crops so fewer mycotoxins, but those produced high in mycotoxins.
- Storage improves.

- New Zealand: more crops/more mycotoxins.

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# Latin America 2050

- Soybean mycotoxins to increase.
- Chance of fungal “extinction”, low mycotoxins.
- Less healthy crops – more mycotoxins.
- Fewer mycotoxins from arid land.
- Storage may be efficient in hot dry areas.

# North America

- Increase yields produce more mycotoxins.
- Floods and drought - more mycotoxins.
- Cool areas change to hot - more mycotoxins.
- Floods/higher temperature - storage probs.

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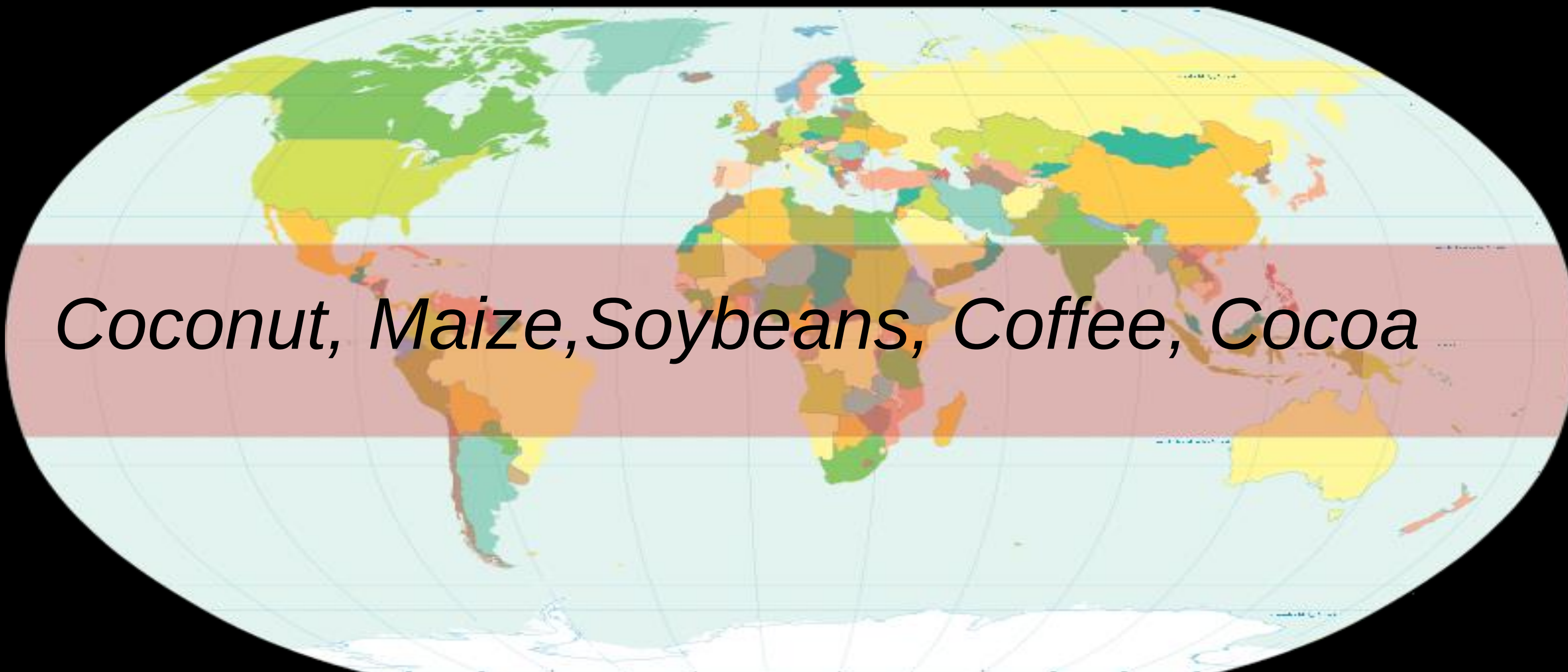
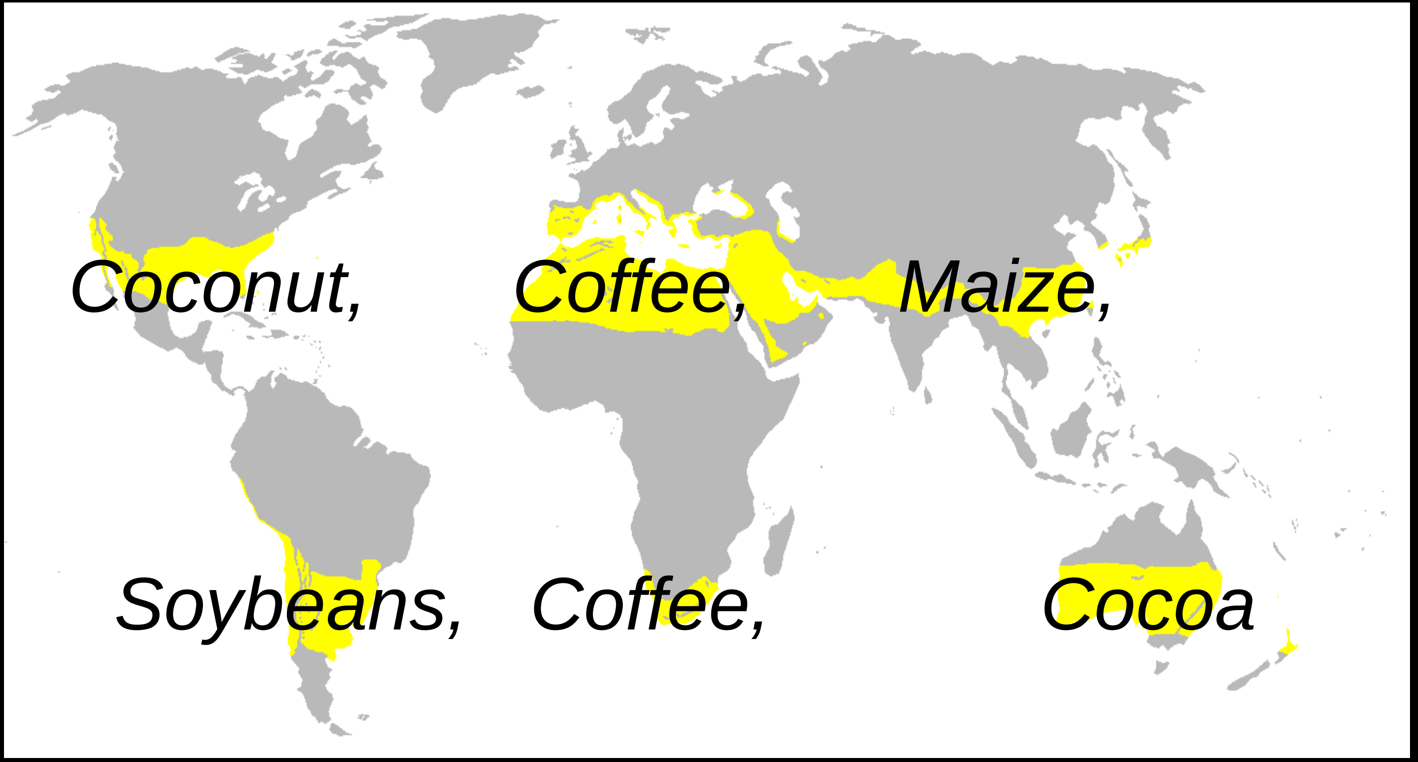
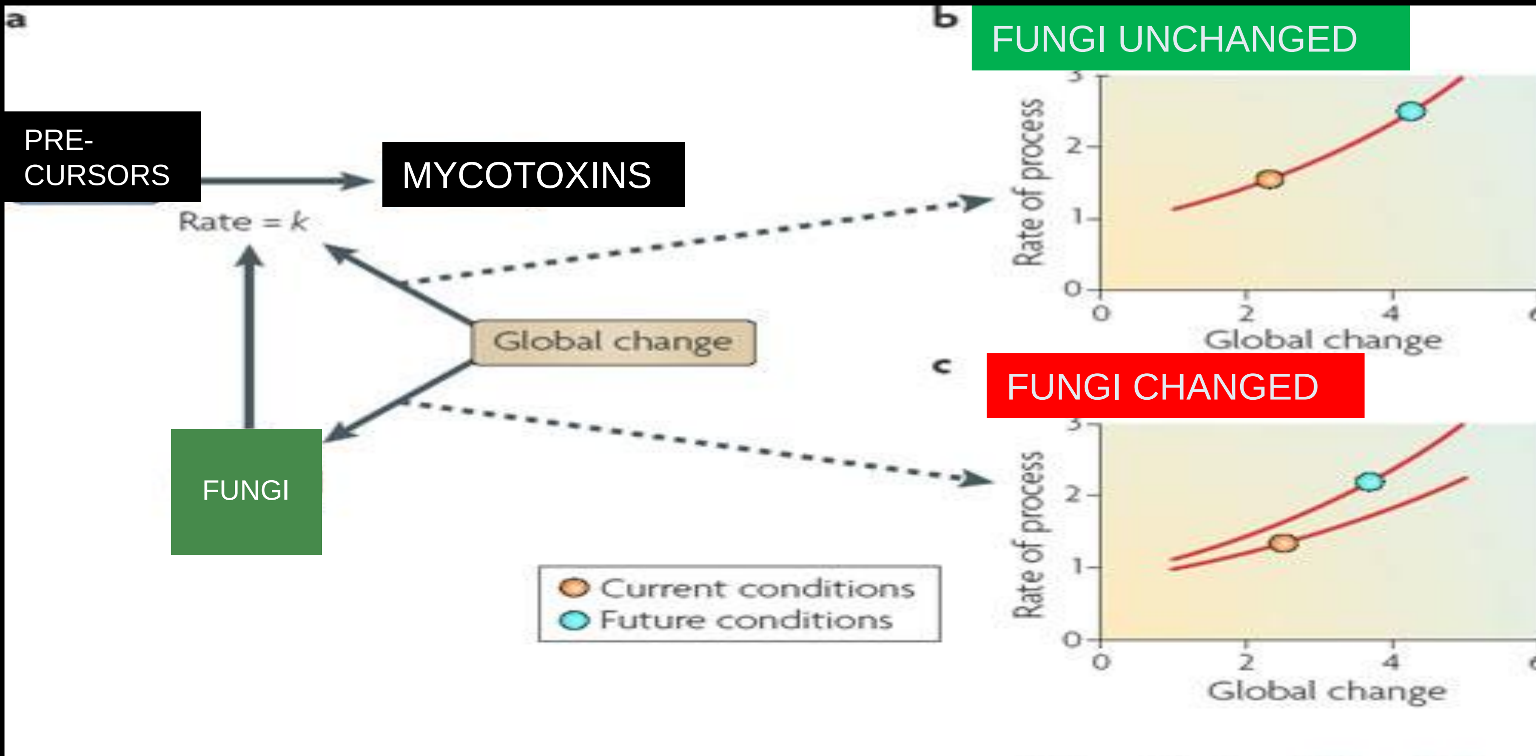
# Tropics: Less Developed Countries



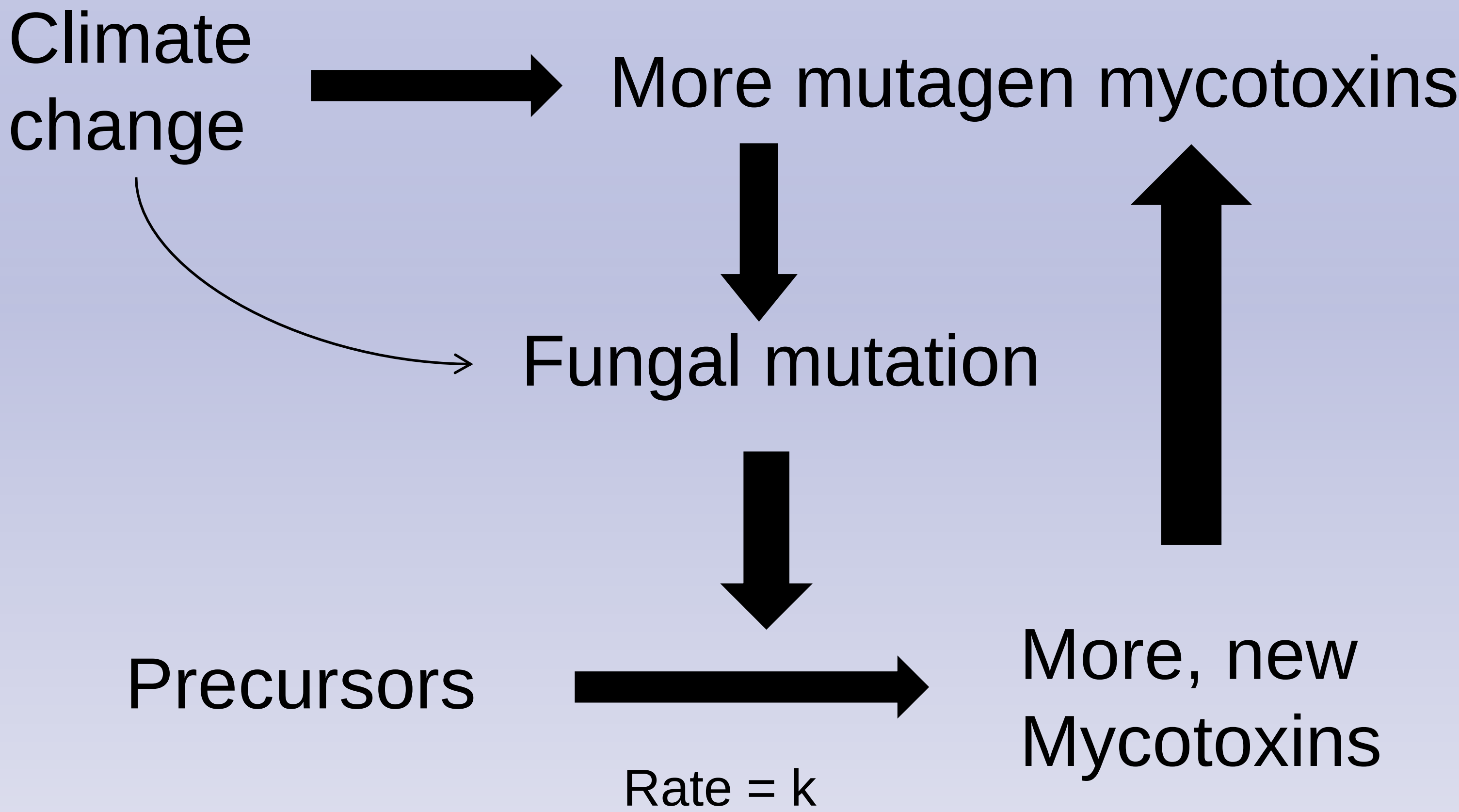
# To Subtropics: Developed



# E. Mycotoxin Biosynthesis Rates and Climate Change



# F. **Climate Change Mycotoxin Cycle Hypothesis**



# G. Water/Drinking Water

| | Yes | No |
|---|---|---|
| Fungi | + | |
| Mycotoxigenic fungi | + | |
| Mycotoxins | + | |
| Agricultural “run off” | + | |
| Growth | + | |
| Mycotoxin production | + | |

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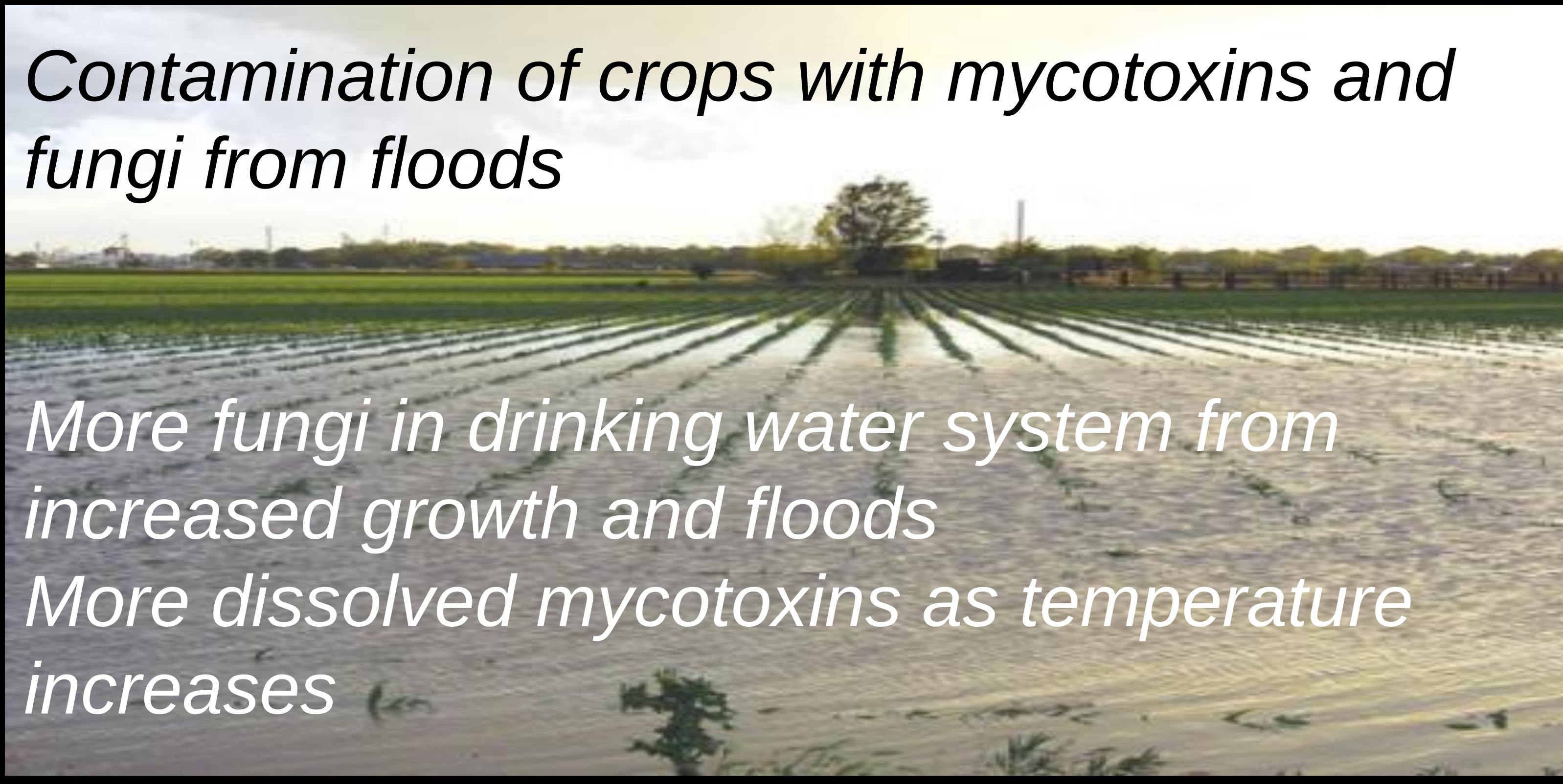
# a. More Water



*Contamination of crops with mycotoxins and fungi from floods*

*More fungi in drinking water system from increased growth and floods*
*More dissolved mycotoxins as temperature increases*

# b. Less Water - Drought

*Less spread of fungi & mycotoxins via water*

# H. Mycotoxins as Bioweapons

| | Mycotoxin | Weapon |
|---|---|---|
| Aflatoxin | Yes | Yes (Iraq) |
| T2 toxin | Yes | Yes |

(Paterson (2006) *Mycol Res*; Paterson, Lima (2010) Springer Verlag.)

Weaponised fungi to take advantage of changed climates.

# I. Fungal Physiology

# 1. Optimum Growth °C

- *A. flavus* 35 - 21 = 14
- *A. ochraceus* 30
- *P. verrucosum* 26
- *P. expansum* < 25
- *Alt. alternate* 23
- *F. graminearum* 21

# Fungal Relative Dominance

(% infected, Brazil)

| | Pepper | Brazil nuts |
|---|---|---|
| *Aspergillus flavus* | 44 | 27 |
| *A. ochraceus* | 4 | 0 |

+ 100 years climate change: No relative change, or extinct in Brazil.

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# Dominance in Grapes (N. Portugal)

| Present | 100 years |
|---|---|
| *A. carbonarius (OTA)* | *A. flavus* |
| *A. flavus* | *A. carbonarius* |
| *P. expansum* | No *P. expansum* |

N.B. Reports of *A. flavus* from grapes and aflatoxin in grape juice exist

# So *Aspergillus flavus with* Climate change at 5°C/100 years

Not dominated by:

*Alternaria, Fusarium, Aspergillus* (other), *Penicillium.*

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# Aflatoxins will not be supplanted by:-

- Alternariol, deoxynivalenol, fumonisins, ochratoxin A, patulin.

- However, all diminished in already hot regions.
- Same calculations for other mycotoxins possible

# Optimum Mycotoxin Production ºC

| | |
|---|---|
| • Aflatoxin | 33 |
| • Deoxynivalenol | 30 or 26 |
| • Ochratoxin A | 28 or 25 |
| • Tenuazonic acid | 20 |

# So aflatoxins will not be supplanted by:

- Ochratoxin in peanuts, corn, wheat, cheese
- Deoxynivalenol in corn, wheat
- Fumonisin in corn

# Tenuazonic acid (20 °C) to Other Mycotoxins

| Mycotoxin | Opt °C |
|---|---|
| Fumonisin | 25 |
| Ochratoxin A | 25 |
| Alternariol | 25 |

# Minimum Moisture (%) Contents Effects

| | *A. ochraceus* | *A. flavus* | *Penicillium* |
|---|---|---|---|
| Soy | 14.75 | 17.25 | 18.5 |
| Peanuts | 9.25 | 10.25 | 12.5 |

# Consequences

- Drought: More *A. ochraceus* & ochratoxin
- Floods: More *Penicillium* spp & *ochratoxin, patulin in temperate wet regions.*
- But ochratoxin more problematic overall from *Aspergillus* & *Penicillium*

# Amelioration Strategy

- Plant in cooler season avoid mycotoxin heat stress.
- Change crop variety e.g. chili has less AF.
- Crop relocation: “Parasite lost”?
- Biodegradation of mycotoxins.
- Move storage facilities to hot dry areas.

# Underlying Policy Framework

- Focus R&D on mycotoxins (effect on competition?).
- Who does R&D in developing countries?
- Land reform: Best crop in 50 years?
- Relocate storage equipment, political decision needed.
- Training; capacity building.

# Implementation Contraints

- Developing countries may not cope with more mycotoxins from increased crops in some regions.
- Markets reject crops grown to avoid mycotoxins e.g. Hot chili too hot, GM?

# Implementation Opportunities

- Analytical kit manufacturers.
- Developed countries cope with tropical crops.
- Plant crops in “Parasites Lost”.
- New hot dry areas good for storage.

# Conclusions

- More mycotoxins
- More “high temperature” mycotoxins
- Region “up” shift - sub trop goes tropical
- Parasites lost
- Heat extinction
- New species
- Storage opportunities

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# Thank you

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# Frequency % Corn

| | | |
|---|---|---|
| *Fusarium verticillioides* | fumonisin | 100 |
| *F. graminearum* | DON | 75 |
| *Alternaria alternata* | alternariol | 21 |
| *Aspergillus flavus* | aflatoxin | 2 |

# Commodity with aflatoxin increase and mycotoxin decrease as too hot in some regions

| Commodity | Mycotoxin decrease |
| --- | --- |
| Corn | fumonisins, ochratoxin A, deoxynivalenol |

# Commodity with aflatoxin increase and mycotoxin decrease as too hot in some regiosn

| Commodity | Mycotoxin decrease |
|---|---|
| Wheat | deoxynivalenol, ochratoxin A |
| Peanuts | ochratoxin A |

# Plus 100 years warming

| | | |
|---|---|---|
| • *A. flavus* | aflatoxin | 1st |
| • *F. verticillioides* | fumonisin | 2nd |

- Too hot:

| | |
|---|---|
| • *F. graminearum* | DON |
| • *A. alternata* | alternariol |

# *Fusarium verticillioides, F. proliferatum*

- will not be repleced by toxigenic (same basic reason relating to optimum temperatures):-
- *Alternaria*
- *Fusarium* (other)
- *Penicillium*

# But could be replaced by...

Toxigenic:

*Aspergillus flavus MOST LIKELY*

*A. ochraceus*

*Fusarium culmurum*

# So in corn...

- Aflatoxins, ochratoxin A (from A. ochraceous) , deoxynivalenol (from ....) could increase in relation to fumonisins

- But probably not *Alternaria* toxins (e.g. alternariol, tenuazonic acid). Not found in corn anyway.

# *Similarly Aspergillus ochraceus/A. carbonarus*

- Will not be replaced by:
- Alternaria
- *Fusarium gaminearum*, *F. Culmorum*
- *Penicillium*

# But could be replaced by...

- Toxigenic:
- *Aspergillus flavus*
- *Fusarium verticillioides, F. proliferatum*

# So in actual commodities

- Peanuts: More aflatoxins compared to ochratoxin A
- Corn: More fumonisns, and aflatoxins than OTA
- Grapes, wine: more aflatoxins possible.

# C. Specific Regions
# 1. Africa 2020

- Crop Yields reduced by 50%. Debatable.
- Agricultural production severely compromised.
- Higher levels of crops in some currently cooler areas.
- Adverse affect food security and exacerbate malnutrition.
- Increase of 5 to 8% of arid and semi-arid land

# 2. Europe

- Magnification of regional differences in natural resources and assets.

- Worsen high temperature/drought reduces water availability/crop productivity in South.

# 3. Austalia/New Zealand 2030

- Water security problems intensify
- Production from agriculture to decline from drought.
- Initial benefits projected in New Zealand.

# 4. Asia

- Freshwater availability to decrease 2050

- Coastal areas at greatest risk from more flooding from sea/rivers.

# 5. Latin America 2050


Increased temperature, decreased soil water.

Tropical forest goes savanna grassland.

Semi arid replaced by arid vegetation.

Significant tropical species extinction

•

# Continued...

- Crop productivity decrease; adverse food security.

- Soybean yields increase in temperate zones – specific

# 6. North America

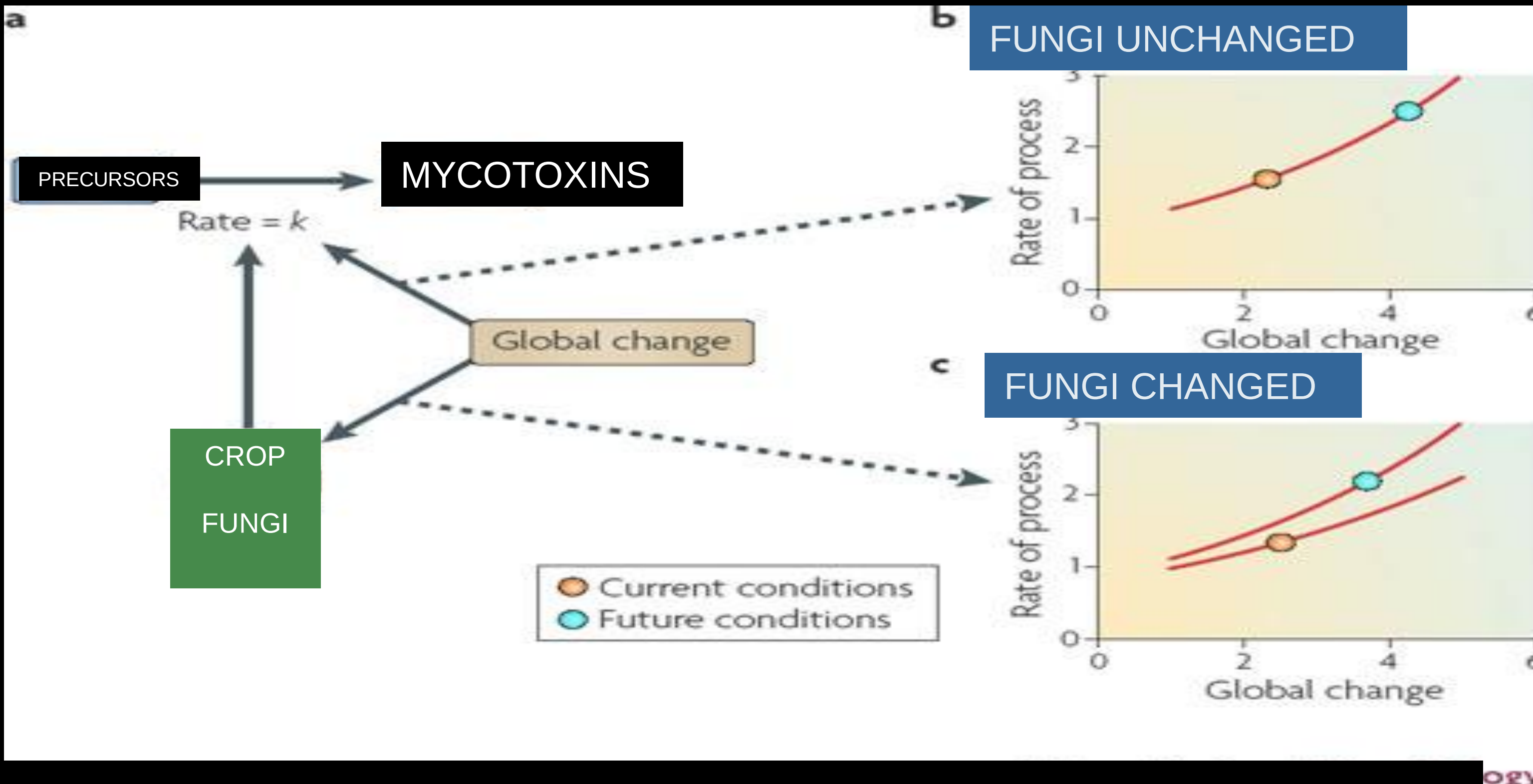
- Warming in western mountains to cause decreased snowpack, more winter flooding and reduced summer flows.

- Water resources stretched.

# North America pre 2050

- Increase in rain-fed agriculture 5 to 20%
- Important variability among regions.
- Crops challenged at warm end of range
- Lack of water resources.

# Toxigenic fungi, biosynthesis rates and climate models

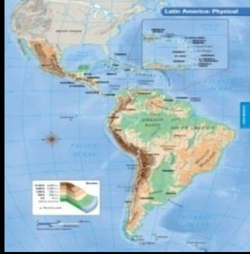


# REPORTED SOYBEAN FUNGI

*Aspergillus flavus, A. ochraceus, A. versicolor*

*Penicillium viridicatum, P. citrinum, P.expansum*

*Alternaria spp*



# POTENTAL SOYBEAN MYCOTOXINS

Aflatoxins, ochratoxin A, sterigmatocystin,

Penicillic acid, patulin, citrinin, griseofulvin,

Alternariol, altenuene

# Soybean mycotoxins?

- Potentially most mycotoxins.
- Soybeans are resistant to aflatoxins in field.
- Susceptible when stored under high moisture/temperature. But storage easier in new dryer regions.

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# However, this talk will focus on...

Climate Change 2007:
Synthesis Report

## Synthesis Report

**An Assessment of the Intergovernmental Panel on Climate Change**

*This underlying report, adopted section by section at IPCC Plenary XXVII (Valencia, Spain, 12-17 November 2007), represents the formally agreed statement of the IPCC concerning key findings and uncertainties contained in the Working Group contributions to the Fourth Assessment Report.*

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# Earth Science & Climatic Change Related Journals

- Journal of Climatology & Weather Forecasting
- Journal of Ecosystem & Ecography
- Journal of Environmental & Analytical Toxicology

# Earth Science & Climatic Change Related Conferences

- 4th International Conference on Earth Science and Climatic Change at Alicante, Spain.

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