A Research Proposal
Submitted in Partial-fulfilment of the Requirement for the
Degree of Master of Philosophy in Physics

ICCS-4 MONTEVIDEO, URUGUAY

UWI

CARIWIG

The Resurgence of Crop Simulation Modelling in the Caribbean- The Case of Sweet Potato, *Ipomoea batatas*

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Collaborators:

UNCW

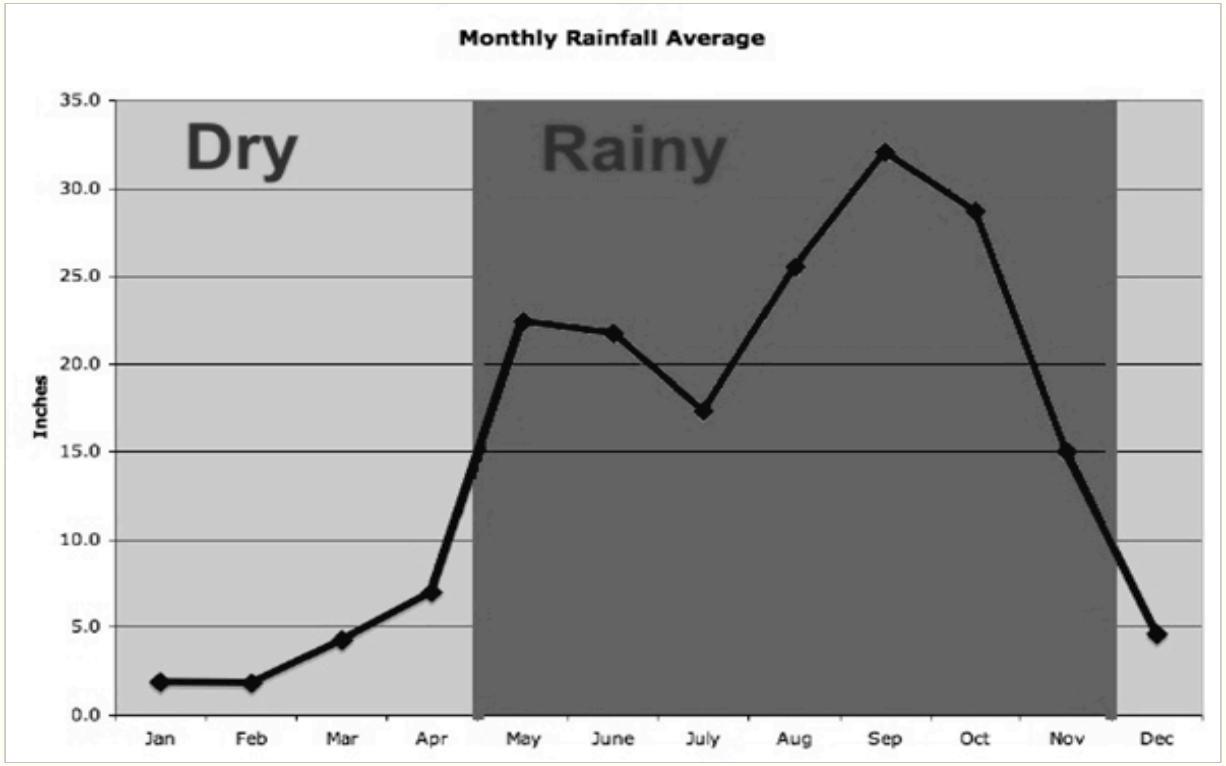
Outline of Presentation

1. Background:
   - Climate Sensitivity of Agriculture (Caribbean Context),
   - Estimating Yields (Manually)- Yield vs. Climate Dilemma
   - Importance or Root Crops to Caribbean Food Security

2. Methodology: Tools and Approaches
3. Results: Parameterization, Climate Change Production
4. Conclusions: Main lessons learnt

1. Introduction: Why This Study?- Caribbean Agriculture is Very Sensitive to Climate

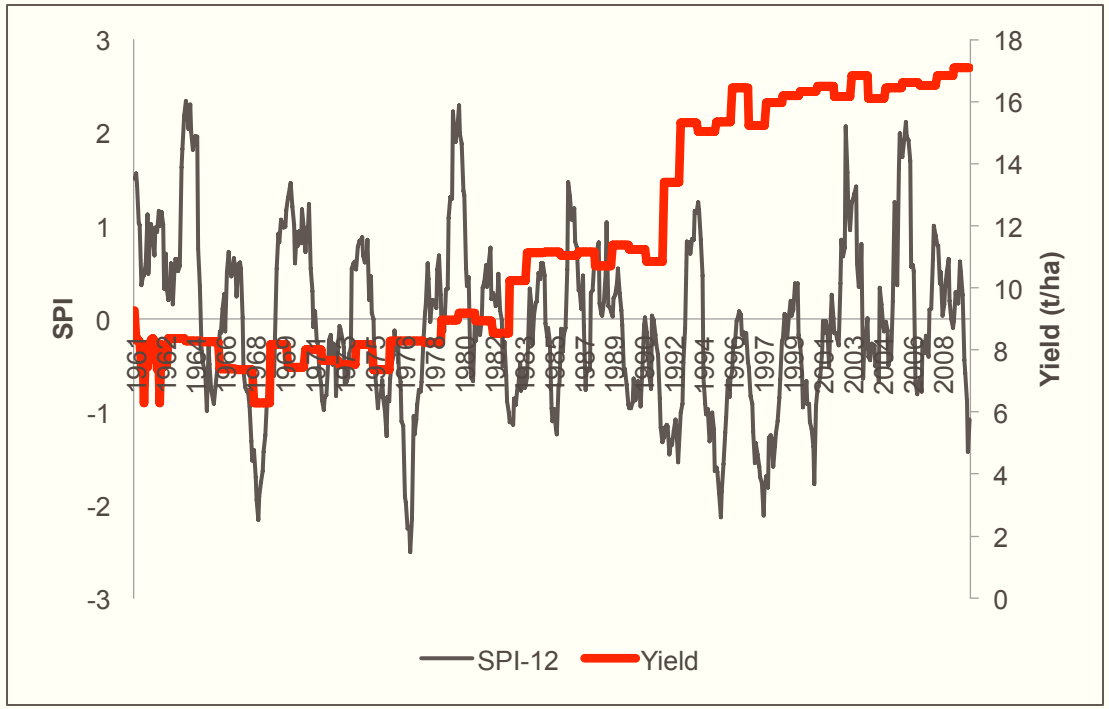
- Agriculture very Climate Sensitive
- Jamaica (Caribbean) rainfall is bimodal
- Timing, intensity of Mid-summer drought affects cropping season
- Limited use of irrigation for drought mitigation



Pattern of mean monthly rainfall in the Caribbean.

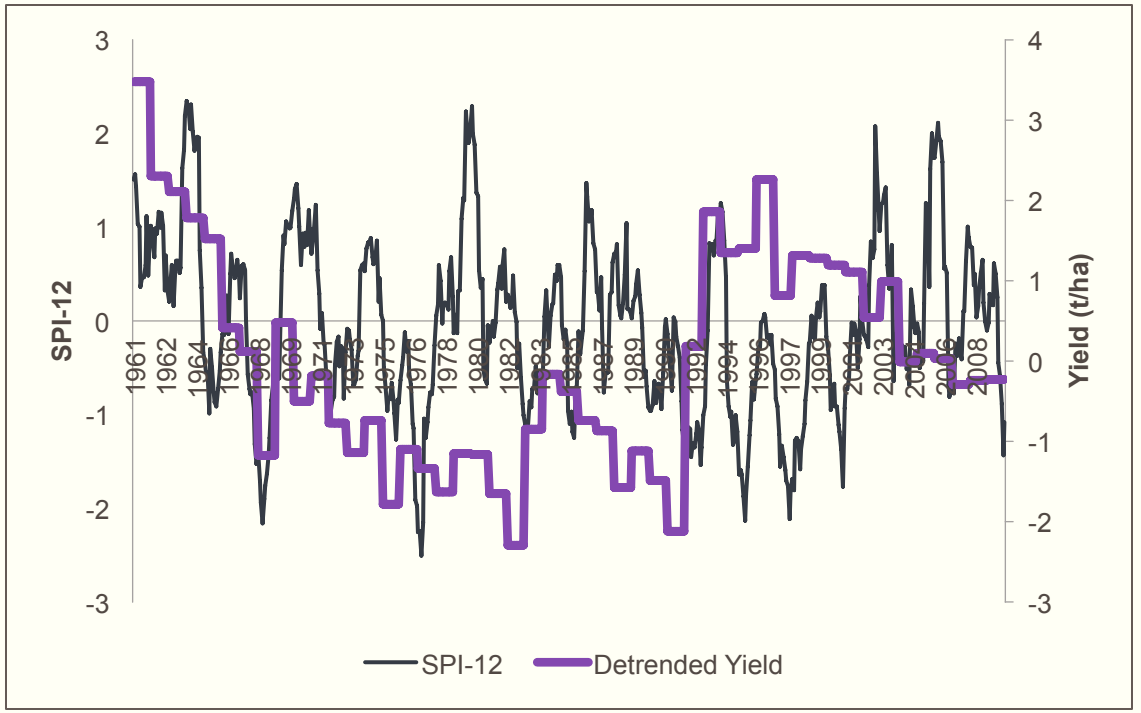
Source: ntsavanna.com

1. Background- Climate Sensitivity not captured by data 'measurement' regime



Annual drought index (SPI-12) versus mean annual Sweet potato yields for Jamaica (1961-2009)

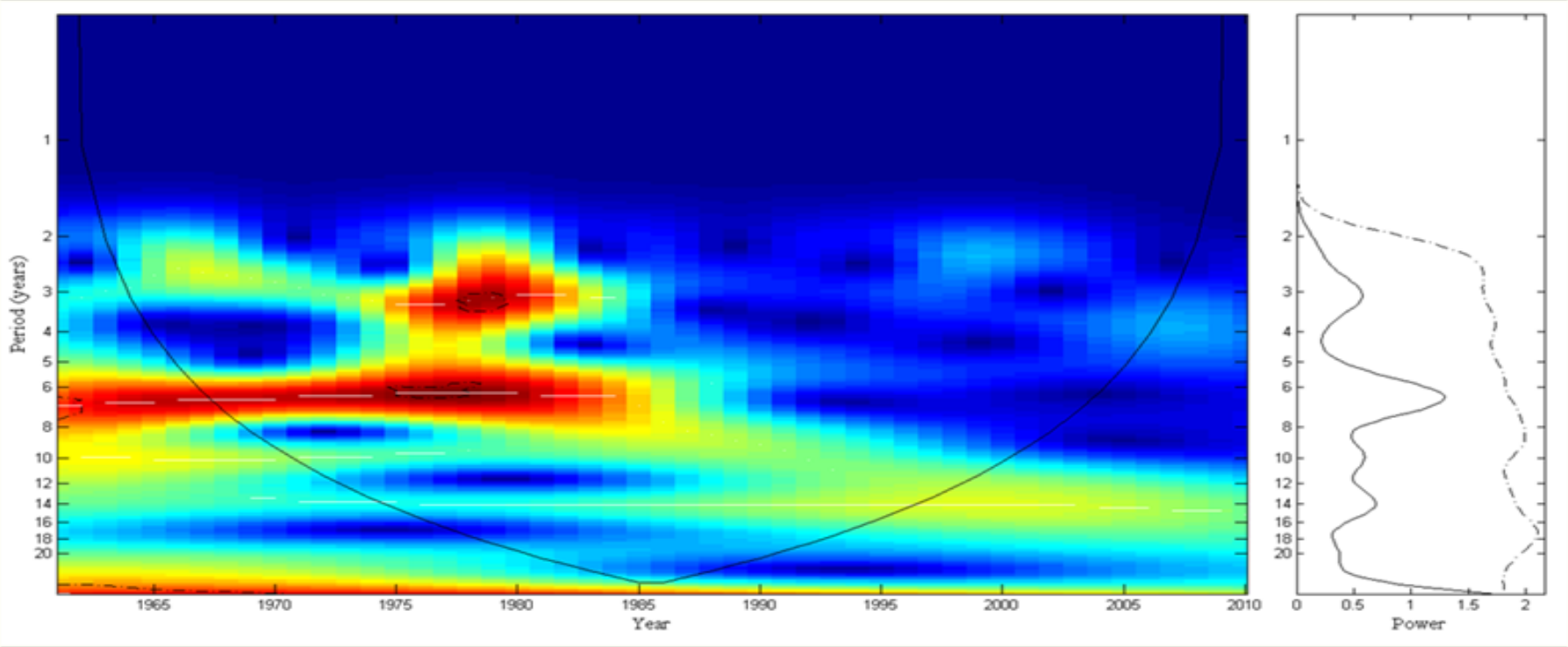
Source: FAOSTAT; Climate Studies Group, Mona



Annual drought index (SPI-12) versus mean annual Sweet potato yields (detrended) for Jamaica 1961-2009)

Source: FAOSTAT; Climate Studies Group, Mona

1. Background-Detection of Climate Signal in Production (Wavelet Analysis)



Wavelet analysis (Cazelles et al. (2007), of area harvested data (1961-2009) suggests strongest periodic signal at 2-6 years (1985-2010) The high value of the power curve also indicates that this is a statistically significant cyclical pattern.

Source: Climate Studies Group Mona (CSGM), 2012

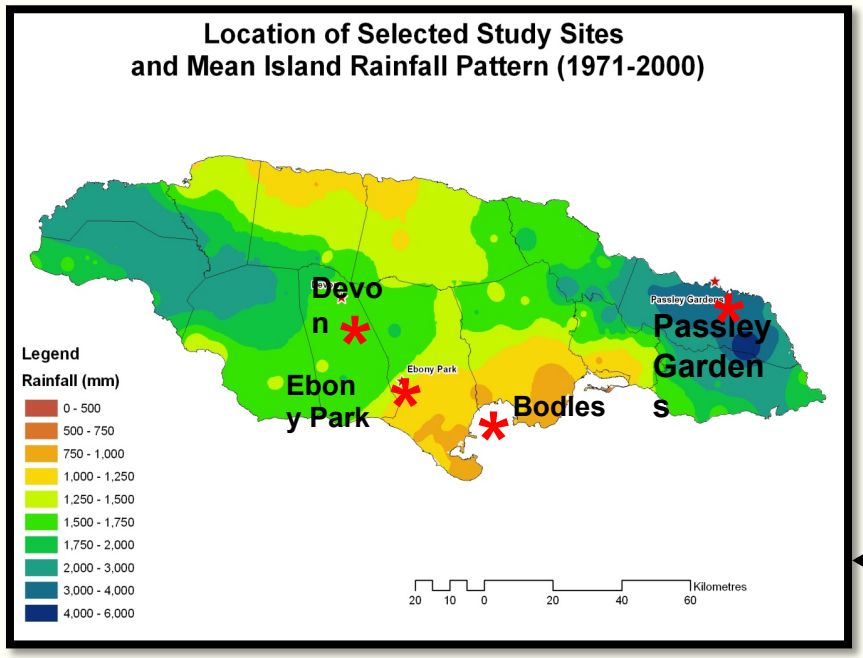
1. Background: Root Crops are Important to Caribbean Agriculture

- Sweet potato, *Ipomoea batatas* (L.), is a 5-month root crop, a dicotyledonous herbaceous trailing vine and the only economically important member of the family Convolvulaceae.
- The crop is propagated from cuttings sown during the period September to December.
- The crop rainfall requirement is 750-1250 mm; of this, about 500 mm should occur during the first third of the crop life. Comparatively lower water requirements than for other crops
- Sweet potato is drought tolerant but…Crop most sensitive to dry conditions at the tuber initiation stage (about 40-50 days after planting) (CARDI 2010; Stathers et al. 2013).
- Central to pursuit of reducing imports of, and reliance on externally grown wheat and cereals

Sweet potato :

- Long history of production
- the 6th most important crop globally after RWPMC
- More nutritious than most

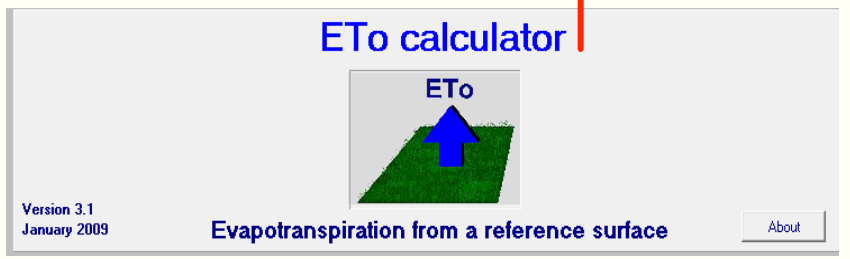
2. Methodology: Research Design and Tools Summarised



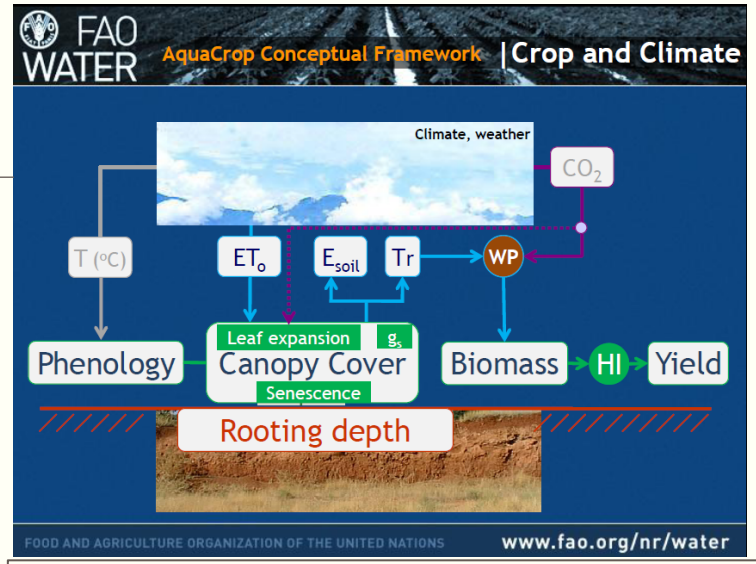
Randomised Complete Blocks (RCBs)

On site weather station

Parameters:
- Rainfall
- Temperature
- Relative Humidity
- Solar Radiation
- Wind
- ET_o



Canopy cover, Biomass (above & Below)



AquaCrop Model Explained

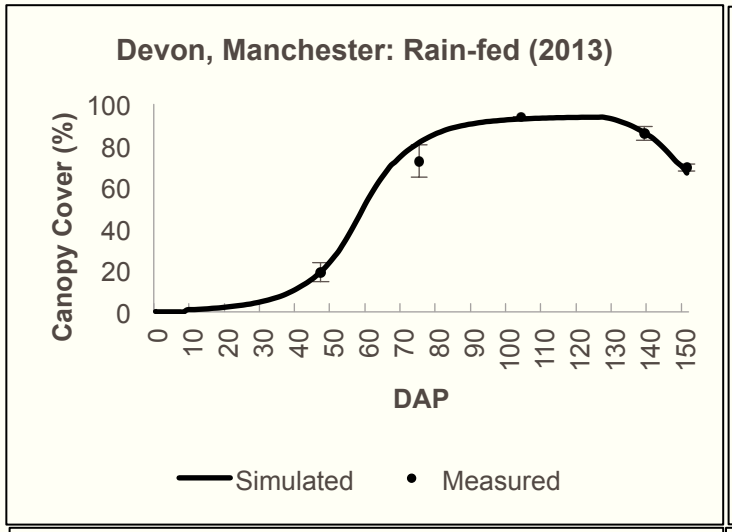
- Biomass=WP x ΣTr [Biomass]
- *ET=E +Tr*
- WP normalised for ET and CO_2
- Y=B x HI [Yield]

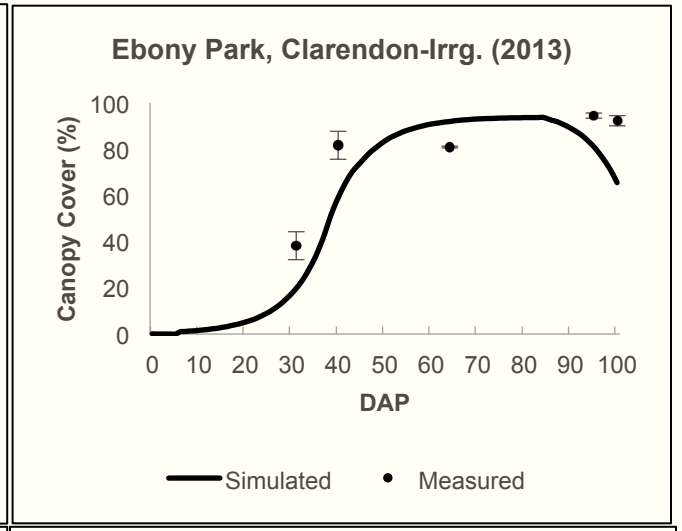
- **Robust, Accurate yet simple**

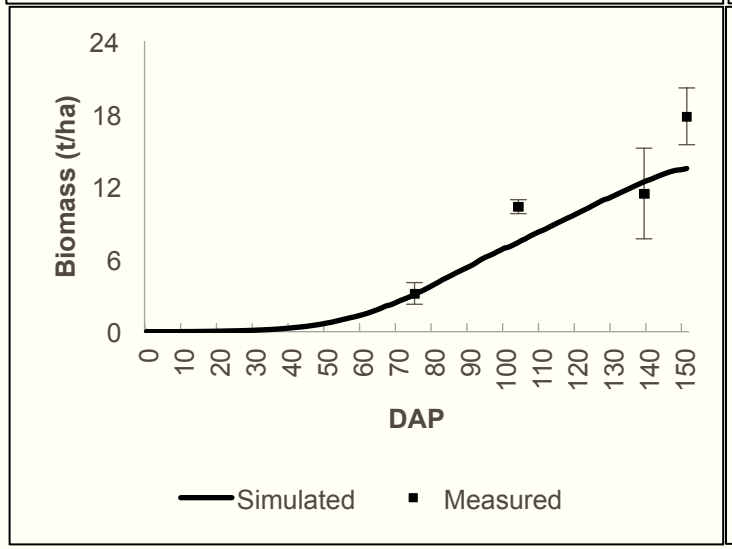
2. Methodology (Analogue Approach): Production in a changing climate

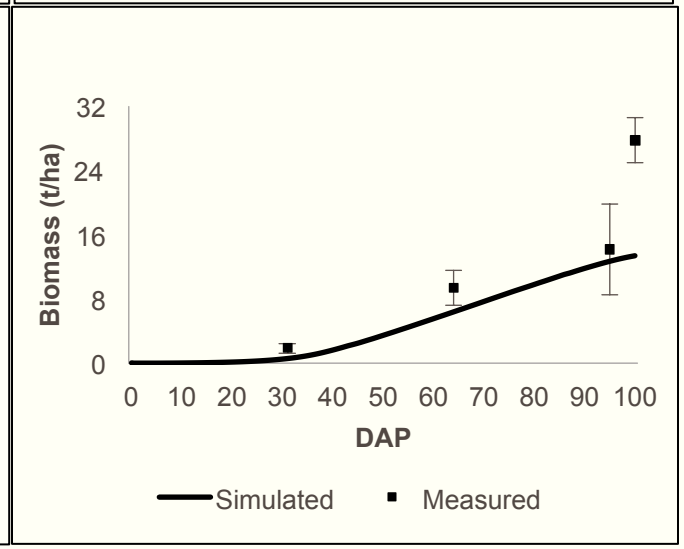
- There is incongruence between the scale at which climate and crop models operate
- Climate Models: 25km resolution (Regional Models); Crop models: location specific, few hectares.
- Climate projections from regional (and global) climate models cannot be directly to crop Models-Data (even PRECIS) not representative.
- Analogue data (1996-2010: NMIA) used to create two future: climates
  - *Cold and Wet
  - *Warm and Dry

3. Results: Validation of AquaCrop (Devon and Ebony Park)-CC and Biomass



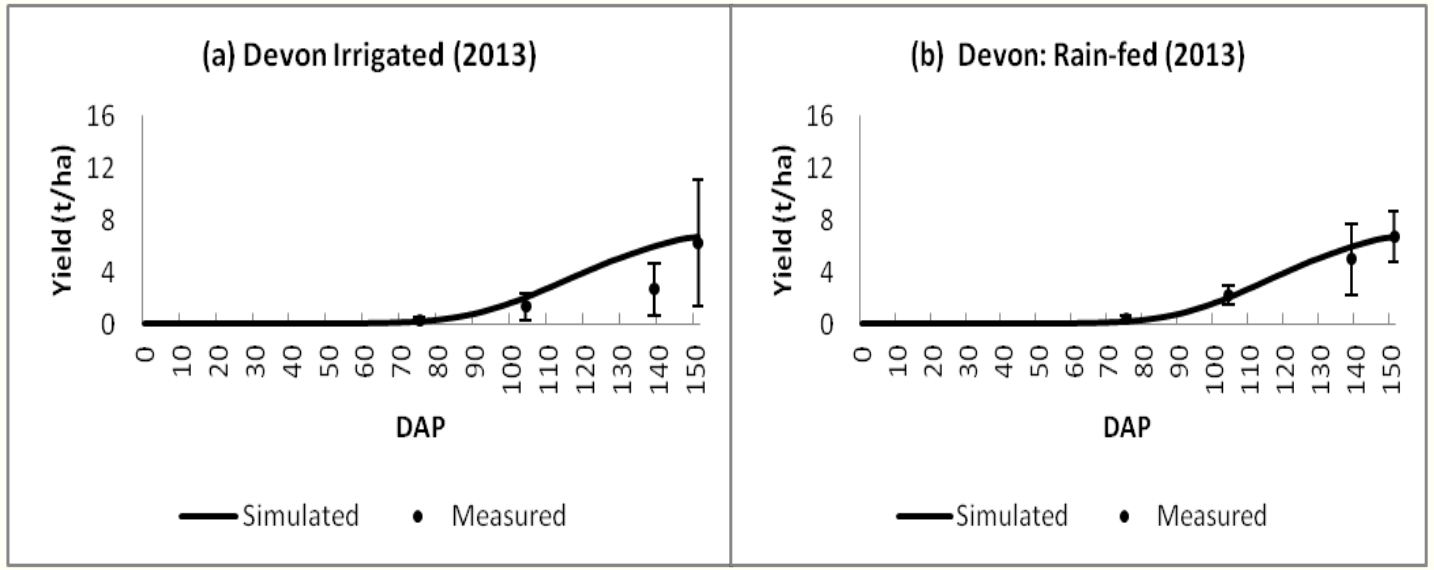






- Parameterization of Sweet potato in AquaCrop- Original contribution
- Excellent agreement between simulated and measured canopy cover (CC)
- Model exhibits good skill in the simulation of biomass at both locations and for the two treatments
- When CC is well simulated, so also is Biomass

3. Results: Validation of AquaCrop (Devon)-Yields



Simulated (line) versus measured (filled circles) yield of sweet potato for rain-fed and irrigated treatments at Devon, Manchester (2013). Error bars represent one standard deviation above and below the mean

- Yield simulation: fairly good; and best for rain-fed treatment at Devon, Manchester
- Irrigation does improve predictability of (final) yields
- Irrigation does not always enhance yields

3. Results: Validation of AquaCrop- Model Performance Summarised

		Final (Total) Biomass (t/ha)			Tuber Yield (t/ha)		
Year	**Treatment**	**Measured**	**Simulated**	**Deviation**	**Measured**	**Simulated**	**Deviation**
Devon							
2012	Irrigated	14.5 ± 6.3	10.3	-29.2	11.2 ± 5.7	5.2	-53.1
	Rain-fed	28.4 ± 18.5	7.7	-72.7	20.8 ± 14.9	3.9	-81.1
2013	Irrigated	16.9 ± 5.7	13.5	-20.1	6.3 ± 4.9	6.7	7.5
	Rain-fed	17.8 ± 2.4	13.5	-24.2	6.7 ± 2.0	6.7	0.24
Ebony Park							
2013	Irrigated	27.8 ± 2.8	11.2	-51.8	11.0 ± 5.8	6.7	-39.5
	Rain-fed	14.6 ± 4.2	10.6	-8.6	2.6 ± 1.4	7.2	158.6

- **Deviation = {(Simulated- Measured)/Measured} *100**
- Biomass estimation within 30% of 'actual' values for four of six simulations (further refined)
- Yields: Deviation for 3 out of 6 treatments < 40 % (highest for rain-fed)

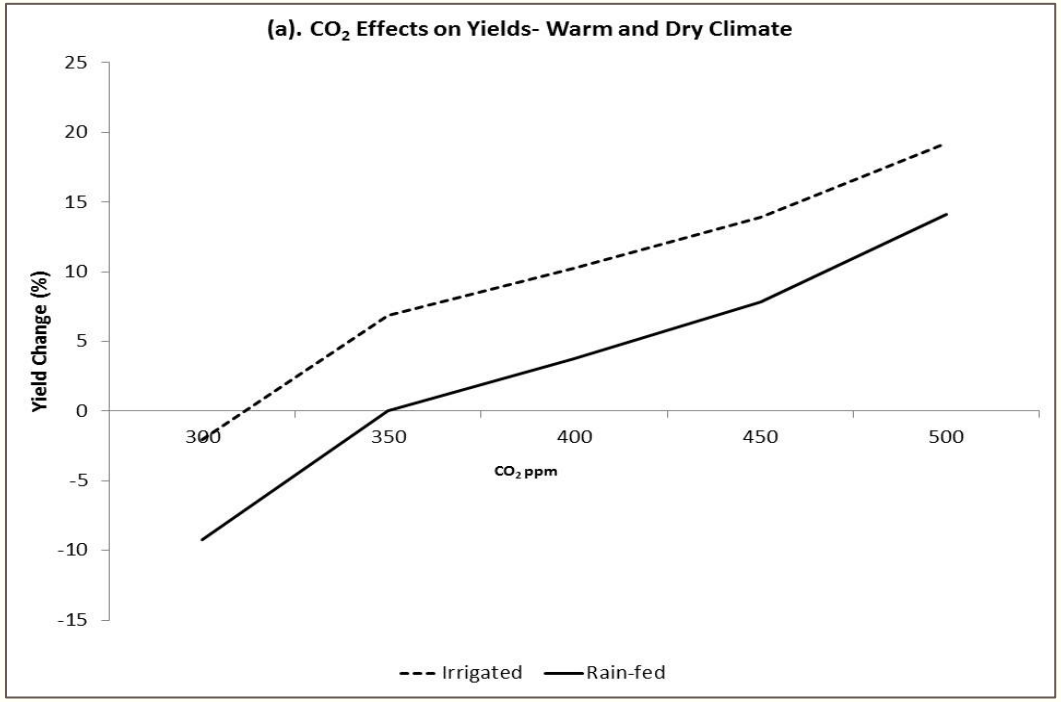
3. Results: Validation of AquaCrop (Summarised)

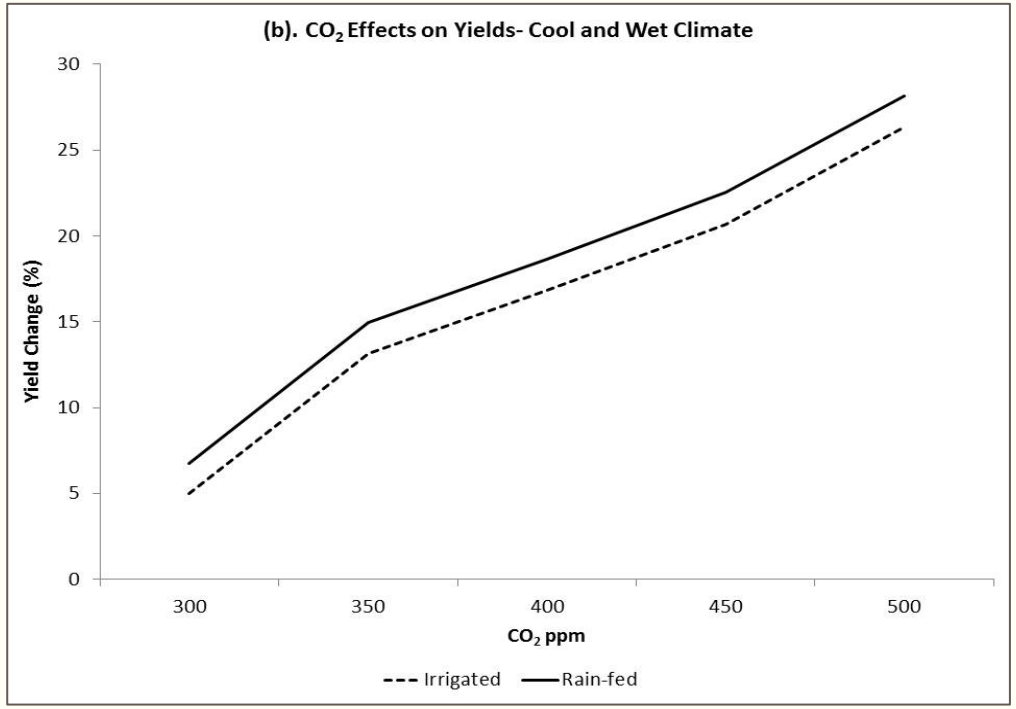
$$E = 1 - \frac{\sum_{i=1}^{N}(O_i - S_i)^2}{\sum_{i=1}^{N}(O_i - \bar{O})^2}$$

Year	Treatment	Canopy Cover		Biomass		Yield	
Devon		RMSE (%)	E	RMSE (t/ha)	E	RMSE (t/ha)	E
2012	Irrigated	25.22	-0.59	3.03	0.70	4.36	-0.51
	Rain-fed	12.79	0.56	12.47	-0.79	10.12	-0.52
2013	Irrigated	10.94	0.85	2.37	0.79	1.70	0.42
	Rain-fed	4.27	0.97	2.65	0. 74	0.51	0.96
Ebony Park							
2013	Irrigated	19.31	0.11	7.42	0.39	2.65	0.61
	Rain-fed	18.43	0.56	1.75	0.89	3.22	-10.54

- Enhanced model performance (2013 vs 2012): prediction of yields for both Rain-fed and Irrigated treatments
- Values have been further refined with improved values for both locations

4. Results: Climate change and Future Production- (A2 and B2) Elevated CO_2





1. For Warm and dry climate: Irrigated yields are higher; converse for cool and wet

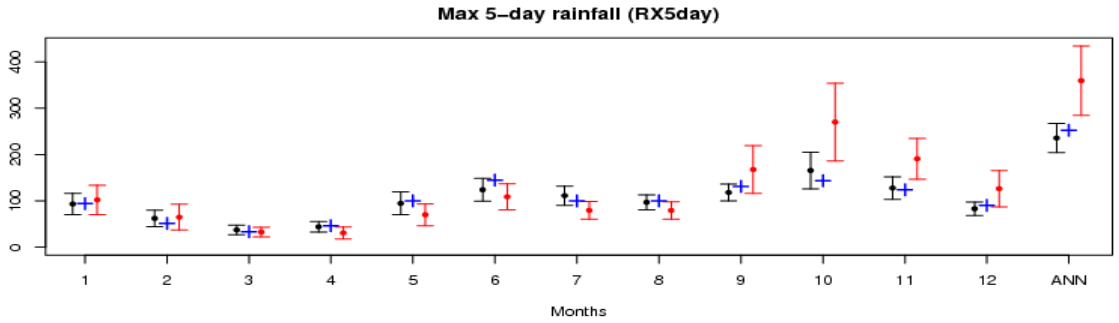
2. The beneficial effects of elevated CO_2 are reduced in all scenarios as 2050 is approached

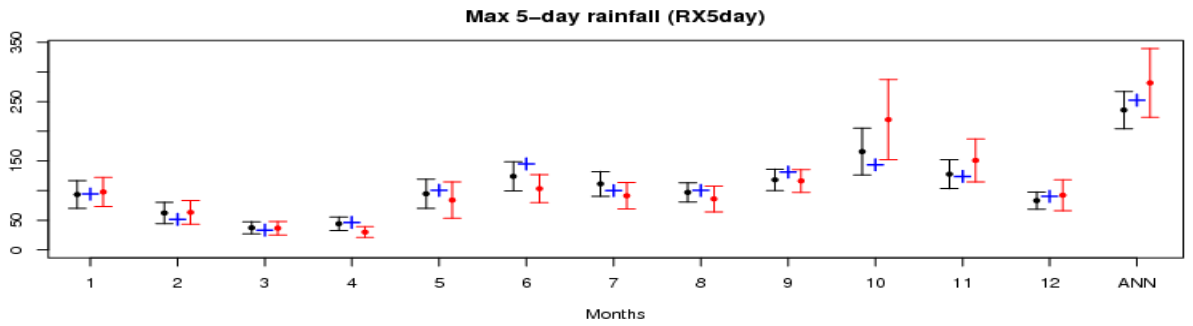
3. Results: What of the Future- In Practice

Urban development and flooding in Belize City

Raquel Chun, Clare Goodess, Ottis Joslyn

The weather generator (WG) has been calibrated using observed daily data from Philip Goldson International Airport and future projections obtained by perturbing the WG parameters with change factors calculated from RCM output .





Observations *WG 1981-2010 (base-line)* ***WG 2041-2070 (2050s) & A1B***
Mean (circle) and spread (vertical lines) across 100 WG runs are shown

The projections suggest ↓ **in rainfall in summer months**, with a **tendency to ↑ inter-annual variability toward end of year** with some indication of **an ↑ in heavy rainfall in some months (e.g., Oct).** The implications of such changes for flood risk and drainage channel management are being assessed.

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4. Conclusions

Activity	Utility for Agricultural Climate Services
Parameterization of the FAO AquaCrop Model for irrigated and rain-fed sweet potato.	• Model suitably calibrated for making accurate estimated of Sweet Potato biomass and yields for any climate • Other Caribbean crops already parameterized in model (e.g. irish Potato, Tomato, Corn, Rice); only minor calibration needed • Model can work with limited weather Parameters, can be excellent optimisation and planning tool (Cassava immediate application??)
Making projections of Agricultural production in a changing climate	• Analouge approach developed that is immediately applicable to other islands (especially members of OECS) • CARIWIG Partnership providing downscaled data at level of islands that is: more representative, higher resolution, immediately applicable to crop models (Worthy Park Case Study, Jamaica).

The Ground work for a resurgence has been laid because…

1. Identification of a robust yet simple model that can work with data sparse reality of Caribbean Agriculture sector-FAO AquaCrop Model
2. Satisfactory parameterization of a highly (yield) Variable and difficult research crop-Sweet Potato
3. Expertise built in crop modelling with opportunities for continued research and wider collaboration (CARIWIG)
4. Greater interest in adopting technology (crop models) to replace trial and error methods of optimisation. The latter is more time consuming, less efficient and more expensive
5. Regional partners are involved, intrigued and interested: CSGM, CIMH, CARDI, CARICOM, CCCCC,

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