FASTER

Farmers' Adaptation and Sustainability in Tunisia through Excellence in Research

2nd FASTER SPECIALIZED TRAINING

on Climate change effects on water & land management in the Mediterranean

22-26 March 2021 (ONLINE)

AGENDA

Modelling approaches in agricultural water management

- Outline
  - Purpose
  - History of model development
  - Type of models
  - Model applications
  - Discussion

- Task
  - Data availability and model applications for agricultural water management in your area

Definition & purpose of agricultural models

Definition

Analytical tools used to approximate processes in agriculture

What is modelled?

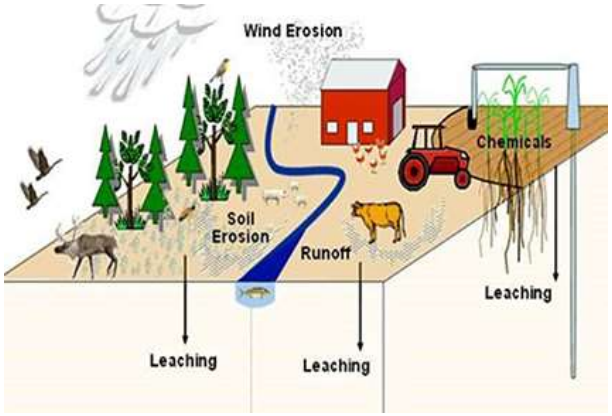
Crop water consumption
Crop water requirement
Water use efficiency
Yield effect from irrigation
Yield effect from fertilizer
Crop production
Nutrient leakage

Application?

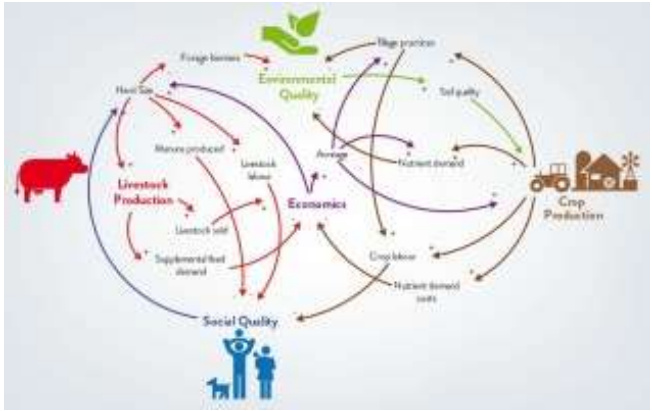
Scientific understanding of crop growth
Irrigation management
Fertilizer management
Identification of alternative crops
Environmental effects from farming
Food security planning
Water resources planning
Climate change adaptation

Crop model

Farm model



Food system model



(Ahuja et al., 2014)

Demand for models

Modelling development and application driven by increasing pressure on:

- Food production
- Water availability
- Farm optimization for commercial interests

Harmonizing effects and relationships across:

- Water use sectors
- Academic disciplines

Main challenges

- Data requirements & model complexity vs precision
- Application
  - Issue to address?
  - Scale of application?

From presentation on IWRM

Drivers of water availability & use:

- Population increase
- Economic development
- Globalized trade patterns
- Migration & mobility
- Governance and management
  - Political objectives (e.g. sustainability, nationalism)
  - Data availability & digitization
  - Technological development (water use efficiency)
- Climate variability & change

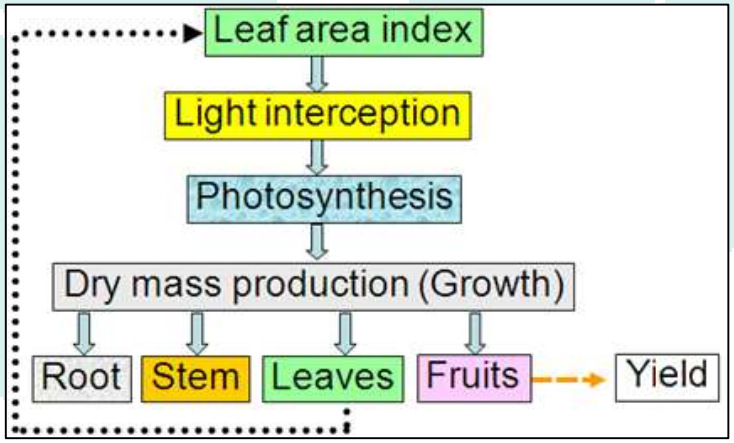
Water as a complex socio-ecological system

Model types and features

- **Process based** (mechanistic)
  - To identify & explain specific crop & soil processes
  - *Explanatory*
    - For scientific understanding
  - Microscale (crop)
  - Large number of parameters
  - Rarely used by producers (too complex and data demanding)
- **Empirical** (deterministic)
  - Empirical relationships between environmental factors and yield
    - To approximate complex relationships
  - Often *predictive*
    - Yield response to certain environmental conditions?
    - Evaluating new farm management & agricultural policies
  - Simplified compared to process based models
    - Low input requirements
    - Large uncertainty
    - Applicable for effects on meso (farm) & macroscale (watershed/region)

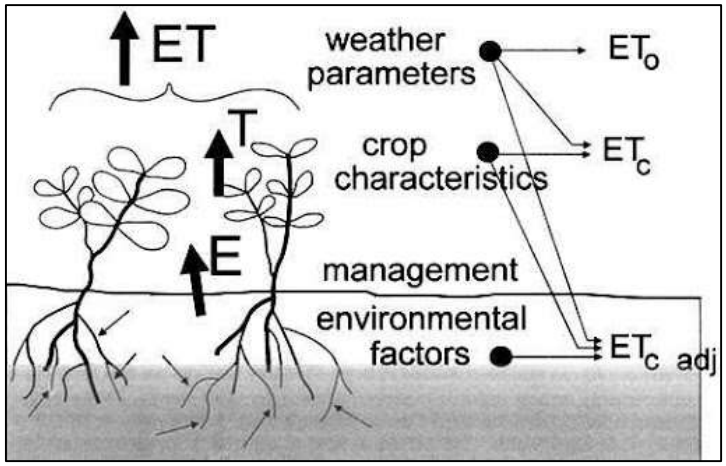
(Ahuja et al., 2015; Jones et al., 2016)

Process based crop model



(Heuvelink, 1999)

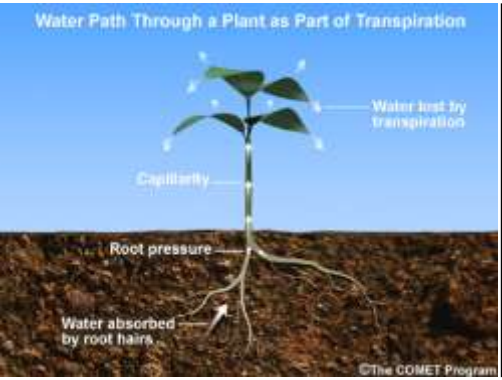
Empirical crop model



(Allen, 1998)

Scale of application

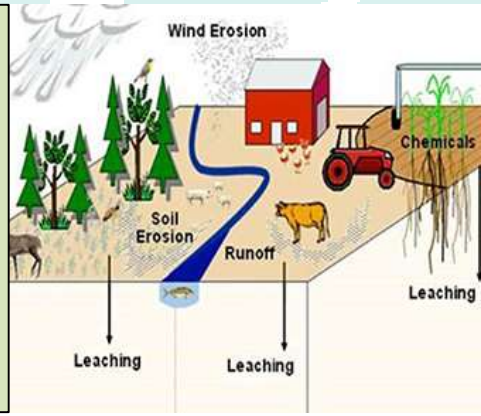
Micro scale (Crop level)



Process based
Explanatory
Application
Understanding of processes
Use in larger scale models
Data
Experimental data
Soil sampling
Capacitance sensors

Meso scale (Farm level)

Process based & empirical
Explanatory & predictive
Application
Farm management
Environmental impacts
Data
Farm level crop data
Farm level soil data (EMI)
Irrigation
Management techniques



Macro scale (Food system level)

Empirical
Explanatory & predictive
Application
Water resources planning
Food security
Climate impacts
Data
Regional crop data
Land use
Climate/weather models
Socio-economic data
Demographic data

Modelling approaches

Model type

Process based
Detailed study of crop processes
High data requirement

Empirical
Low data requirement
Simplified relationships
Less precise

Application

Explanatory
Evaluating current conditions

Predictive
Evaluating new management & scenarios

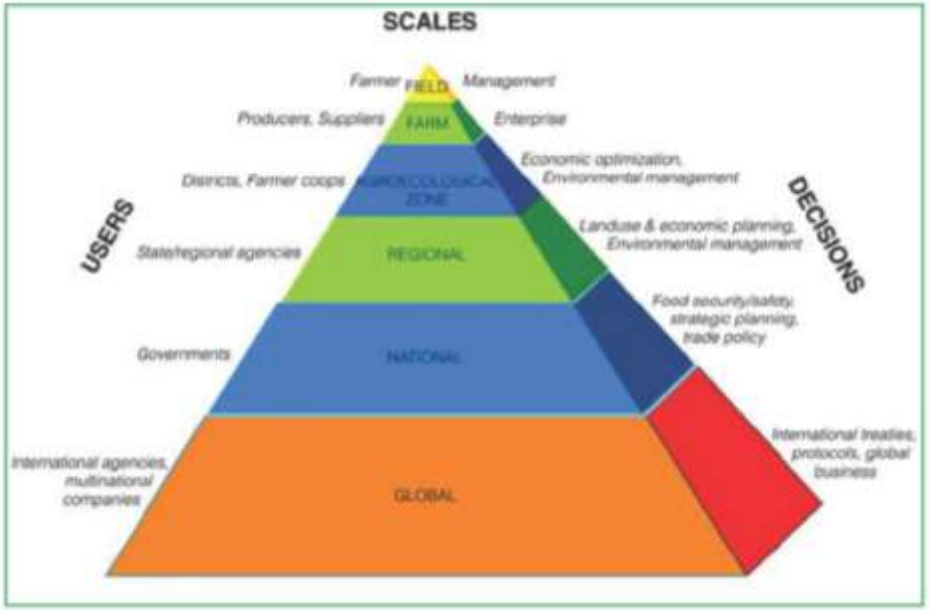
Scale

Micro (crop)
Crop development

Meso (farm)
Farm management

Macro (food system)
Food security
Policy evaluation
Water basin planning

Modelling scales, users & decisions



(Jones et al., 2016)

Modelling approaches

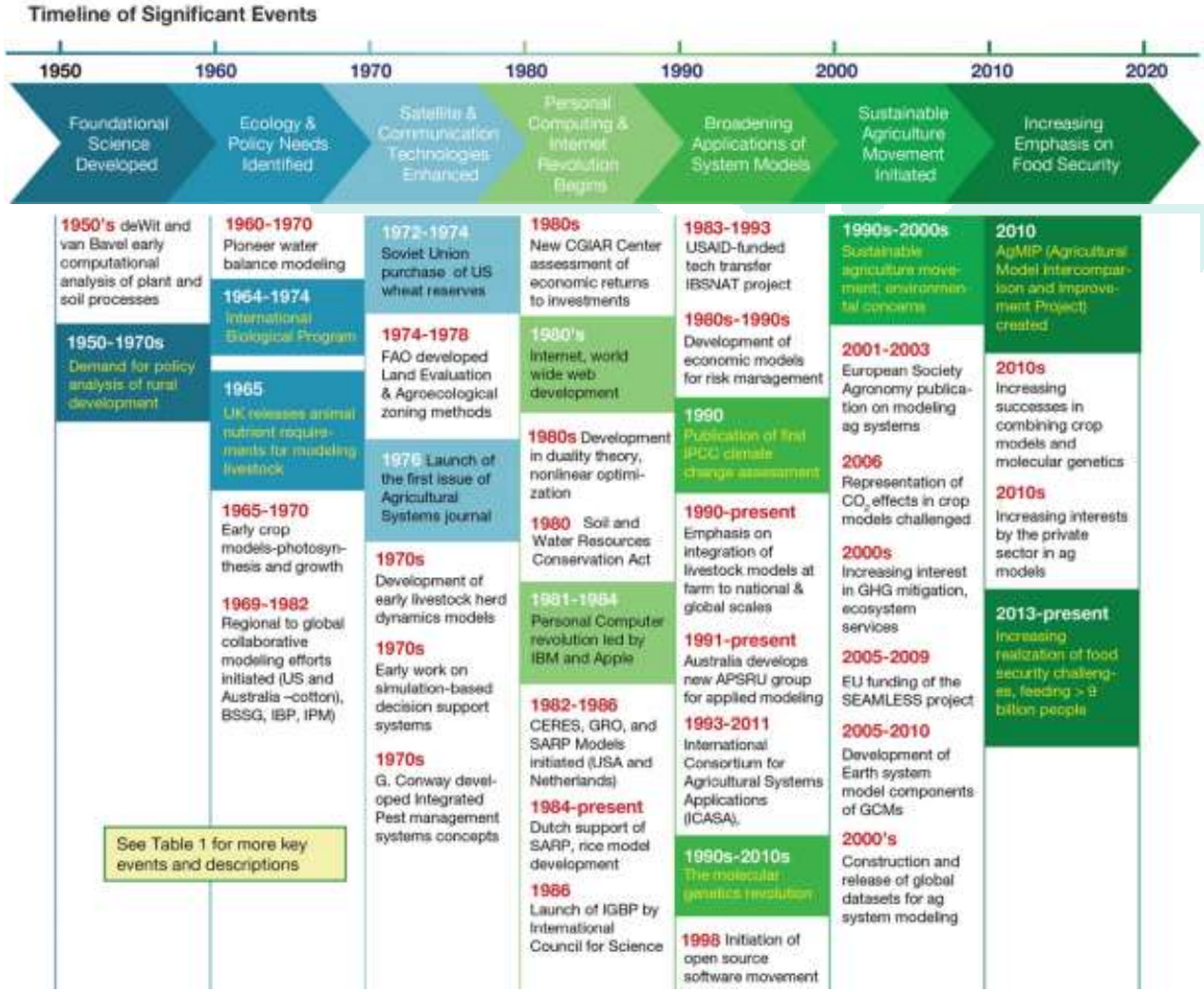
Due to high diversity of agricultural conditions

→ **High requirements for model *calibration* & *validation***

History of agricutural modelling

Main developments:

- Demand for policy analysis
- Pesticide control
- Market price spikes
- Soil erosion
- Climate change impacts
- Sustainable agriculture
- Commercial interests
- Demand for increasing food production

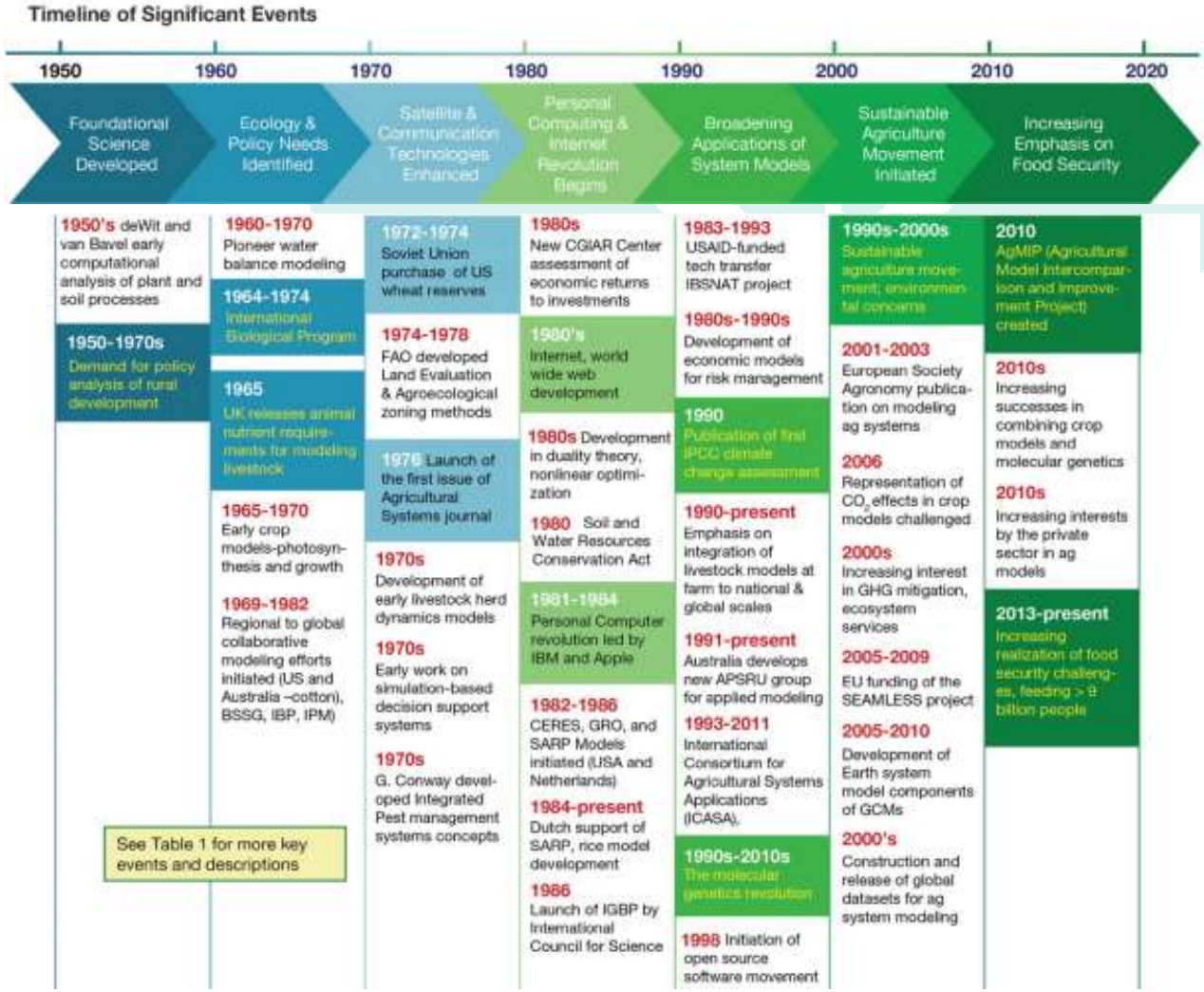


(Jones et al., 2016)

History of agricutural modelling

Current model developments:

- Molecular genetics
- Collaboration between public & private actors
- Digitization of data and internet communication technology (ICT)



(Jones et al., 2016)

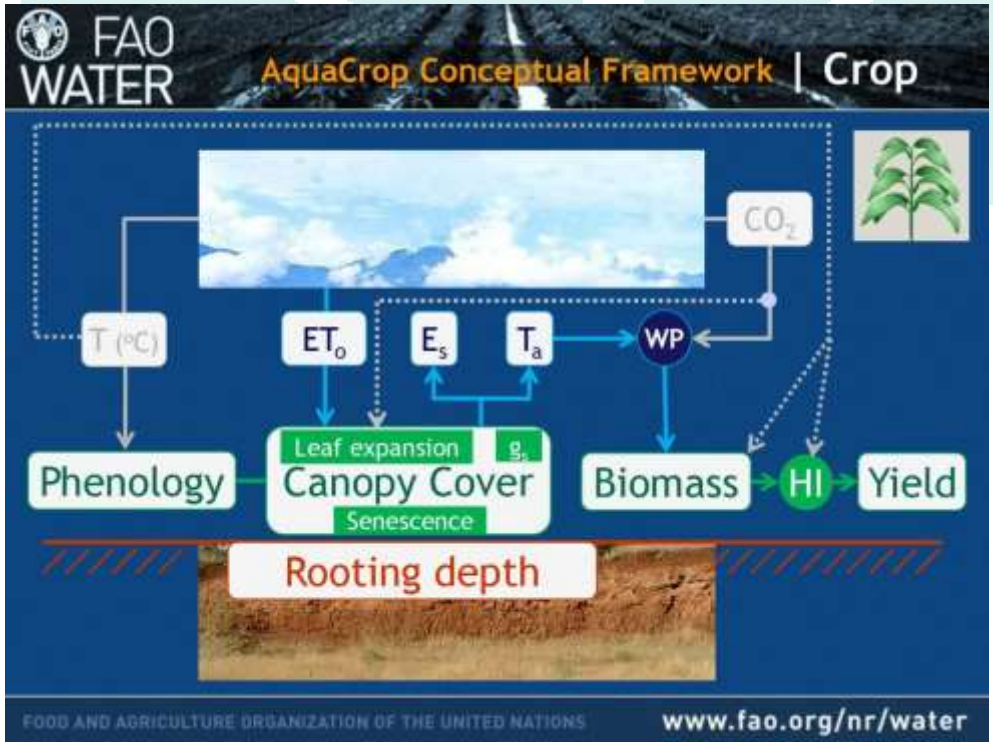
Example models – FAO AquaCrop

Estimates yield based on crop specific water requirements and availability, and CO_2 levels

- Weather, crop type, irrigation, soil profile
  - Daily or monthly
- Empirical model

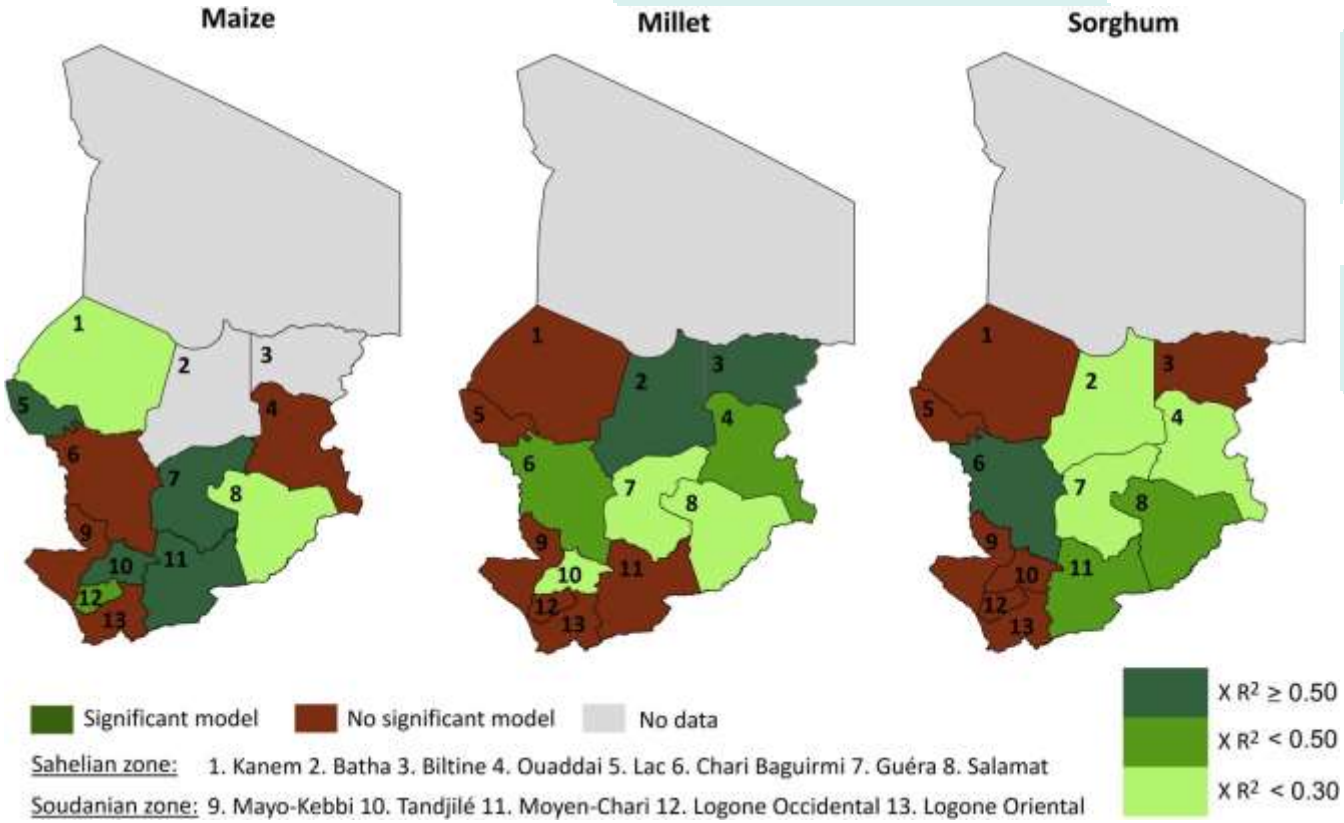
Adapted to agriculture where water is the main limiting factor

- Low input requirements
  - No simulation of nutrient cycles
  - Remote sensing sources applicable
- Easy to use
- Irrigation management
- Scenario analysis (e.g. climate)
- Aimed at practical end-users
  - Farmers
  - Irrigation associations
  - Extension services



(Ahuja et al., 2015; FAO, 2016)

Example models – FAO AquaCrop



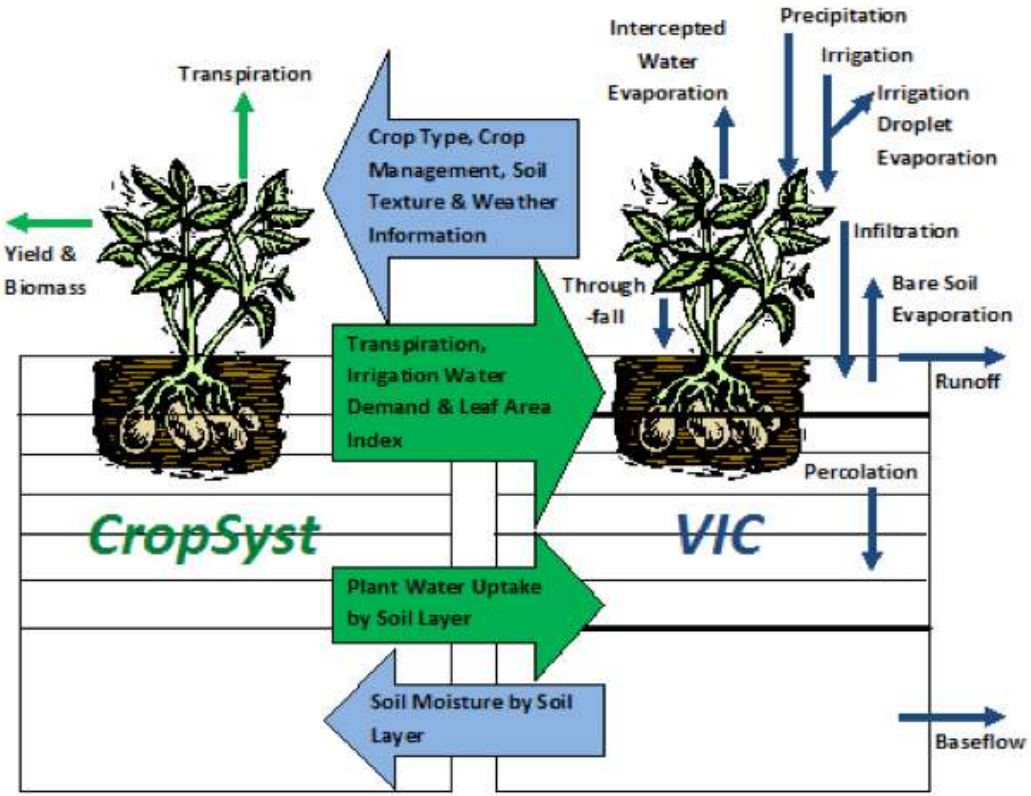
Regional analysis on crop production in Chad (regional crop statistics & remote sensing weather data)

Can explain large interannual variations

Mainly applicable as explanatory analysis – not precise enough for predictions

(Nilsson et al., 2020)

Example models – CROPSYST-VIC



Process based model to study the effects of crop management on yield and surrounding environment

Higher input requirements than AquaCrop

- Daily weather data, soil profile, pH, irrigation & fertilizer management

Simulates impact of farm management

- Yield simulations 3-22% accuracy
- To evaluate soil suitability, new technologies, N-leaching, salinity
- Used to build decision support systems for farm management

(Bioearth, 2021; Ahuja et al., 2015)

Example models – DSSAT

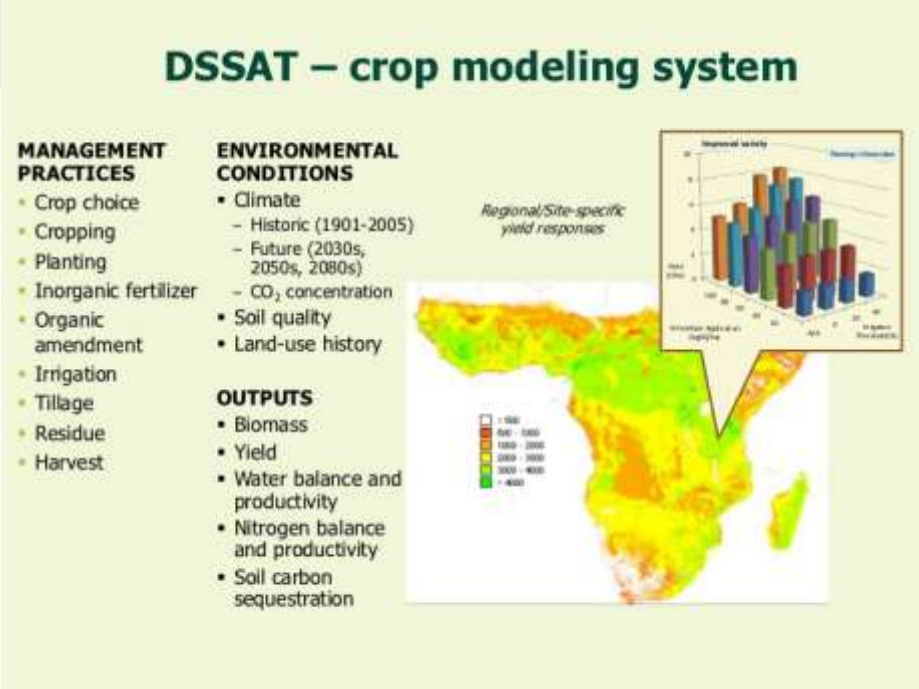
Decision Support System for Agrotechnology Transfer

Collection of models within single software

Detailed carbon-, soil water-, N-processes

Application

- Crop yield
- Evaluating management practices
  - E.g. sowing optimization
  - Irrigation management
  - Production costs
  - Nitrogen leakage
- High requirements for input data
  - Experimental data required for calibration
  - Daily weather, soil profile, soil nitrogen, crop variety & genetic information
  - If validated, can be used to replace field observations



(DSSAT Foundation, 2020 ; Ahuja et al., 2015)

Selecting model

Table of model names and features

Name	Crop growth model type	Sub-Model[a]	Scale of Application	Time step	Crop addressed	Examples of where applied	Code/Software availability	Main Reference
ALSIM [‡]	Mechanistic	W,N,P	Field	Daily	alfalfa, perennial grass, corn, small grain, soybean	North America (V[1])	CSMP III (AR)	2
AFRC-WHEAT	Mechanistic	W,N	Field	Daily	wheat	United Kingdom, Europe, New Zealand (V[3])	Fortran (UR)	4
AGRO-BGC	Hybrid	W,N,C	Regional to Global (Ecosystems)	Daily	General biomes	Nebraska (NE), North Dakota (ND), Pennsylvania (PA), and Illinois (V[5])		6-7
AgroMetShell*	Hybrid	W	Regional to Global (Ecosystems)	Decadal	maize, millet, tef, beans, wheat, sorghum	Pakistan, Zambia, French	Executable software for Windows with GUI (AO)	8

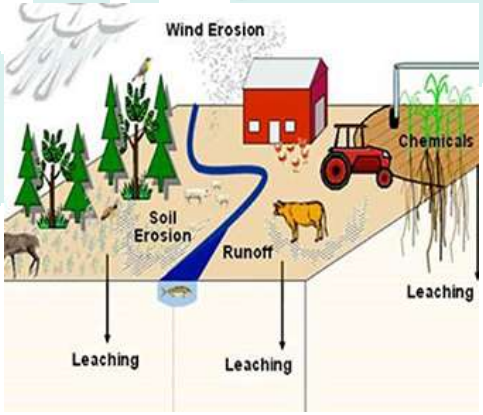
Also provided during the course:"Crop models list and major features" (Di Paula et al,. 2016)

Note – not required for task, explore further if interested

Selection steps:

- Purpose of application
  - Predictive / explanatory?
- Model complexity
  - Water, nutrient (nitrogen, phosphorous)
  - Compromise between precision and simplicity (data requirements)
- Scale of application
  - Micro, meso, macro?
- Type of crop

Common issues



Model application

- Lack of experimental field data
  - Local weather data, soil water balance, nutrient levels
- Models applied to contexts they are not adapted for
  - Without field data for validation, model performance often uncertain
- Large complexity for meso- and macroscales

Focus areas for model improvement

- Effects of water stress on crop growth processes
- Interactions between water and nitrogen stress
- Quantification of spatial variability of soil parameters
- Uncertainty of weather conditions
- Extreme heat effects
- Clarification on domain of validity
- Clarification on uncertainties

(Ahuja et al., 2015)

References

- Ahuja, L. R., Ma, L., Lascano, R. J., Saseendran, S. A., Fang, Q. X., Nielsen, D. C., Wang, E., & Colaizzi, P. D. (2015). Syntheses of the Current Model Applications for Managing Water and Needs for Experimental Data and Model Improvements to Enhance these Applications. *Advances in Agricultural Systems Modeling*, *5*(December), 399–437. https://doi.org/10.2134/advagricsystmodel5.c15
- Jones, J. W., Antle, J. M., Basso, B., Boote, K. J., Conant, R. T., Foster, I., Godfray, H. C. J., Herrero, M., Howitt, R. E., Janssen, S., Keating, B. A., Munoz-carpena, R., Porter, C. H., Rosenzweig, C., & Wheeler, T. R. (2016). Brief history of agricultural systems modeling. *Agricultural Systems*, *155*, 240–254. https://doi.org/10.1016/j.agsy.2016.05.014
- FAO, 2016. Introducing Aquacrop. http://www.fao.org/3/i6321e/i6321e.pdf
- Bioearth, 2020. The CropSyst and VIC-CropSyst Models. http://bioearth.wsu.edu/cropsyst_model.html
- DSSAT Foundation, 2021. What is DSSAT? https://dssat.net/
- Di Paola, A., Valentini, R., & Santini, M. (2016). An overview of available crop growth and yield models for studies and assessments in agriculture. *Journal of the Science of Food and Agriculture*, *96*(3), 709–714. https://doi.org/10.1002/jsfa.7359
- Nilsson E, Uvo CB, Becker P, Persson M (2019) Drivers of regional crop variability in Chad. *J Arid Environ*. https://doi.org/10.1016/j.jaridenv.2019.104081

Discussion points

- Experience of agricultural modelling?
  - Strengths & weaknesses for water related issues?
- Application needs for selected areas?
  - Main water issues?
  - Ability of models to address these issues?

- **Task**
  - Data availability and modelling application for agricultural water management in your selected area

Task description

1. Describe the data availability for water management in agriculture in your selected area (e.g. soil moisture, soil salinity, weather, crop statistics)
2. Based on the available data, suggest the main water issues in agriculture to be addressed by modelling
   - E.g. irrigation optimization, crop growth, evaluation of farm management techniques, environmental impact, policy evaluation, water resource management, food security
   - Describe the scale of application of the model
3. What type of additional data collection do you recommend to improve agricultural water management in your area?

Write 1-2 pages. Give general descriptions of the type of data that is available. The focus should be on connecting your model applications and data recommendations to the main water issues in your area.

That´s all!

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