Use of Crop-Climate Models to Develop Advisories

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Plant Health in South Africa – Threats to Biosecurity, Biodiversity and Food Security

National Science and Technology Forum

UNIVERSITY OF THE FREE STATE UNIVERSITEIT VAN DIE VRYSTAAT YUNIVESITHI YA FREISTATA UFS UV

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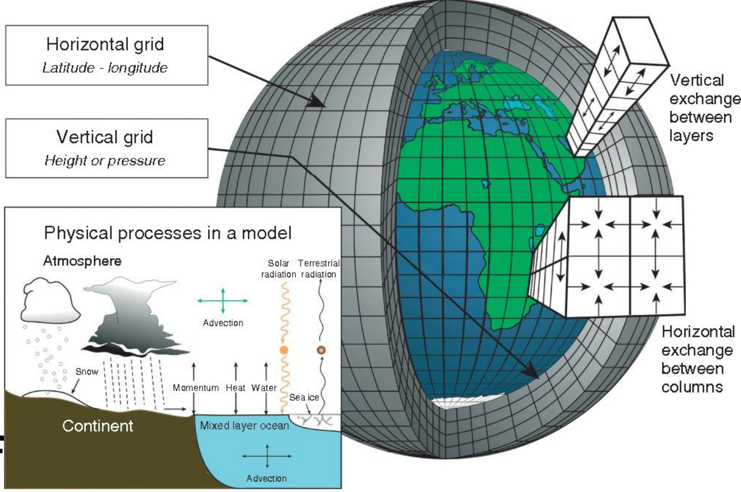
Some Basics



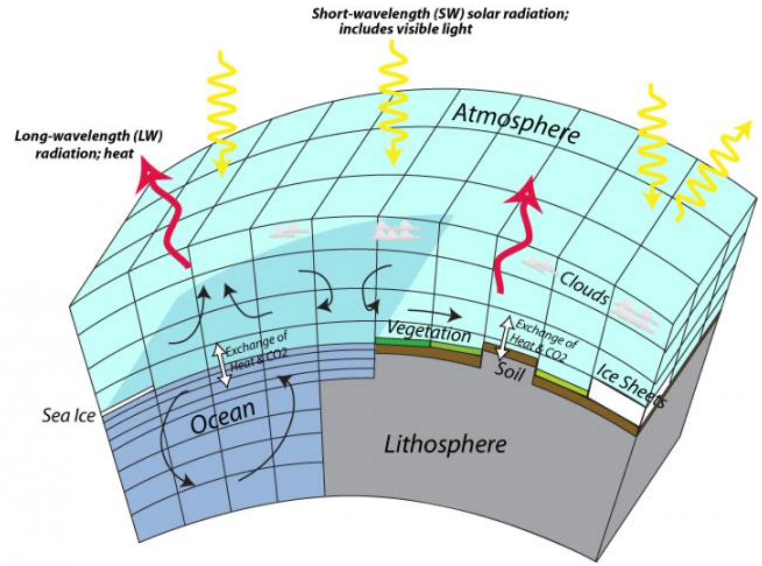
- A model is representation of the real

A global climate model (GCM) is

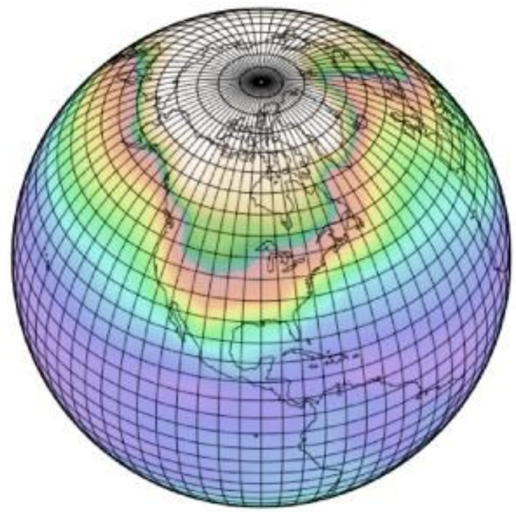
- a simulation of all factors that can aff
- a complex mathematical representation of major climate system components (**atmosphere, land surface, ocean, & sea ice**), **& their interactions**.
- Separates the Earth's surface into 3-dimension grid of cells.
- Results of matter & energy processes modelled in each cell are passed to neighbouring cells over different time steps.
- Earth's energy balance between the four components is key to long- term climate prediction.
- Some factors do not change - region's distance from shore, elevation & latitude.
- Some factors do change - seasons, volcanic eruptions, air pollution.

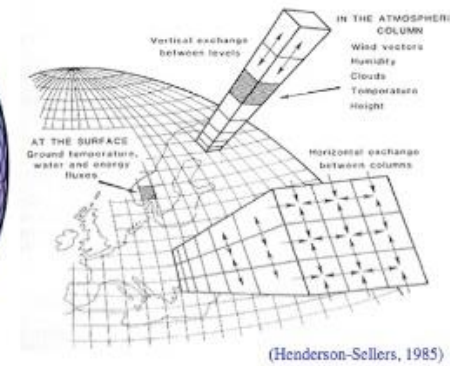
Climate Models

Energy balance

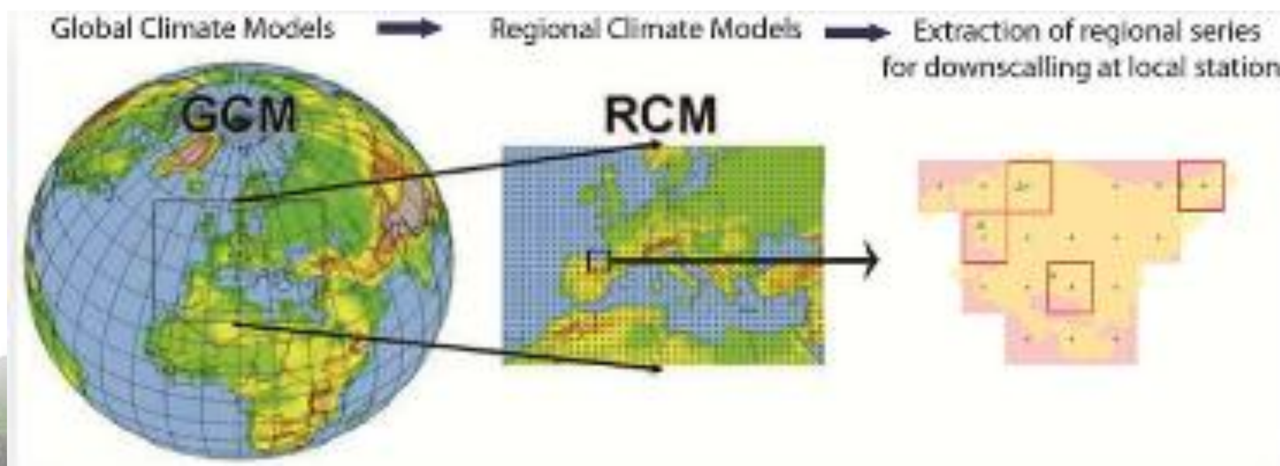


3-Dimension grid around globe

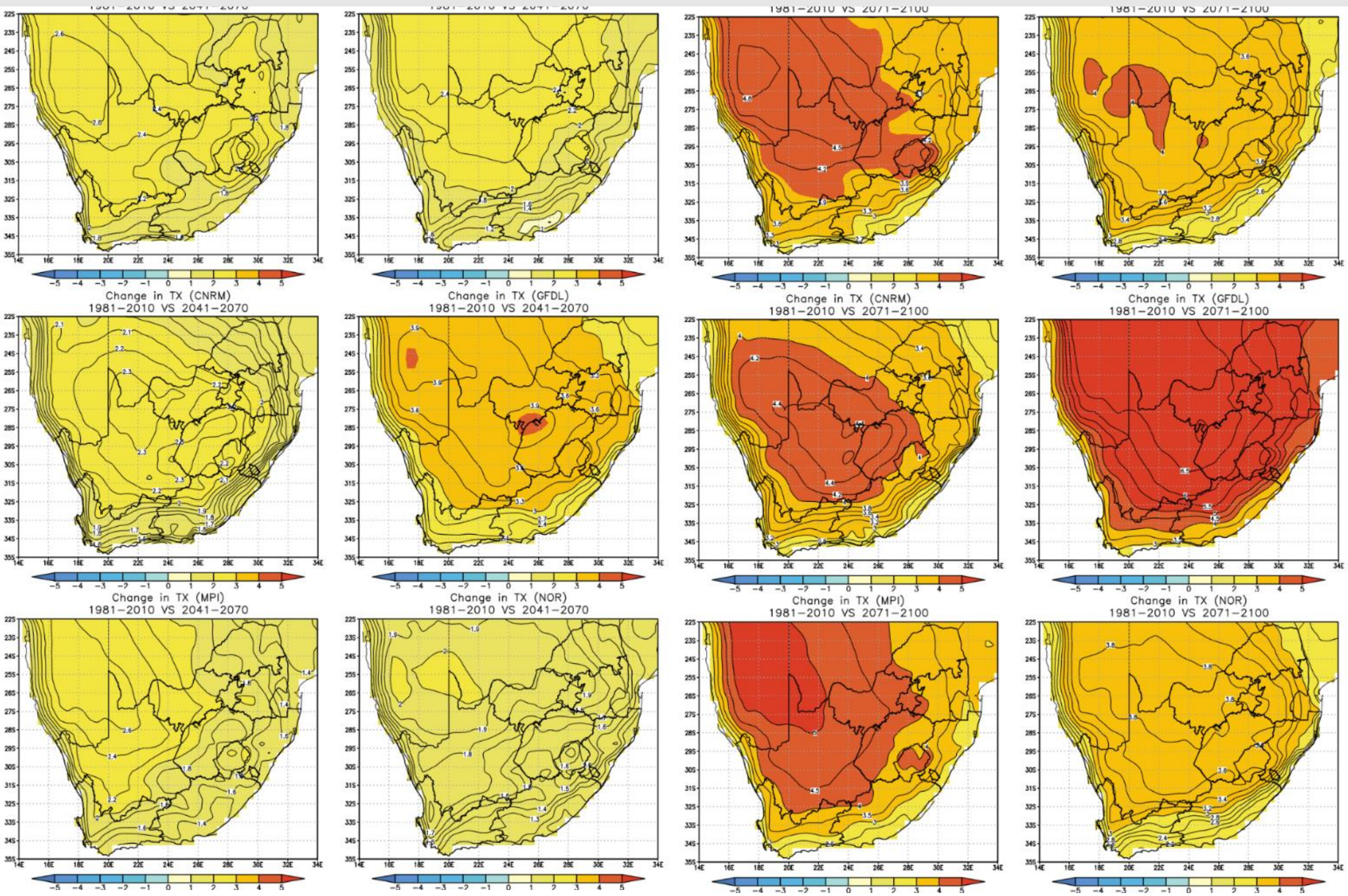




Down-scaling



Climate change across RSA



Warming is projected to take place over entire country.

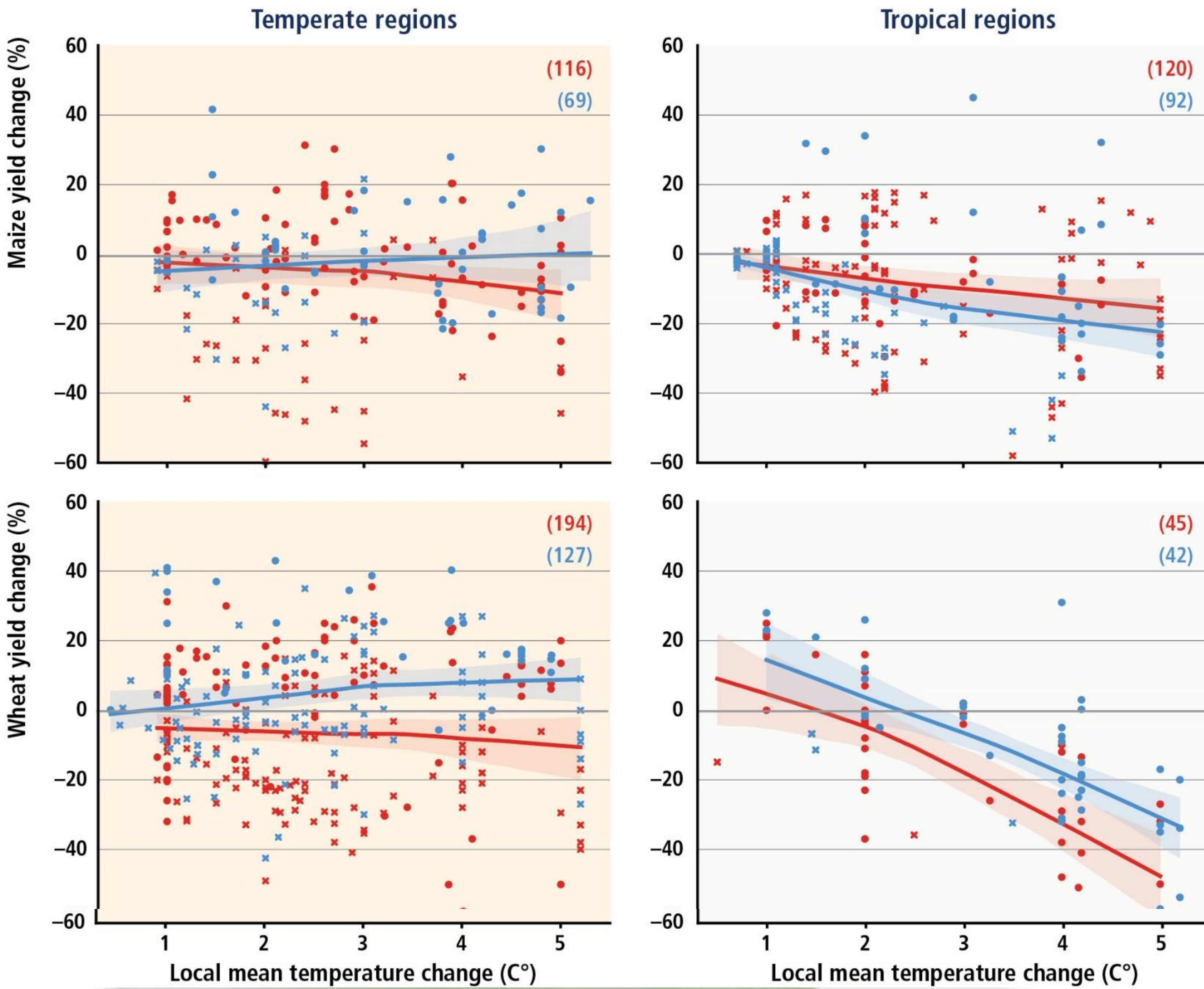
- On left change in maximum temperature for 2041-2070 ±2-3°C
- On right ±3-5°C for max Temp 2071-2100
- Relative to 1981-2010

IMPLICATIONS FOR AGRICULTURE IN SOUTH AFRICA

More frequent droughts - More heat waves of longer duration - Reduced soil moisture - Shorter growing season - Longer burning season - Reduced maize crop yield - Reduced livestock production

Part of the ARC-CCCC project titled *"Future projections of extremes, singularities and atmospheric mass transport, and its implications for the agricultural sector"* Dr Christien Engelbrecht

Effect of Temperature on Crop Production



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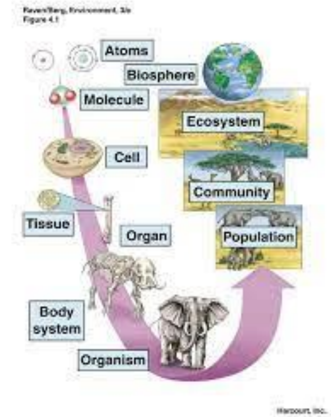
Some Basics continued



- **A crop-climate model** is mathematical equations t
represent reactions occurring within plants & intera
between crops & environment.
- Agricultural systems are characterized by many organizational levels - from individual components in single plant, thru constituent plants, to farms or a whole agricultural region or nation.
- main aim of crop models is to estimate harvestable (economic) yield.
- Types of models:
  - Empirical – regression equations – not easily transferable
  - Mechanistic – describe behavior of system & mimic relevant physical, chemical or biological processes
  - Static and dynamic models – without or including Time - as differential equations
  - Deterministic & stochastic models – definite predictions for quantities
  - Simulation & optimizing models – imitate system & management options

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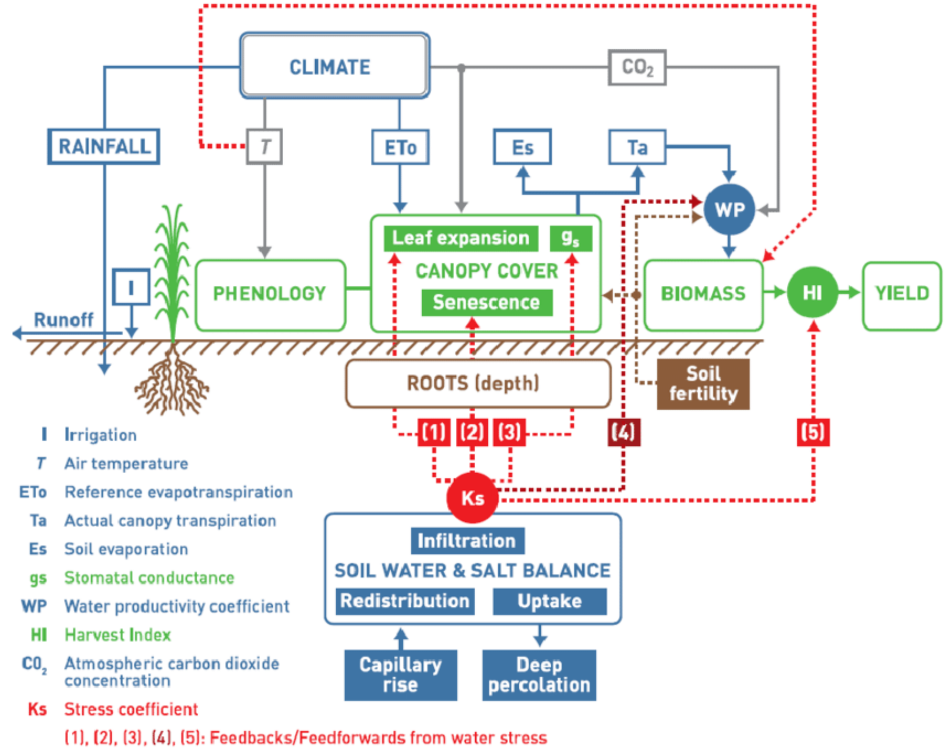
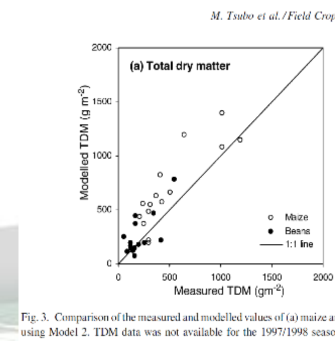
Crop Simulation Models

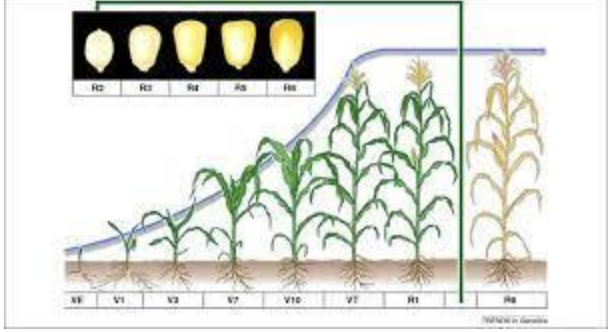
According to specific crop characteristics and environment



- **Usually daily time step**
- Soil and crop characteristics as standard input
- **Daily climate data**
- Agronomic management practices
- Need calibration & validation for cultivars & environment
- Predict **growth, development, yield, water use**



Use of Crop Models



- Research tools
  - Understand system across disciplines,
  - yield analysis, genetic improvement, data analysis etc
- Crop system management tools
  - Agronomic practices, input management,
  - Risk / investment assessment, site specific optimization
- Policy analysis tools
  - Establish best practice for recommendations, yield forecasting, assessing crop-climate suitability
  - Global climate change & crop productivity or gap analysis

Crop System Management Tool

Agronomic practices, inputs management & Advisories

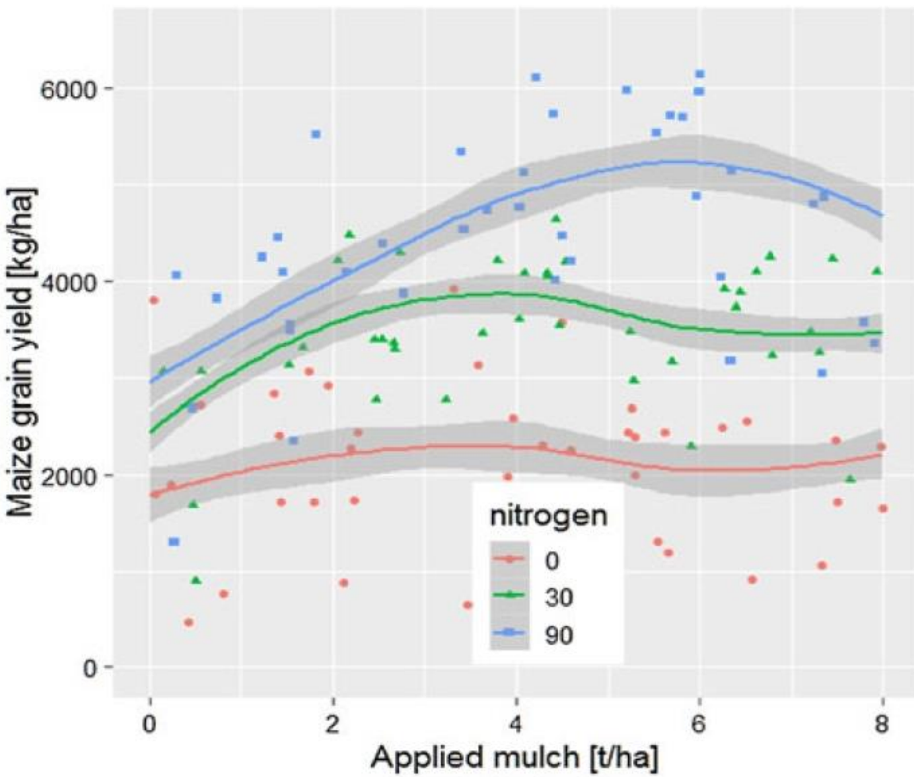


Fig. 4. Interaction effects of residue biomass levels and N fertilizer on grain yield a
University of Zimbabwe site in 2014 growing season.

Zimbabwe Maize Grain Yield under Mulch vs Nitrogen Applications

Mupangwa et al., 2019 Renewable Agriculture Food Systems

Risk/investment Assessment, site specific optimization & Advisories

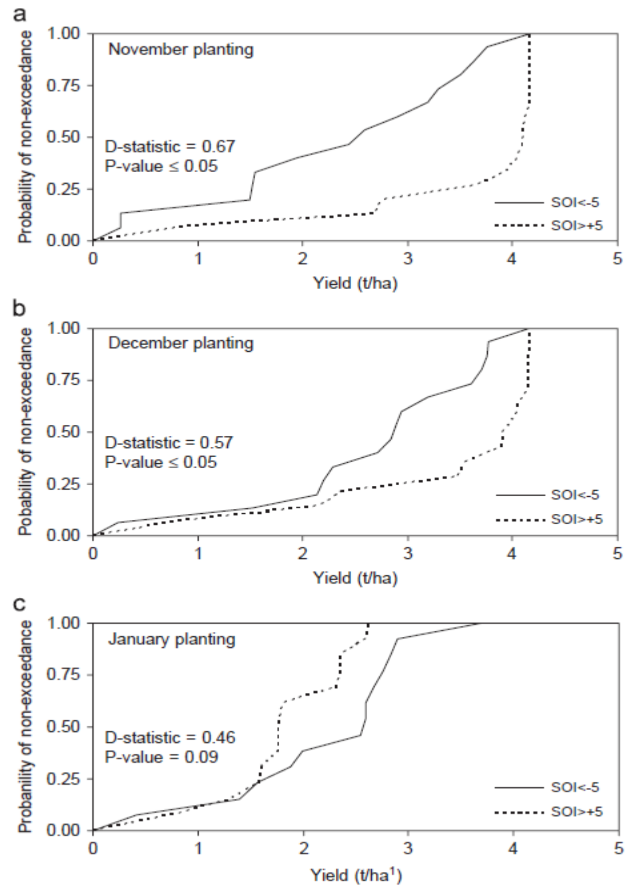


Fig. 3. Cumulative probabilities of simulated long-term (1950/1951–2001/2002) maize yield with water harvesting for three planting dates (averaged over cultivar, plant density and initial water content) in two SOI classes

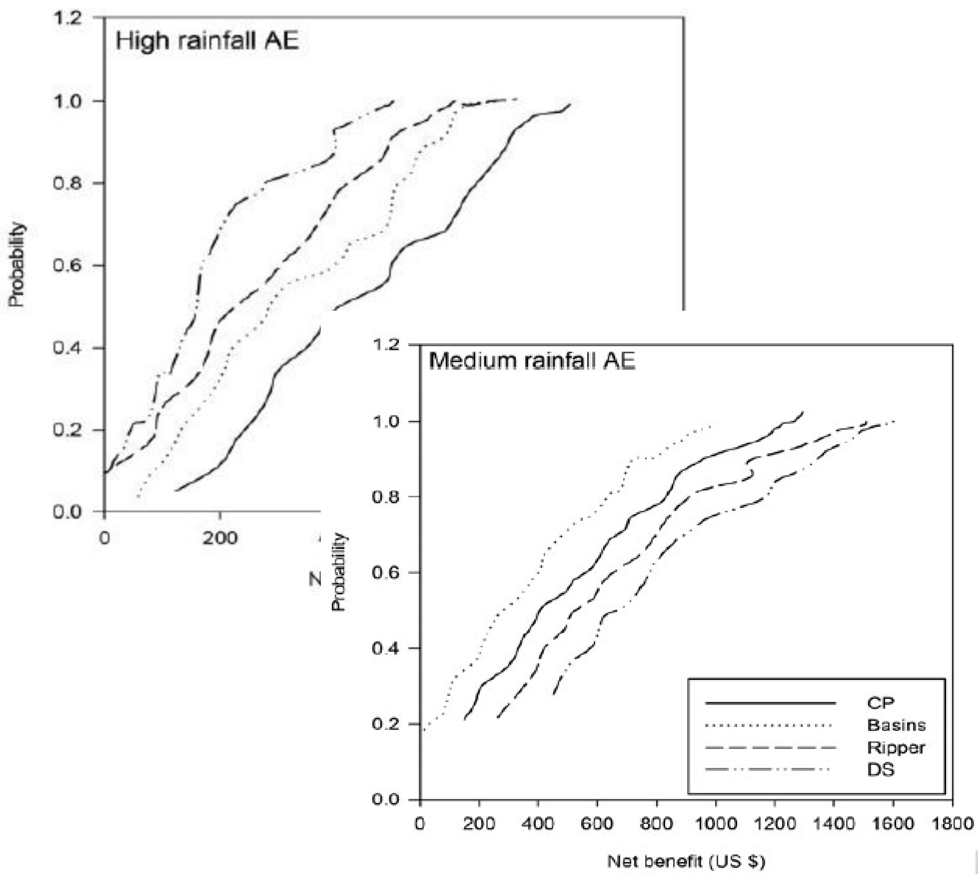
Bloemfontein Maize Grain Yield under El Ninõ vs La Nina

Tsubo & Walker, 2007. J. Arid Environments Systems

Policy Analysis using Crop Models

Establish best practice for recommendations

Conservation agriculture for smallholders



Zimbabwe Maize Grain Yield under Conservation vs Convectional Tillage

Mupangwa et al., 2016 Renewable Agriculture Food Systems

Global climate change & crop productivity or gap analysis

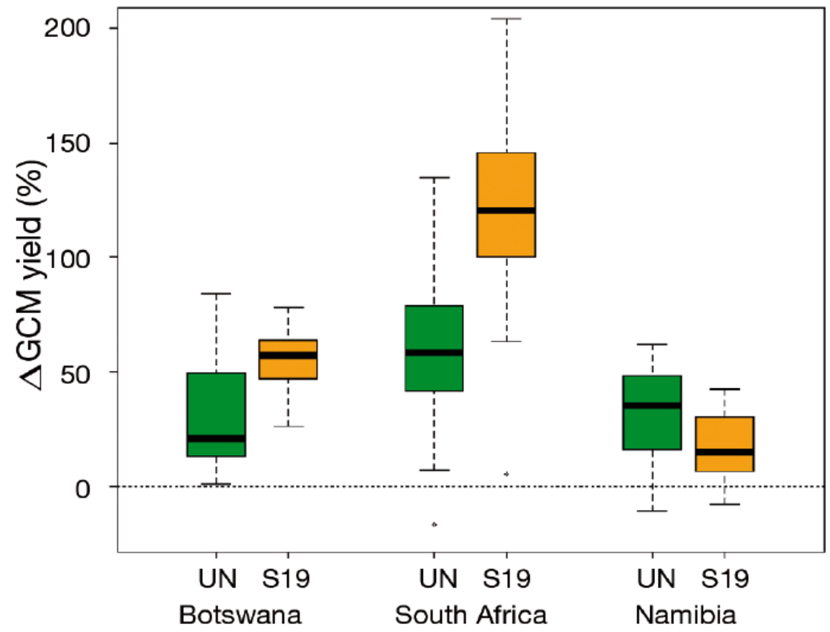


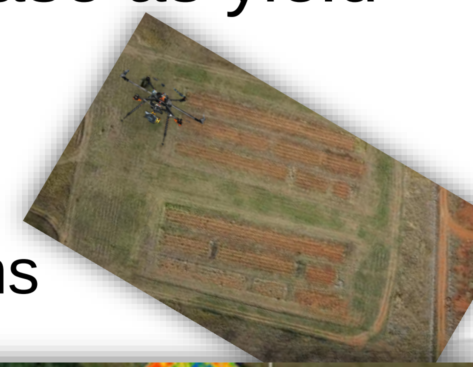
Fig. 6. Box and whisker plots of mean yield changes (%) in 20 GCMs (A–T in Table 1) under the RCP8.5 scenario in mid-century (2040–2069) at Botswana-Gaborone, South Africa-Bloemfontein and Namibia-Caprivi for the 2 landraces UN (green) and S19 (orange). Horizontal lines: median; boxes: range between lower and upper quartiles; whiskers: minimum and maximum values in the data set excluding outliers

Southern Africa Bambara groundnuts Yield 1980-2010 vs 2040-69

Karunaratne et al., 2015. Climate Research

Gaps in Crop-Climate Models

- Diseases & Pests Modelling
  - Not holistic and powerful enough
  - Not simulate pest and disease outbreaks
  - No qualitative impact of pests & disease as yield-reducing factors
- Variability across field lacking
  - Only under precision agriculture applications
- Correct initialization point needed
  - Need monitoring instruments
  - For pests & diseases and infections



Disease control methods that can be modelled

- Agronomic practices
  - Mulching, crop rotation, fallow
- Chemical control
  - Spraying, fumigation, etc
- Biocontrol agents
  - Integrated pest & disease management
  - a/c inoculation mode, time, duration
- Resistant genes
- Geocontrol
  - a/c temperature, rainfall, radiation etc

To reduce biomass accumulation

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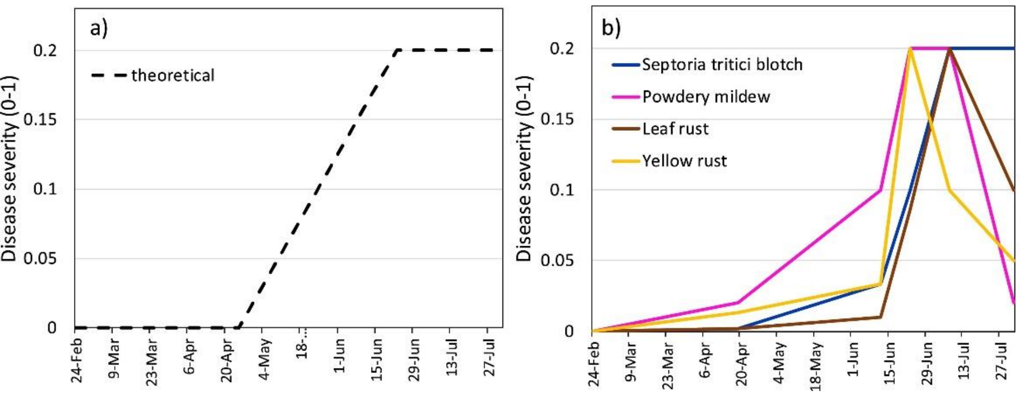
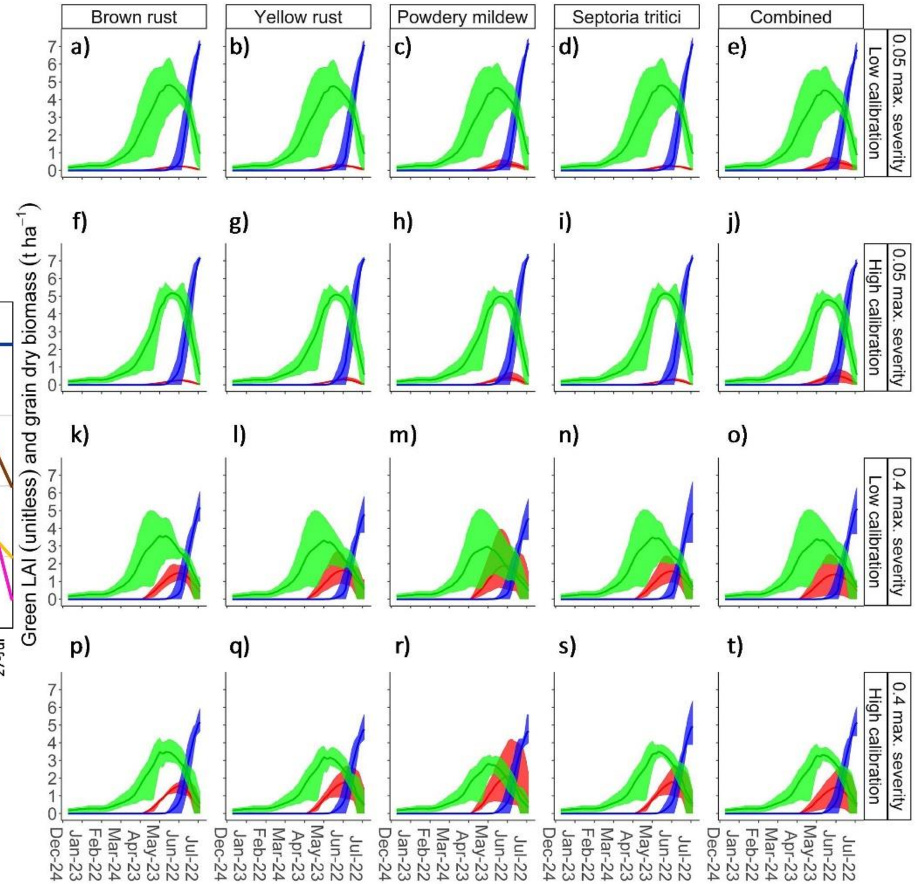
Disease Modelling

Characterize disease cycle by an infection chain





Functional traits in response to environmental traits

- Temperature & rainfall & leaf wetness effect
- To retard leaf growth
- To decreased biomass

Process-based information

- to constitute building blocks of a simple, generic, process-based modelling structure
- Relate disease to yield

Examples: Weather affecting Diseases

Wheat Stem Rusts infection – temperature

- Temp >20°C increase spread stem & leaf rust
- Temp ≤15°C favor stripe or yellow rust

Soybean Rust development

- Favored by temperatures range 12°-29°C
- continuous period of wetness on leaves
- with relative humidity >75% for more 12 hours.

Maize Smut

- Optimum germination 13 to 20°C
- Unfavorable at soil temperatures above 25°C
- Relative humidity 60-90% & 1 mm rain

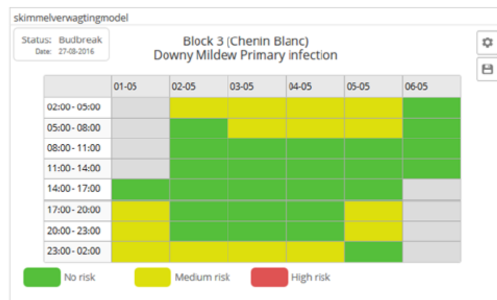
Downy Mildew

- hourly rainfall, temperature & relative humidity
- For primary infections period: 24-h rainfall > 10 mm wet leaves > 3 hours when 24-h average air temperature >10°C.
- For secondary infection: 4 continuous h RH > 92% with 2+h wet leaves & mean air temperature ≥13°C.

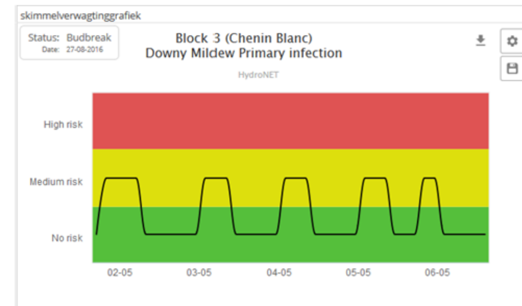
Examples of Early Warning Model

Grape Compass

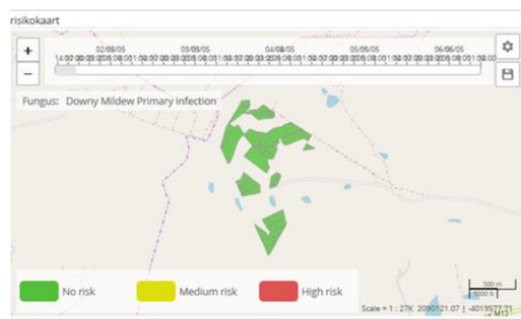
- An on-line decision support system for viticulturists / grape growers
- makes reliable forecasts of fungal disease risks in vineyards
- including
- **powdery mildew,**
- **downy mildew and botrytis**



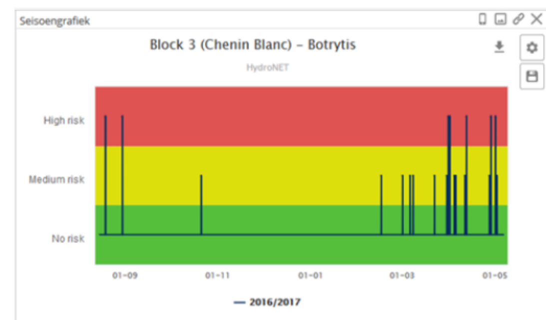
1. Downy mildew disease forecast (table)



2. Downy mildew disease forecast (graph)



3. Downy mildew disease forecast (map)



4. Botrytis risk events per season (graph)

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AgriCloud with spray advise

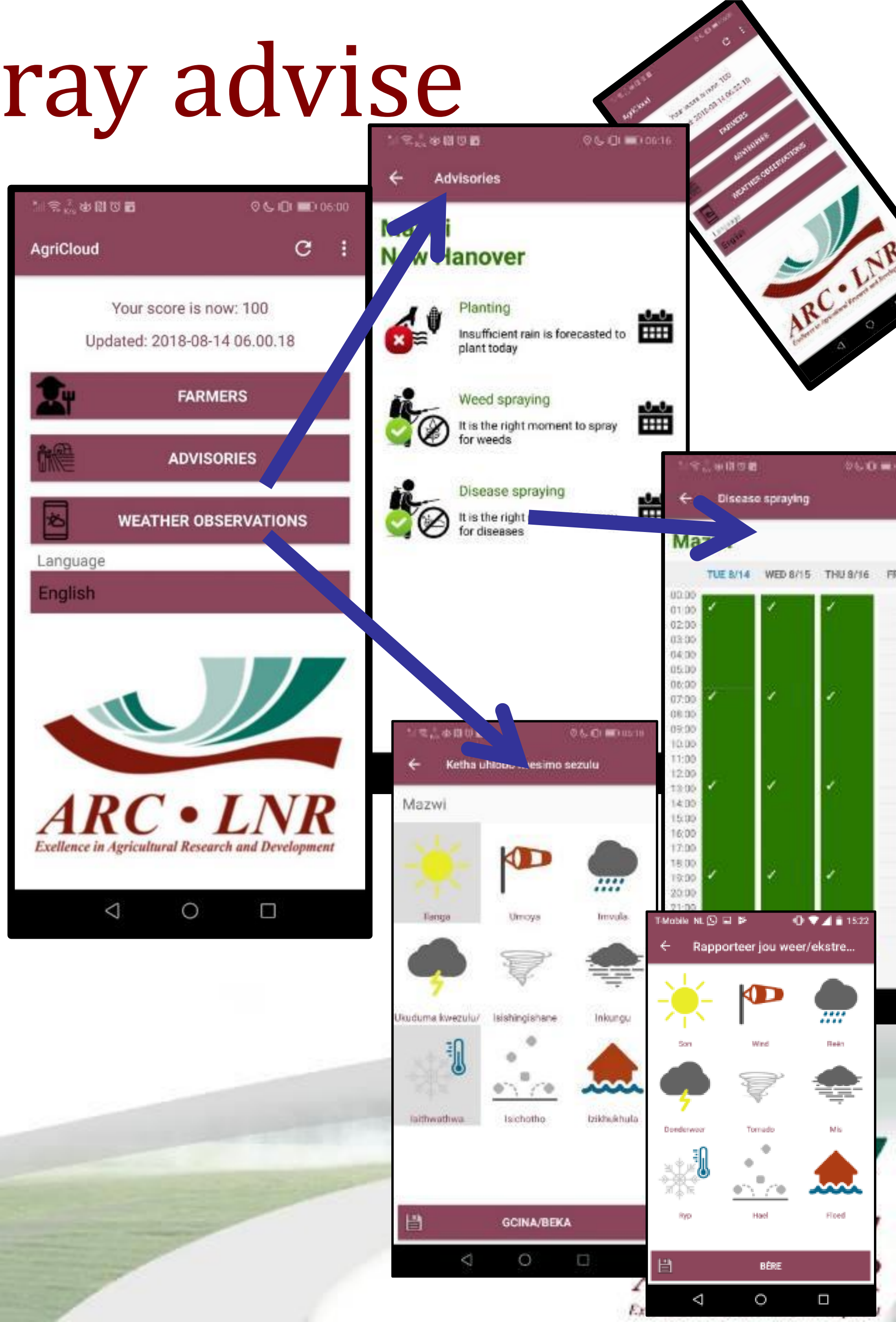
Online weather based agricultural advisory system that:

- Enriches weather & climate data with agricultural info & local knowledge
- Generates real-time personalised forecasts & warnings
- All aspects are tailored to farmers own needs & location.
- **Includes advice on weather conditions for spraying with ARC-PHP**

To assist with:

- Making well-informed farm management decisions
- Optimising use of farm inputs
- Reducing weather & climate related risks
- Improving food production in a sustainable manner.

Advisories must include an action that a farmer can take to change an adverse effect of weather parameters on production.



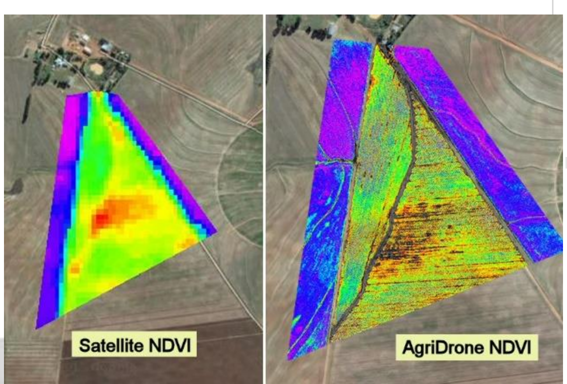
Formulation of Advisories

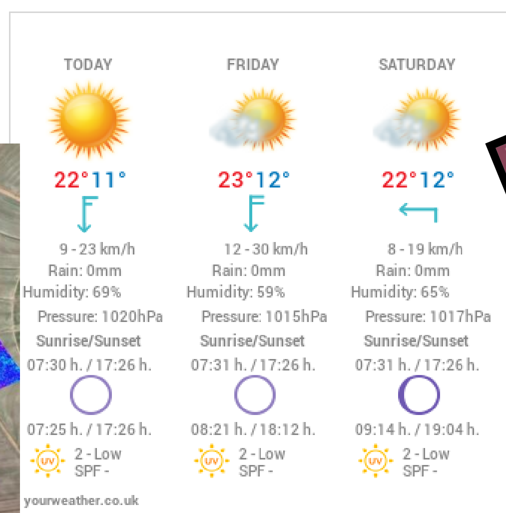
Inputs:

- Basic experimental results
- Relationships between crop growth & disease infestation and weather parameters
- Weather forecasts
- Satellite monitoring of fields

Outputs:

- Routine advisories
- Location specific info
- Message relevant to farm operations
- Delivery system
- Client database





Need to Work Across Disciplines . . . .

- **Climate models & weather forecasts**
  - down-scaled to at least $15km^2$
- **Crop models**
  - For variety of crops including effects of environmental stress
- **Disease / Pest models**
  - few available and not yet integrated with crop models
- **Advisories**
  - As early warning of conducive weather conditions for infestation
  - As advice to spraying for pests and diseases
  - As monitoring of cumulative favorable conditions for outbreaks
  - Need further development by transdisciplinary teams

Acknowledgements
- ARC-NRE Team
- Prof Sue Walker WalkerS@arc.agric.za

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