문서번호 APCC-출장-17-1580(2017-12-20)

결재	사원	부서장	부서장	
	12/19 Christianne Aikins	12/20 문상원	대결 12/20 김형원	
협조	선임연구원	팀장	부서장	
	12/19 전종안	12/19 조재필	12/20 김형진	

TRAVEL REPORT FORM
출장보고서

I. Reporter 보고자

Department 소속	Position 직위(직급)	Name 성명	Travel Date 날짜	Note 비고
Climate Application	Research Fellow	Jong Ahn Chun	2017.12.11.~ 2017.12.14	라오스, 비엔티엔
Climate Application	Research Fellow	Daeha Kim		
External Affairs	Staff	Christianne Aikins		

II. Major Activities 주요업무 수행내용

1. Main Contents and Activities 주요내용 및 활동

○ Venue

- 2017.12.11.~ 2017.12.14., 라오스 NAFRI Headquarters, KOPIA Office

○ Background

- The project, Agriculture Risk Management Support (ARMS) for Rain-fed Rice in Lao PDR begun this year in partnership with the International Research Institute IRI and the National Agriculture and Forestry Research Institute (NAFRI), collaborating with the Ministry of Agriculture and Forestry. (The project will run 2017/02~2018/06)
- The purpose of this project is to reduce climactic risk in Lao PDR by integrating historical weather data and climate forecasts with locally-calibrated agricultural models to provide tailored information that produces an agro-climate advisory.

- NAFRI produces and maintains this agro-climate advisory, as well as delivers trainings to farmers on key concepts in applying climate-smart farming approaches and utilizing the agro-climate advisory.
- This trip enabled APCC to update project partners on 2017 outputs, plan for 2018, increase project visibility, and deliver a training seminar on the AquaCrop and CERES-Rice Model for NAFRI Staff and interested beneficiaries
- Dr. Jong Ahn Chun is the PI of this project, with Dr. Daeha Kim acting as the co-supporting scientist, and Ms. Christianne Aikins as the PM

○ Key Events

- 2017/12/11 (Tue): ARMS Final Presentation (with guests from key beneficiaries and project partners)
- 2017/12/13 (Wed): AquaCrop and CERES-Rice Model Training Seminar

2. Relevance to APEC Climate Center's Activities 결론 및 소감

- Updated partners on ARMS 2017 outcomes and collected feedback
- Increased visibility for ARMS project amongst key government agencies
- Delivered a training on AquaCrop and CERES-Rice Model
- Discussed changes to budget and APCC goals for 2018

Full details are provided in the attached Travel Report.

III. References 참고사항

(with attachment of any information or report in case of attendance of conferences, workshops and meetings) 학술대회, 워크숍, 회의 등 참석 시 관련 정보 및 문서 첨부

1. Presented and Collected Materials 주요 수집자료

The travel Report, presentation slides, and attendance sheets from the 2017 ARMS Final Presentation and Training Seminar are attached.

2. Suggestions and Remarks 건의사항

Travel Report

ARMS Project
Vientiane and Savannakhet, Lao PDR
11-14 December, 2017

2017.12.15. PREPARED BY CHRISTIANNE AIKINS @ EXTERNAL AFFAIRS DEPARTMENT

1 Summary

1.1 Personnel

- Dr. Jong Ahn Chun (Research Fellow, Climate Application Team, Climate Application Department)
- Dr. Daeha Kim (Research Fellow, Climate Application Team, Climate Application Department)
- Ms. Christianne Miko Aikins (International Project Officer, External Affairs Department)

1.2 Details

Location: Vientiane, Lao PDR
Dates: 11 (Mon) – 14 (Thu) December 2017
Project: Agriculture Risk Management Support for Rain-fed Rice in Lao PDR (ARMS)
Key Partners: The National Agriculture and Forestry Research Institute (NAFRI) and the Department of Meteorology and Hydrology (DMH) of Lao PDR.

Key Events:

1. ARMS Final Presentation [Tue 12 December]
2. ARMS AquaCrop and CERES-Rice models Training Seminar [Wed 13 December]

Both shall be held at the NAFRI Headquarters in Vientiane

1.3 Itinerary

Day	Time	Schedule	Location
Mon 11 Dec, 2017	09:00	APCC departure from Busan	
	12:00	Arrival in Vientiane	
Tue 12 Dec, 2017	10:30-12:00	ARMS Final Presentation	NAFRI Headquarters
	12:30-14:30	Informal Lunch	
	14:30-15:30	Meeting with NAFRI to discuss 2018 plans	NAFRI Headquarters
Wed 13 Dec, 2017	9:30-11:00	Meeting with KOPIA to discuss Lao context and suggestions for eventual development of mobile application	KOPIA Office
	11:00-12:00	Preparation for training	NAFRI Headquarters
	13:00-17:00	ARMS AquaCrop and CERES-Rice models Training Seminar	NAFRI Headquarters
Thu 14 Dec, 2017	00:40	Departure for Busan	
	06:50	Arrival in Busan	

1.4 Accommodation

S Park Design Hotel: $59/night for 2 nights (Dec 11, 12). No late check-out was used.

2 Travel Purpose

2.1 Background

- The project, Agriculture Risk Management Support (ARMS) for Rain-fed Rice in Lao PDR has begun this year in partnership with the International Research Institute IRI and the National Agriculture and Forestry Research Institute (NAFRI), collaborating with the Ministry of Agriculture and Forestry.
- The purpose of this project is to reduce climactic risk in Lao PDR by integrating historical weather data and climate forecasts with locally-calibrated agricultural models to provide tailored information that produces an agro-climate advisory.
- NAFRI produces and maintains this agro-climate advisory, as well as delivers trainings to farmers on key concepts in applying climate-smart farming approaches and utilizing the agro-climate advisory.
- Dr. Jong Ahn Chun is the PI of this project, with Dr. Daeha Kim acting as the co-supporting scientist, and Ms. Christianne Aikins as the PM.

2.2 Key Events

Final Presentation (12 Tuesday December)

A final presentation was held to report on ARMS outcomes for this year and discuss the upcoming plans for 2018.

ARMS AquaCrop and CERES-Rice Models Training Seminar (13 Wed December)

A training seminar for NAFRI and other interested staff was held on AquaCrop and CERES-Rice models to simulate rice growth and yield.

2.3 Objectives

- Update project partners on ARMS 2017 outcomes and collect feedback
- Increase visibility for ARMS project amongst key government agencies
- Deliver mini-training on AquaCrop and CERES-Rice models to NAFRI staff, in preparation for major ARMS training workshop to be held in October 2018 (TBD).
- Enhance relations with local partners
- Finalize 2017 project activities and discuss 2018 plans

3 December 12, 2017

3.1 Final Presentation

A final presentation was held to report on ARMS outcomes for this year and discuss the upcoming plans for 2018. Representatives from NAFRI, the Department of Meteorology and Hydrology (DMH) in the Ministry of Natural Resources and Environment (MONRE), the Ministry of Agriculture, and the Korea Programme on International Agricultural (KOPIA) were present.

The Director of NAFRI was unable to join the presentation, due to being called to a government meeting that morning, so Dr. Thavone Inthavong, as the Director of the Research Center for Climate Change Resilience in Agriculture (RCRA), delivered both the welcome message, introducing the Agriculture and Forestry Research Strategy 2025 Program, and the project introduction. While the presentation was delivered in Lao, the accompanying slides were in English.

Ms. Christianne Miko Aikins and Dr. Jong Ahn Chun gave presentations on APCC and ARMS, respectively. These were translated into Lao to ensure that all government representatives understood. PowerPoint slides are attached separately for the three presentations.

Agenda:

Time	Item	Details
10:10 – 10:30	Arrival and registration	
10:30 – 11:00	Opening Remarks and Project Introduction from the National Agriculture and Forestry Research Institute	Dr. Thavone Inthavong *Director of the Research Centre for Climate Change Resilience in Agriculture, NAFRI*
11:00 – 11:10	Introduction to the APEC Climate Center	Ms. Christianne Miko Aikins *International Project Officer, APCC*
11:10 – 11:40	Presentation on 2017 activities of the APCC Agriculture Risk Management Support project	Dr. Jong Ahn Chun *ARMS Principle Investigator, APCC*
11:40 – 11:55	Question and Answer Period	

Discussion:

There was some discussion among participants on how climate information is transferred. Dr. Myeong Cheoul Cho, Director of the Laos office of the Korea Programme on International Agricultural (KOPIA), wanted to know how to get data sets from DMH. NAFRI promised collaboration on older datasets, but newer ones would have to be purchased. This brought up relevant consideration for maintaining the ARMS mobile application after it is completed by APCC.

NAFRI also inquired if APCC could arrange for field demonstrations of the use of the mobile application to help encourage its adoption by farmers. In essence, NAFRI is eager to have APCC fund more demonstration plots and training programs, in addition to developing the application. As Dr. Jong Ahn Chun pointed out, the application will be based on NAFRI and end-user needs, the application should be designed for optimal uptake. However during the final training with NAFRI, plans for the dissemination with provincial- and district-level Ministry of Agriculture and Forestry officers should be discussed. Dr. Daeha Kim highlighted the fact that information is different than decision-making, and the best that can be done with an application like this is providing clear, usable information.

One important note was that currently climate information (monthly and weekly for rainfall distribution, tropical cyclone warnings, etc) is disseminated from DMH to famers. However Dr. Thavone Inthavong said that this process, going from national to provincial to district offices can take up to a week, making a mobile application extremely important. DMH shared that they do post weather updates on their social media (Facebook).

Lunch was held at the nearby Pizza Company.

4 December 13, 2017

4.1 KOPIA Tour and Presentation

The Director of the Lao Office of the Korea Programme on International Agricultural (KOPIA), Dr. Myeong Cheoul Cho gave a tour of their research farm and gave a presentation on KOPIA's work in Laos. In the presentation he highlighted areas of potential collaboration between APCC and KOPIA, and also shared insights on dynamics in other provinces.

4.2 ARMS AquaCrop and CERES-Rice Models Training Seminar

A training seminar for NAFRI staff was held on AquaCrop and CERES-Rice models to simulate rice growth and yield. Hands-on training classes was provided for the attendants with observed meteorological and survey data collected from rice paddy fields in Savannakhet. 19 participants took part, including the Director of the Research Center for Climate Change Resilience in Agriculture in NAFRI, Dr. Thavone Inthavong. The training seminar was a good success, with participants giving positive feedback

Time	Topic	
12:50 – 13:00	*Arrival, registration, downloading datasets*	
13:00 – 13:10	Overview of crop models and their applications	
13:10 – 13:45	Introduction of AquaCrop	Dr. Daeha Kim
13:45 – 14:30	Hands on training: Running the AquaCrop model with experimental data	Dr. Daeha Kim
14:30 – 14:45	*Break*	
14:45 – 15:15	Introduction of CERES-Rice	Dr. Jong Ahn Chun
15:15 – 17:00	Hands on training: Estimation of Genotype Coefficients using GenCalc	Dr. Jong Ahn Chun

Training slides and attendance sheets are attached separately.

Agriculture Risk Management Support for rain-fed lowland rice in Lao PDR

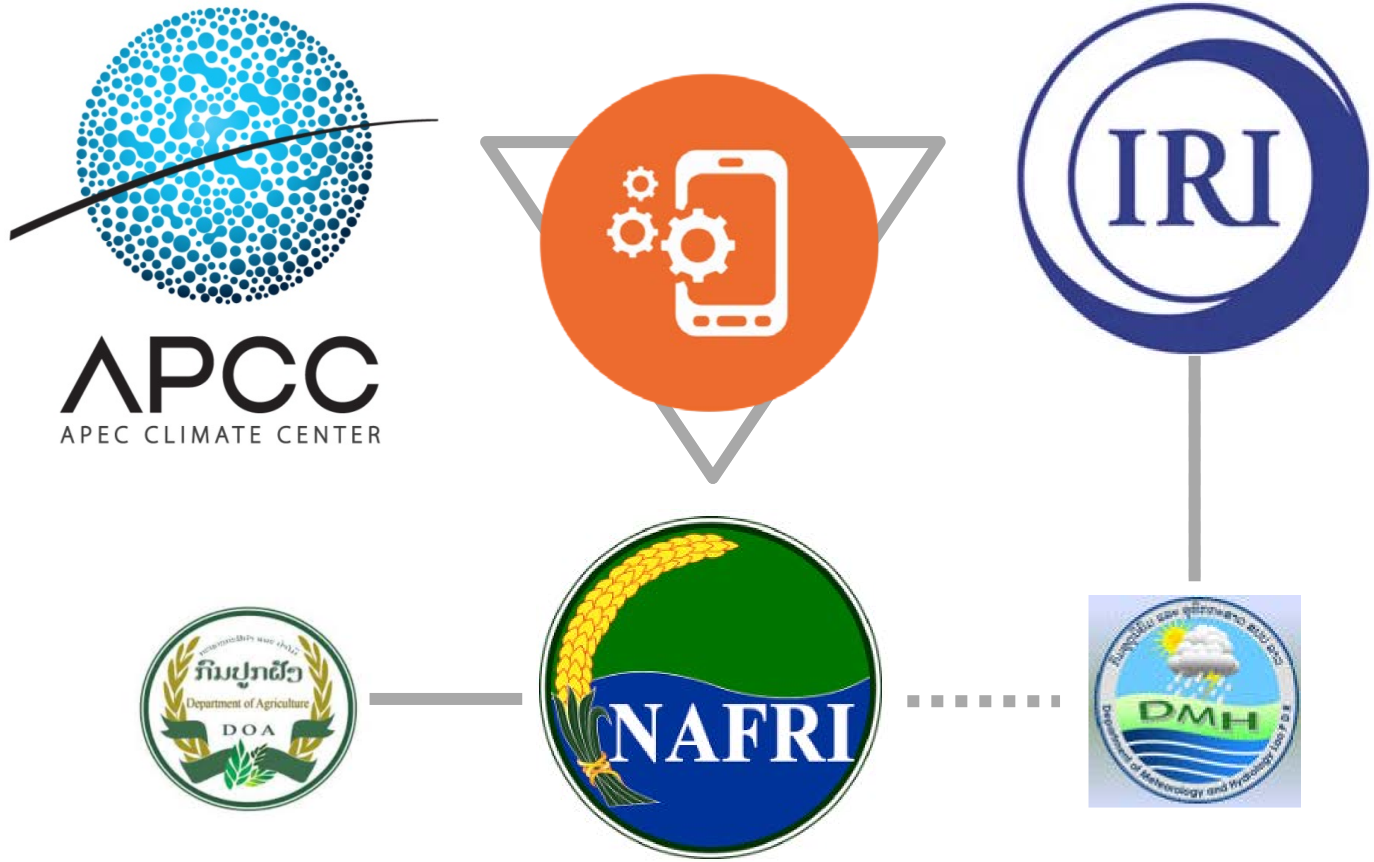
(Project acronym: ARMS for Laos)

Jong Ahn Chun, Daeha Kim, Eun-Jeong Lee , Christianne Aikins

APCC APEC CLIMATE CENTER

Introduction

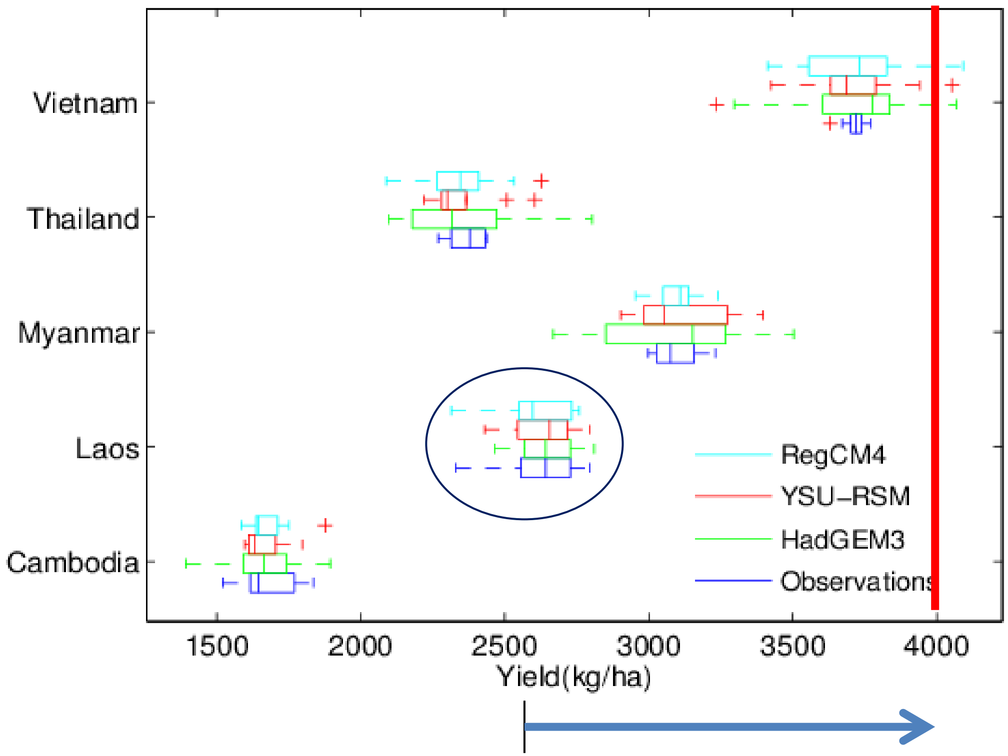
Partner organizations and project framework



Agriculture in Lao PDR

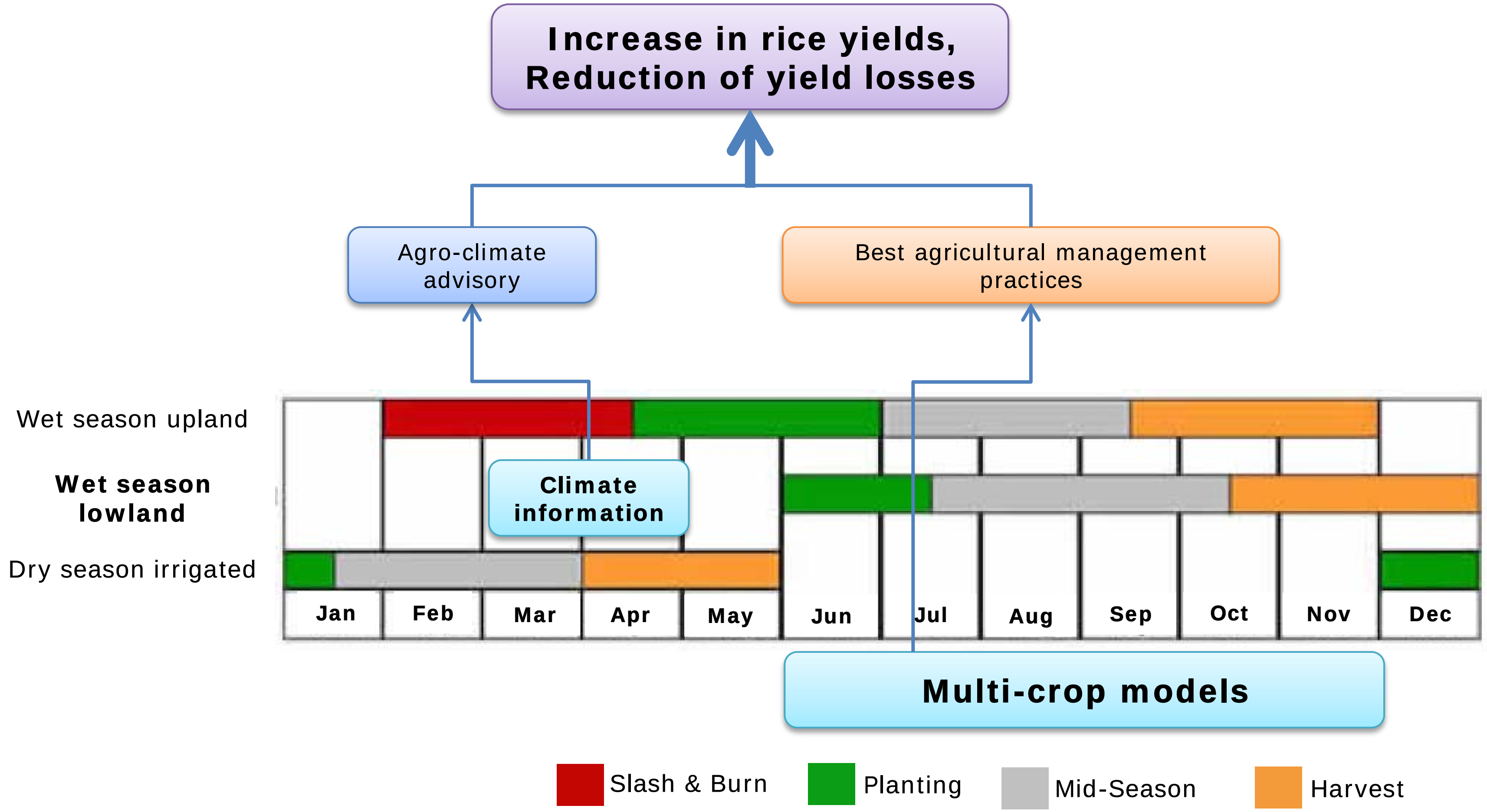
- **Arable area: at least 5 million ha (about 21%)**
- **Cultivated area : 850 000 ~ 900 000 ha (17% of arable area, less than 4 % of the total area)**
- **Rice : about 80% of cultivated area (1989-90 growing season)**
  - 422 000 ha of lowland wet rice and 223 000 ha of upland rice
- **Agriculture sector: 65% of GDP in 1980 to about 61% in 1989 and further decreasing to between 53 and 57% in 1991**
- **Paddy rice production decreased in 1987-88 and 1991-92 due to drought**
  - Cut annual yields by nearly one-third (in 1987-88)

Validation of GLAM-Rice at the National-Level



Comparison of the simulated and observed average economy-level rice yields for the baseline period (1991–2000)

Agro-climate outlook



Agro-climate Advisories

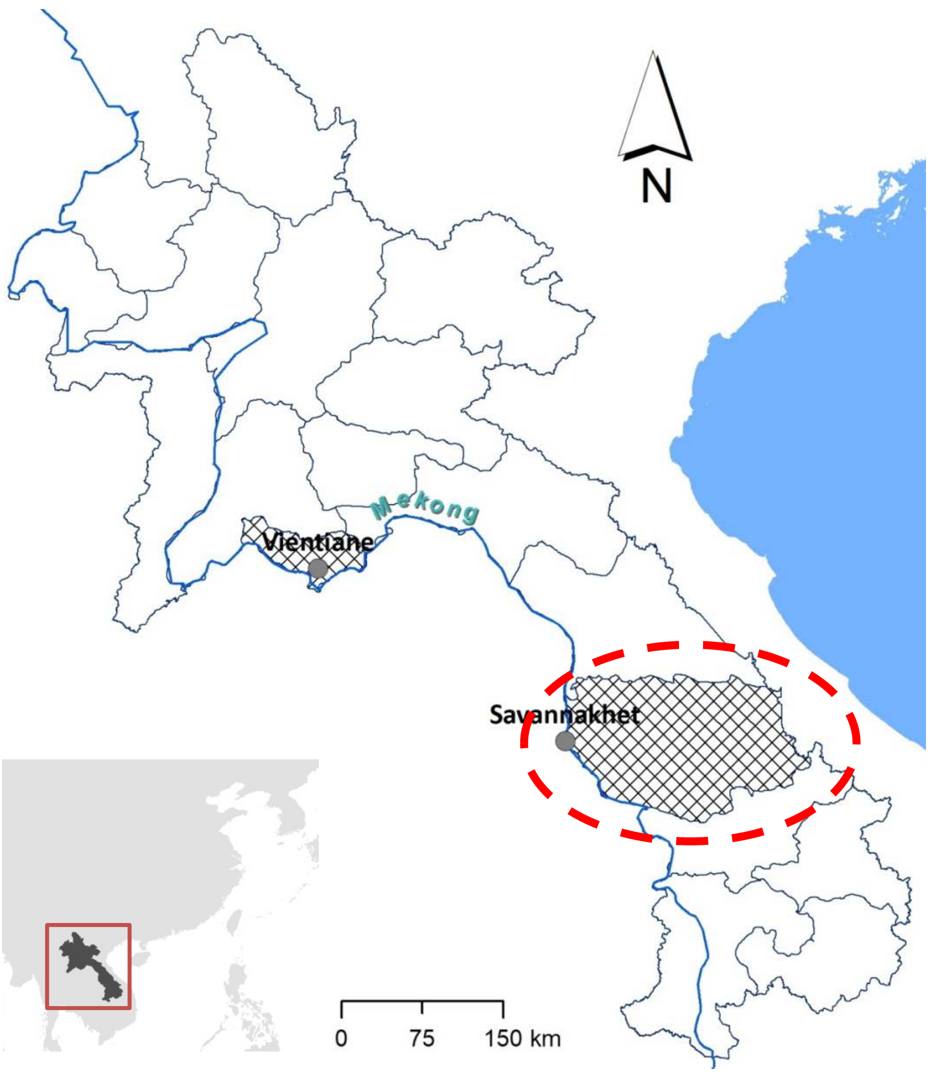
- **Variety recommendation**
  - Short/medium/long duration
- **Planting method**
  - Transplanting-Nursery preparation
  - Direct Seeding
- **Fertilizer applications**
  - Rate
  - Timing

Objectives

- To introduce **a risk management framework** to enhance **preparedness and resilience** of agricultural sectors to climatic variability
- To develop a **mobile application** for agro-climate advisory based on **S2S climate forecasts**
- To **build capacity** of human resources at relevant **institutes** (DMH and NAFRI) for a sustainable management of the proposed system in this program
- To increase **farmers' capacity** in response to seasonal climate variability through training and educational programs.

Materials and Methods

Study Region



- **Focus on rain-fed lowland rice farming areas in Savannakhet Province**
- **The Savannakhet Province accounted for 23% of total lowland rice areas in the country as of 2004**
  - The largest portion compared to other provinces
- **Wet season (May-Oct), highest rainfall in Aug**
- **Chronic drought has been the major risk for rain-fed lowland rice farming in the wet season in the Savannakhet Province (Inthavong et al., 2012)**
  - Studies on the impact of water availability and soil characteristics in the past

Research Tasks and Methodology

- **Tailoring climate forecasts** at seasonal and subseasonal timescales
  - Assess predictability of rainfall statistics around monsoon onset and of onset date over Laos, based on seasonal and subseasonal forecast models
- Producing distributed **precipitation data at a high resolution**
- **Transforming climate forecasts** and evaluating agricultural information
  - Assess the ability to establish crop yield outlooks with satellite-based RS data (e.g., NDVI) at critical crop growth stage
  - Calibration and validation of process-based crop models including AquaCrop, CERES-rice and EPIC considering different complexity of crop models
- Developing **a mobile application** for agro-climate advisory based on S2S forecasts
- **Stakeholder engagement and training** for co-development

Research Tasks and Methodology

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Predictability assessment of rainfall statistics around monsoon onset

- Aphrodite rainfall dataset
  - daily, 0.5° by 0.25° degree resolution, 1951-2007
  - to determine seasonal (MMJASO) rainfall and rainfall onset date for Savannakhet (16.375 to 16.875N, 104.625-105.125E).
- The area-mean timeseries of total rainfall and onset date for the MJJASO seasons
  - standardized and the resulting values were categorized as either above normal, below normal or normal
- The ERA Interim reanalysis (2° by 2°)
  - used to construct composites of atmospheric variables for the greater Laos region
- Geopotential height, specific humidity, zonal and meridional wind, and vertical velocity on three atmospheric pressure levels (850hPa, 500hPa and 250hPa).
  - during early (more than one standard deviation below the mean, or Mar 1-Mar 21), normal (Mar 21-Apr 25) or late (greater than one standard deviation above the mean, or after Apr 25) onset years
- Onset date was here defined as the first wet day of the first seven-day wet spell, not followed by a long dry spell.

Research Tasks and Methodology

- **Tailoring climate forecasts** at seasonal and subseasonal timescales
  - Assess predictability of rainfall statistics around monsoon onset and of onset date over Laos, based on seasonal and subseasonal forecast models
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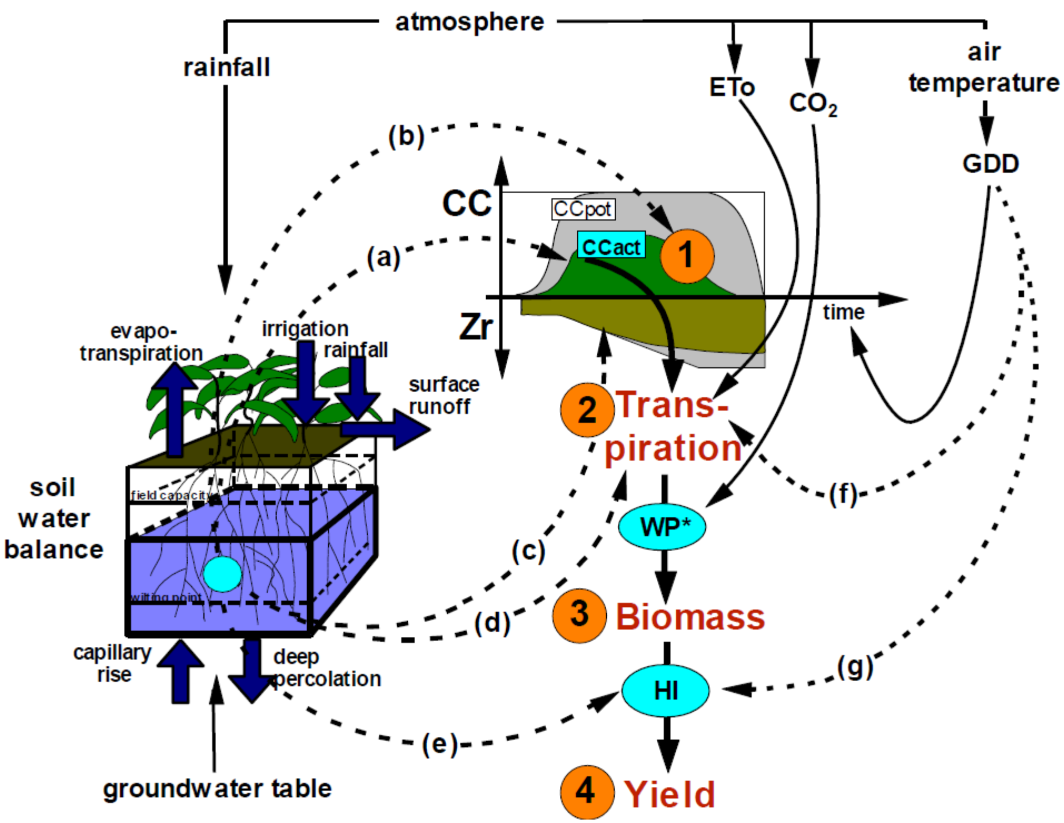
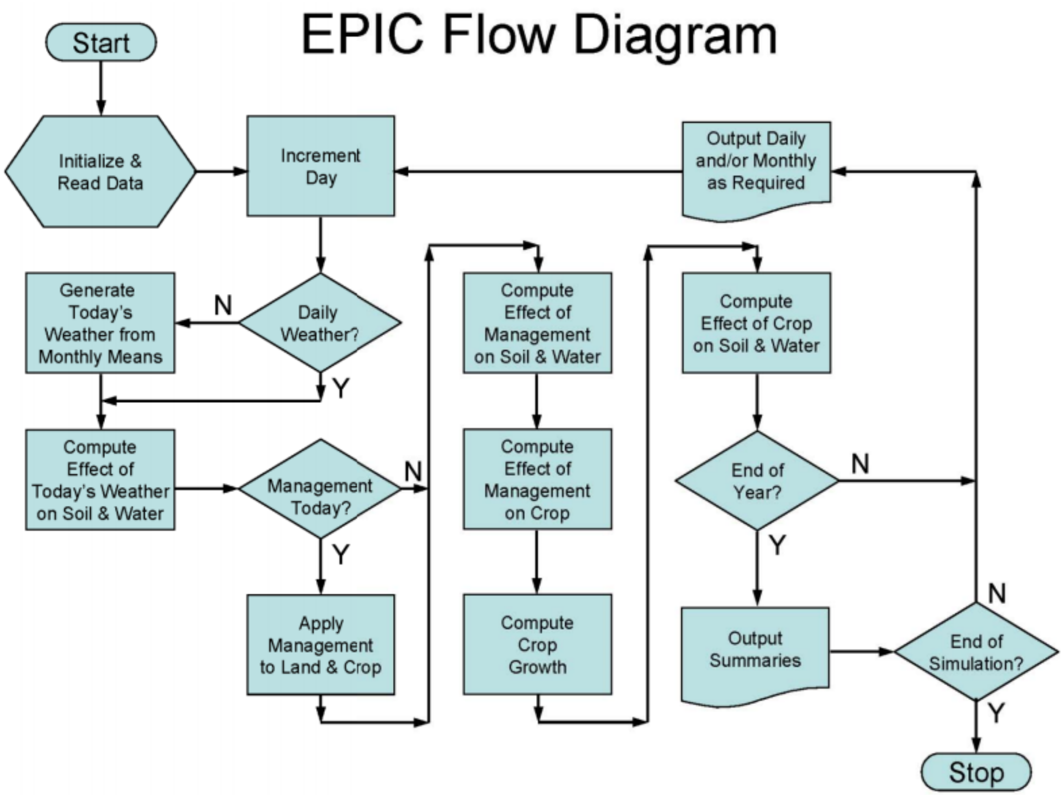
AquaCrop



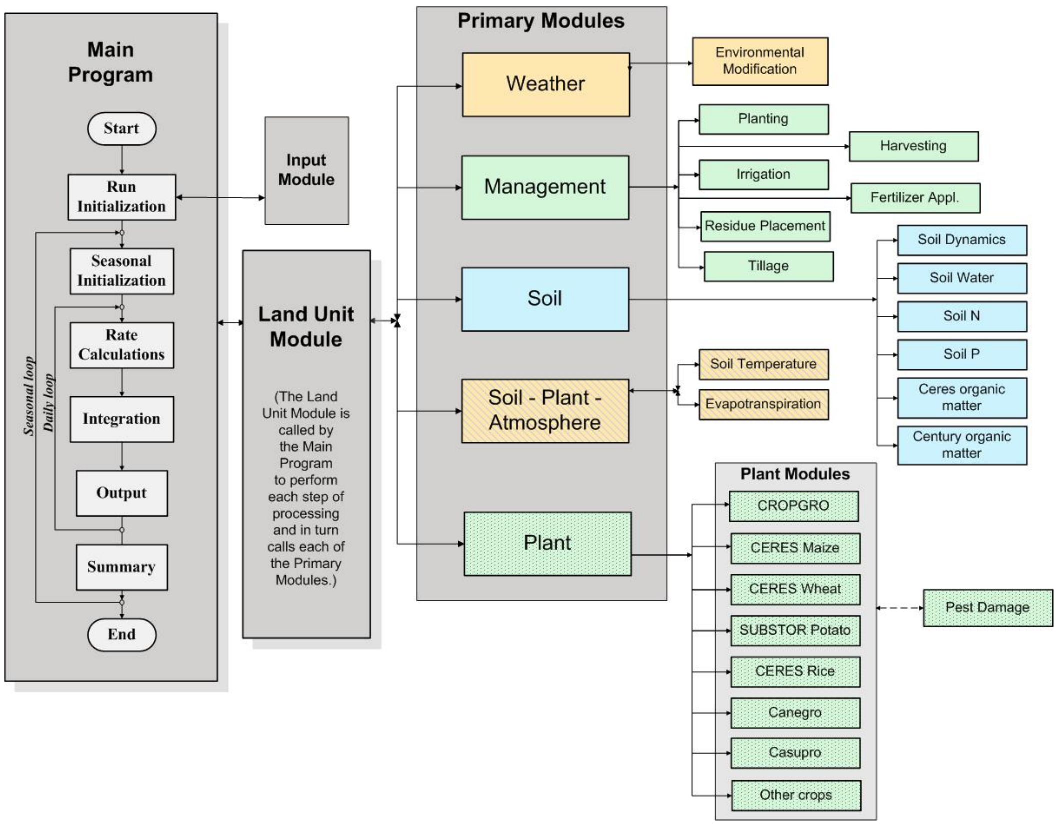
- **AquaCrop** includes the following sub-model components:
  - **Soil** (water balance)
  - **Crop** (development, growth and yield)
  - **Atmosphere** (thermal regime, rainfall, evaporative demand and CO_2 concentration)
  - **Management** (major agronomic practice such as irrigation and fertilization)

EPIC



- **Environmental Policy Integrated Climate (EPIC) Model**
- **A cropping systems model**
- **Soil productivity**
- **Approx. 80 crops**
- **Management decisions on**
  - Soil
  - Water
  - Nutrient and pesticide movements

CERES-Rice



- Widely used as a decision support system
  - To assess the potential impacts of climate change and the efficacy of adaptation options
- Proven model for Asian regions
- Simulating rice growth, development and yields
- Physiological-based, management-level rice model

Calibration and Validation

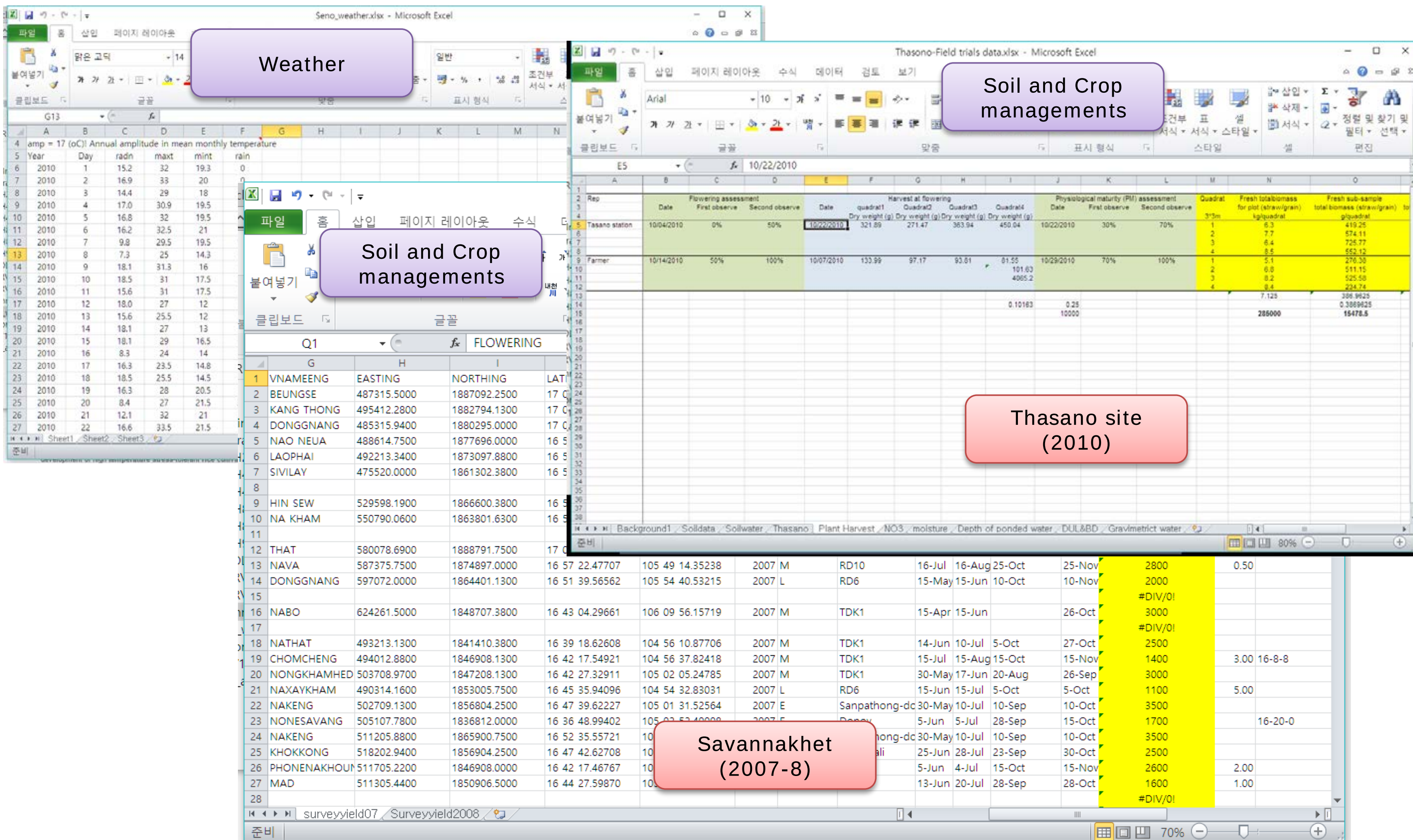
- **AquaCrop**
  - While fertility and water stresses affect crop productivity in the study area (Inthavong et al., 2014), the built-in paddy rice was calibrated for water stress only. Thus, we used the semi-quantitative calibration scheme in the AquaCrop model to consider fertility stress.
- **EPIC**
  - Soil depths, the heat units form planting to harvest, and the plant population and indices or ratios including plant stress levels, the leaf area index, and the Harvest Index (HI) and the Biomass-Energy Ratios (WA)

Calibration and Validation

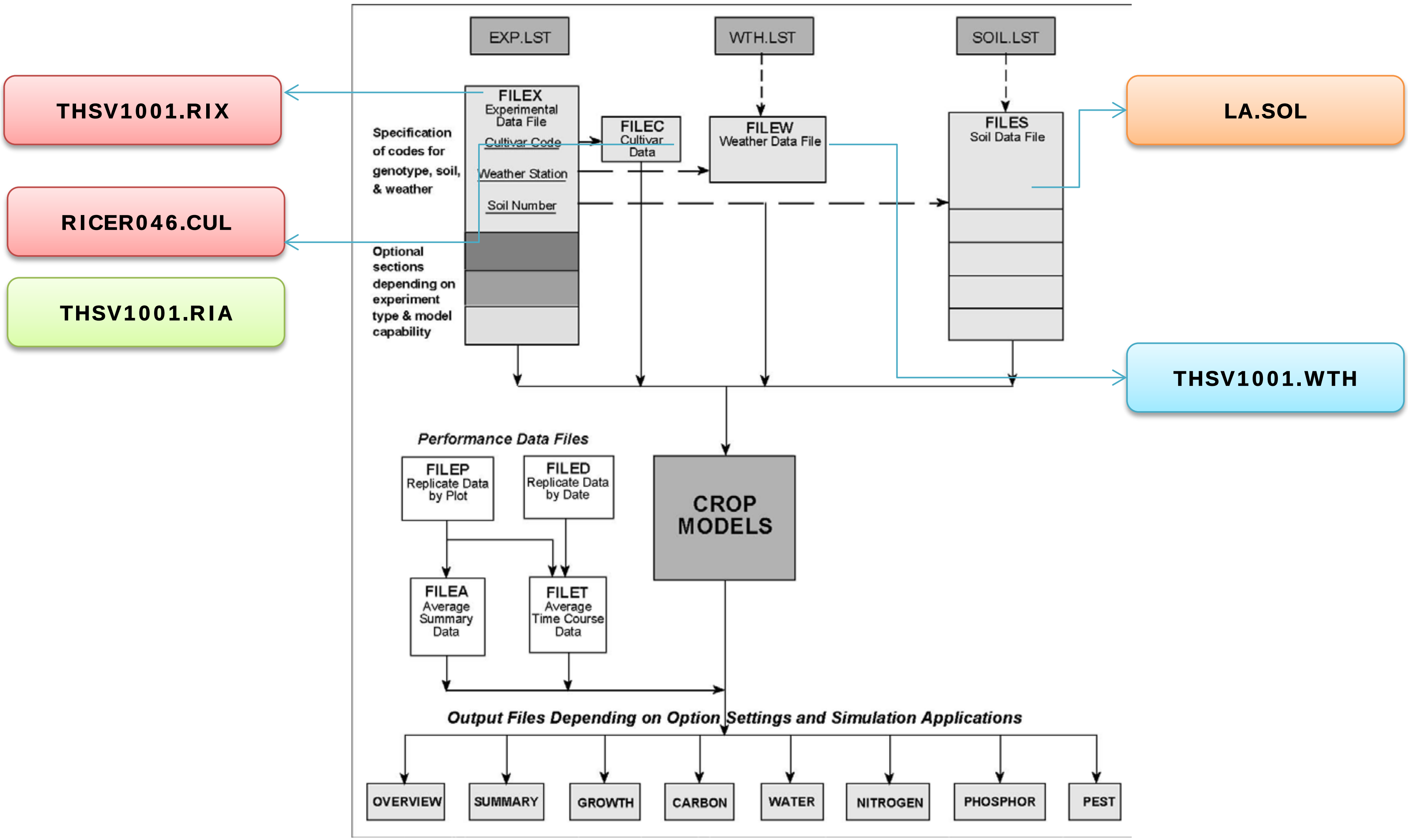
- **CERES-Rice**
- **GenCalc program**

Genotype Coefficient	Description
P1	Time period (expressed as growing degree days [GDD] at °C above a base temperature of 9°C) from emergence to the end of the juvenile phase.
P2O	Critical photoperiod or the longest day length (in hours) at which the development occurs at a maximum rate.
P2R	Photoperiod sensitivity coefficient, extent to which the phase development leading to panicle initiation is delayed (expressed as GDD in °C).
P5	Time period (expressed as GDD in °C) from the beginning of grain filling to physiological maturity with a base temperature of 9 °C
G1	Potential spikelet number coefficient as estimated from the number of spikelets per g of the main culm + spike dry weight at anthesis.
G2	Single grain weight (g) under nonlimiting growing conditions, i.e., nonlimiting light, water, nutrients, and absence of pests and diseases.
G3	Tillering coefficient (scalar value) relative to IR64 cultivar under nonlimiting conditions.
G4	Temperature tolerance coefficient.

Field survey datasets



Overview of input and output files used by DSSAT crop models

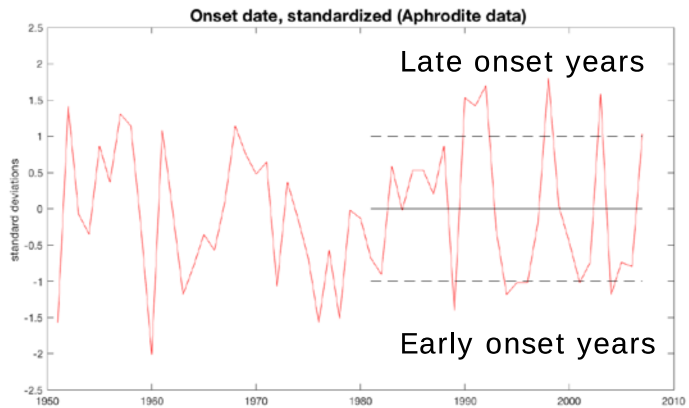


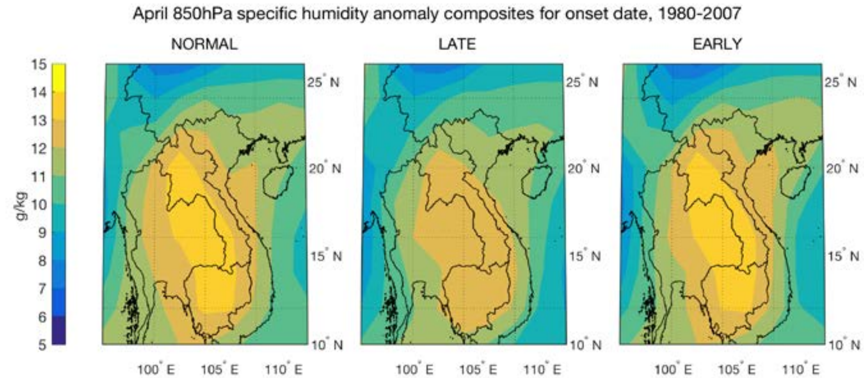
Results and Disucssion

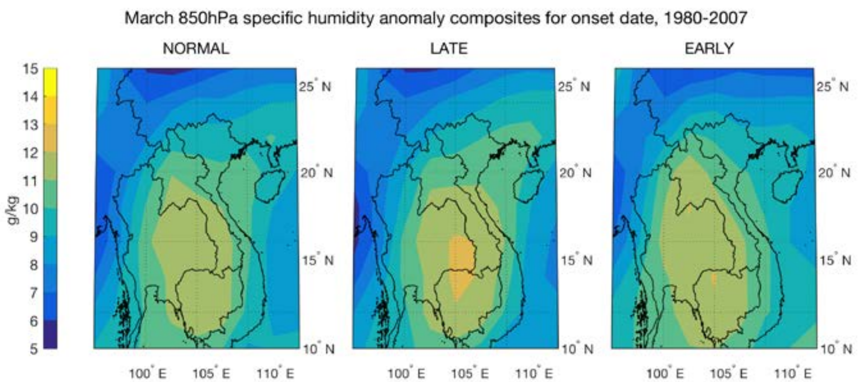
Research Tasks and Methodology

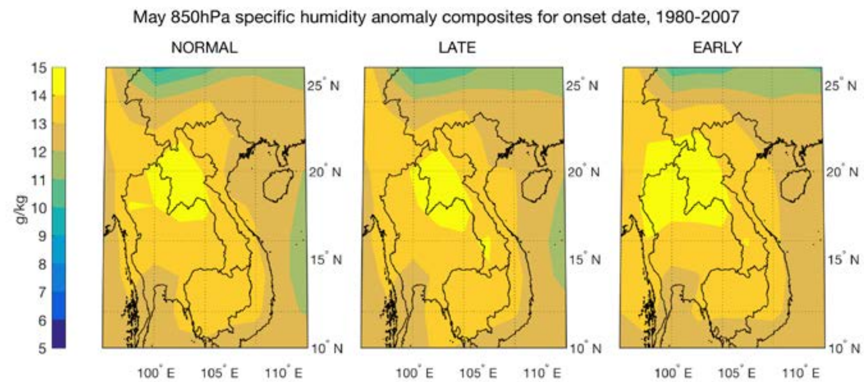
- **Tailoring climate forecasts** at seasonal and subseasonal timescales
  - Assess predictability of rainfall statistics around monsoon onset and of onset date over Laos, based on seasonal and subseasonal forecast models
- Producing distributed **precipitation data at a high resolution**
- **Transforming climate forecasts** and evaluating agricultural information
  - Calibration and validation of process-based crop models including AquaCrop, CERES-rice and EPIC considering different complexity of crop models
- Developing **a mobile application** for agro-climate advisory based on S2S forecasts
- **Stakeholder engagement and training** for co-development

Predictability of rainfall statistics around monsoon onset and of onset date









Predictability assessment of rainfall statistics around monsoon onset

- The regional geopotential height and specific humidity fields in particular have the potential to be used operationally to improve predictability of total seasonal rainfall as well as late monsoon onset (post April 25)
- The results showed that the relationship is sensitive to definitions of onset dates, and thus monsoon onset date should be carefully defined in agricultural context, not following to typical definition based on atmospheric condition.
- Rainfall amount and frequency in vegetative stages (MJJ) positively affected the rice yields, while negatively in late growing season.
- Dry spell showed opposite results: positive correlation in reproductive and ripening stages (ASO) and negative correlation in vegetative stages.

Research Tasks and Methodology

- **Tailoring climate forecasts** at seasonal and subseasonal timescales
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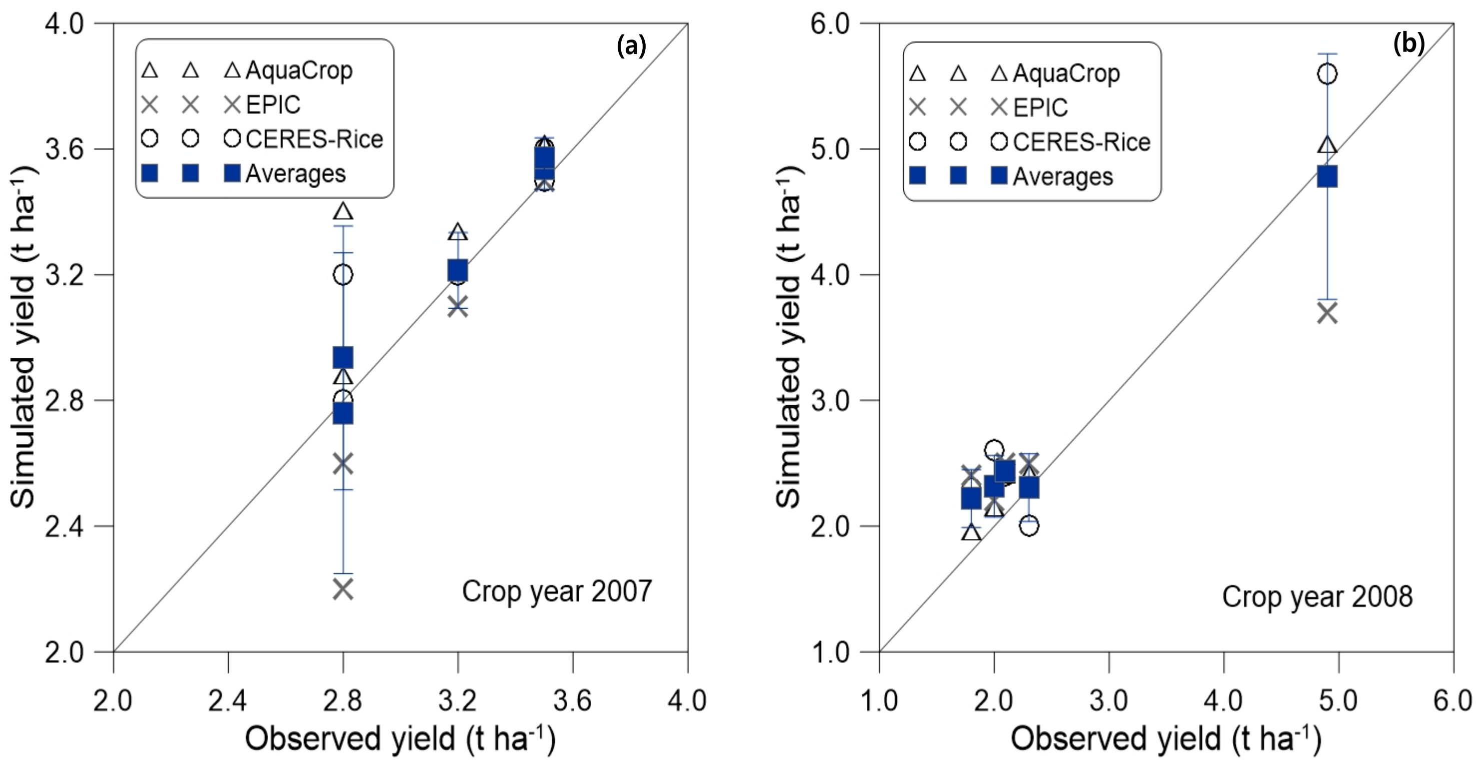
Observed and simulated rice yields (a) in 2007 and (b) in 2008



Goodness-of-fit measures for the three models against observed rice yield

Model	Year	PBIAS (%)	MAPE (%)	RMSE (t ha^{-1})
AquaCrop	2007	-6.68	7.08	0.42
	2008	-6.79	7.93	0.18
EPIC	2007	5.7	6.34	0.64
	2008	-1.16	18.79	1.43
CERES-Rice	2007	-2.75	3.27	0.4
	2008	-12.91	19.28	1.1
Ensemble	2007	-1.38	1.97	0.03
	2008	-7.35	11.61	0.41

ARMS Climate Farmer Field Workshop

Summary

- **Main Events**
  - ARMS Kickoff Workshop [Wed 17, May 2017]
  - ARMS Climate Farmer Field Workshop: Training of Trainers [Thu 18 – Fri 19, May]
  - ARMS Climate Farmer Field Workshop: Training of Farmers
    - Phonyanang Village [Sat 20 – Sun 21, May]
    - Houmeug Village [Wed 24 – Thu 25, May]
- **Key Partners**
  - International Research Institute for Climate and Society (IRI)
  - National Agriculture and Forestry Research Institute (NAFRI)
  - Provincial Agriculture and Forestry Offices (PAFO), and District Agriculture and Forestry Offices (DAFO)

Research Tasks and Methodology

- **Tailoring climate forecasts** at seasonal and subseasonal timescales
  - Assess predictability of rainfall statistics around monsoon onset and of onset date over Laos, based on seasonal and subseasonal forecast models
- Producing distributed **precipitation data at a high resolution**
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- Developing **a mobile application** for agro-climate advisory based on S2S forecasts
- **Stakeholder engagement and training** for co-development

ARMS Climate Farmer Field Workshop

- **Objective 3: To build capacity of human resources at relevant institutes (DMH and NAFRI) for a sustainable management of the proposed system in this program.**
  - In order to have a successful project, the national and local government must be capable of benefitting from the agro-climate outputs of ARMS and successfully communicating this information to the target beneficiaries: farmers.
  - ARMS aims to enable key government partners to translate climate forecasts to agricultural information and evaluate benefits of forecast-based agricultural decision making
- **Objective 4: To increase farmers' capacity in response to seasonal climate variability through training and educational programs.**
  - Prepare farmers for the ARMS agro-climate advisory and mobile application, which will be developed in year 2 of the project by enhancing their understanding of the existence and relevance of climate information

ARMS Climate Farmer Field Workshop: Training of Trainers in Savannakhet

ARMS Climate Farmer Field Workshop: Training of Farmers in Phonyanang

ARMS Climate Farmer Field Workshop: Training of Farmers in Houmeug

DMH Training Workshop

November 8 – 11, 2017, Vientiane Lao PDR

NAFRI Training Workshop

November 8 – 14, 2017, Vientiane Lao PDR

Conclusions

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- The regional geopotential height and specific humidity fields in particular have the potential to be used operationally to improve predictability of total seasonal rainfall as well as late monsoon onset (post April 25)
- The results showed that the relationship is sensitive to definitions of onset dates, and thus monsoon onset date should be carefully defined in agricultural context, not following to typical definition based on atmospheric condition.
- Rainfall amount and frequency in vegetative stages (MJJ) positively affected the rice yields, while negatively in late growing season.
- Dry spell showed opposite results: positive correlation in reproductive and ripening stages (ASO) and negative correlation in vegetative stages.

Conclusions

- Crop models:
  - AquaCrop: to predict attainable yields under no stress conditions
  - CERES-Rice: to assess detailed agricultural management information to determine BMPs
  - Useful:
    - For the reduction of the climate-related risk managements in rain-fed lowland rice production ecosystems in Laos
    - For the improvement of the livelihood of the rural people of Laos,
    - Subsequently for the enhancement of food security in Laos.


Thank you

Introduction to FAO AquaCrop model and its applications

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APEC Climate Center

APCC
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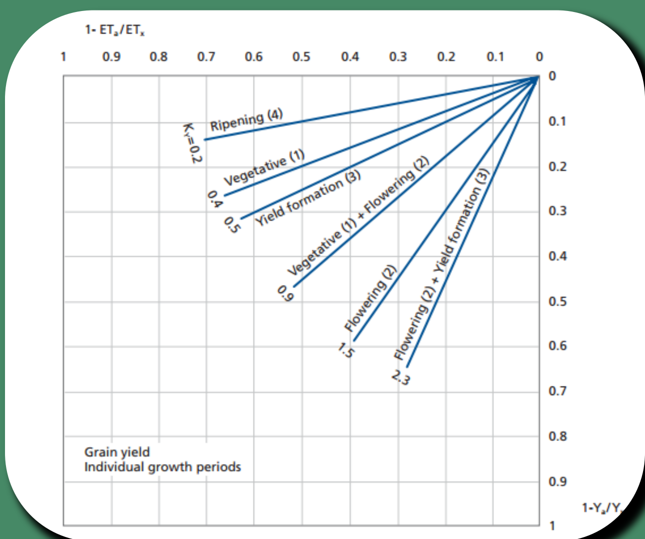
Background – Crop Yield Estimation

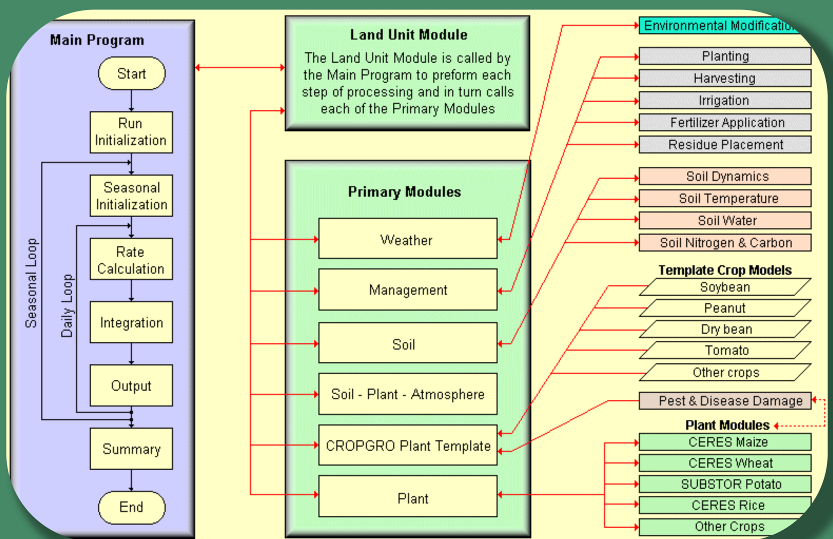
Quantifying Crop Yield:

Empirical Functions



- ✓ Simple
- ✓ low data need
- ✓ But, low reliability

Sophisticated Crop Models



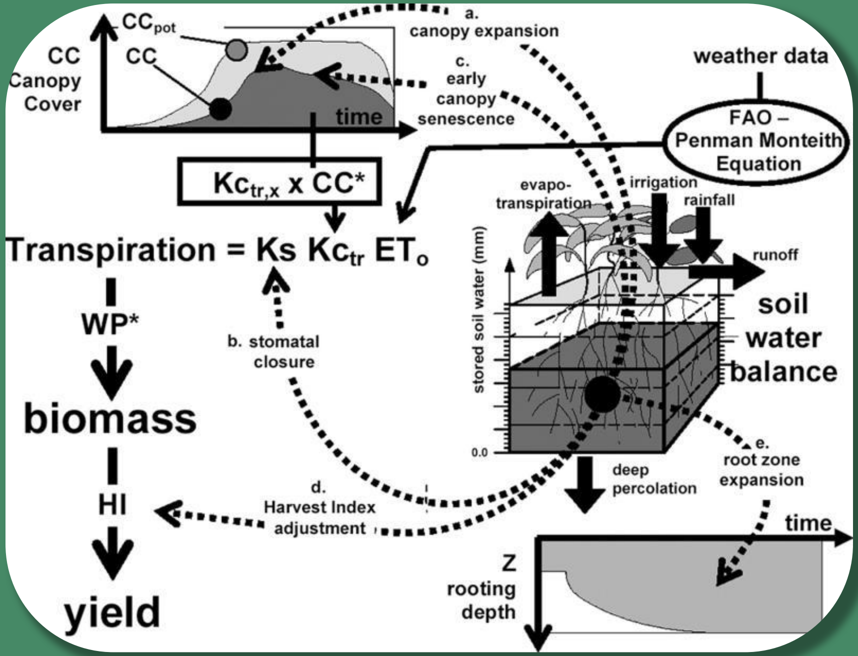
- ✓ Scientific & reliable
- ✓ But, high complexity and data requirement

Background – AquaCrop

General features:

- ✓ Balanced btw. the two approaches
- ✓ Simple and robust
- ✓ Water and salt balance
- ✓ E + Tr estimation
- ✓ Crop development, Yield
  (CC – canopy cover;
  ABG – aboveground biomass)

less input requirement
But, reliable and robust

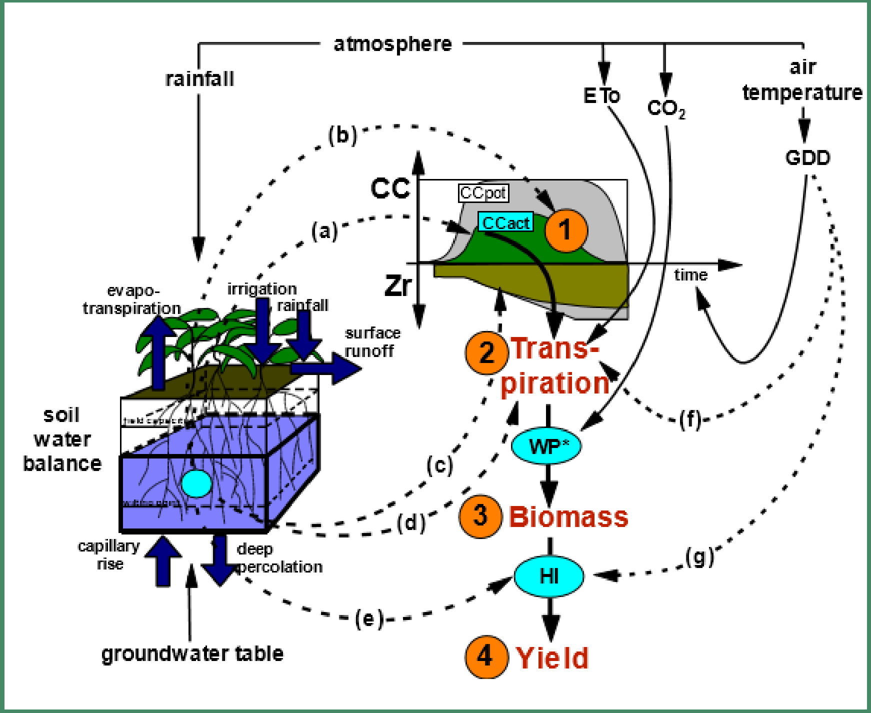


: FAO's AquaCrop Model

Calculation Scheme

4 steps for estimating crop yield:

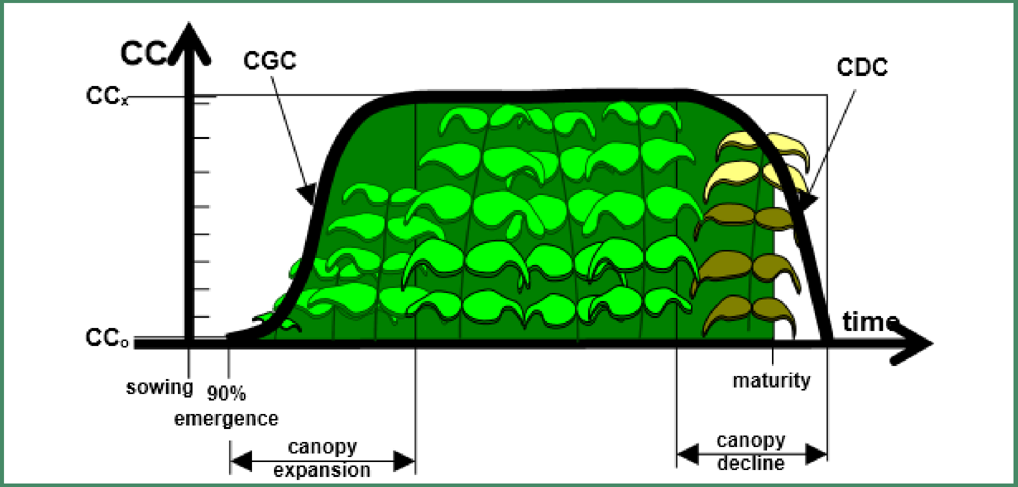
- ✓ Green canopy cover (CC)
  $Kc_{Tr} = Kc_{Tr,x} \times CC$
- ✓ Transpiration (Tr)
  $Tr = Ks \times Kc_{Tr} \times ETo$
- ✓ Aboveground Biomass
  $B = WP^{*} \times \sum (Tr / ETo)$
- ✓ Crop Yield
  $Y = HI \times B$



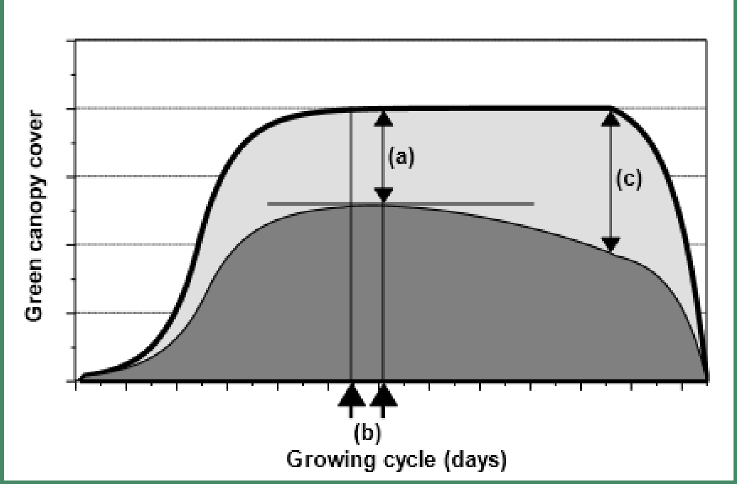
Green Canopy Cover

Green canopy cover development:

- ✓ A crop has a generic trend in CC development
- ✓ Under stresses over tolerance, CC decreases



: CC development under no stress

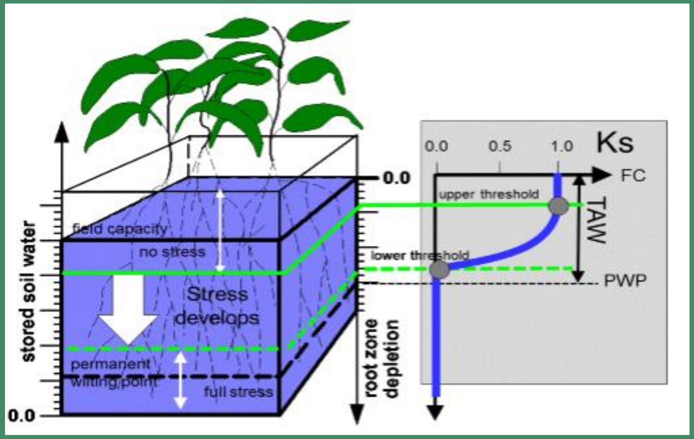


: CC development under stresses

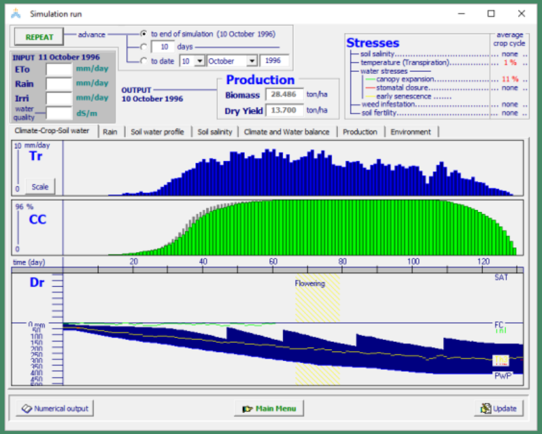
Consideration of Water Stress

Estimation of Water Stress Coefficient (Ks):

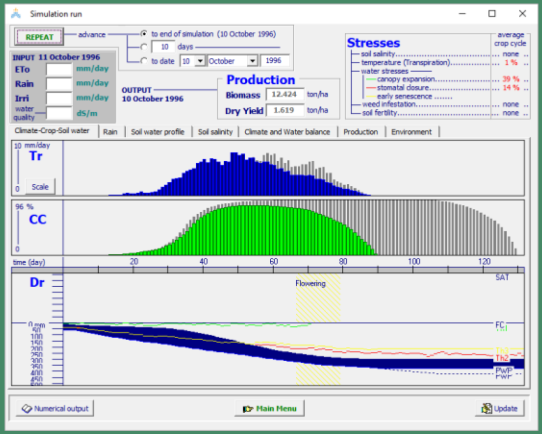
- ✓ Obtained by soil water balance simulations
- ✓ Daily Ks values are estimated



: concept of stress coefficient



: stress under irrigation

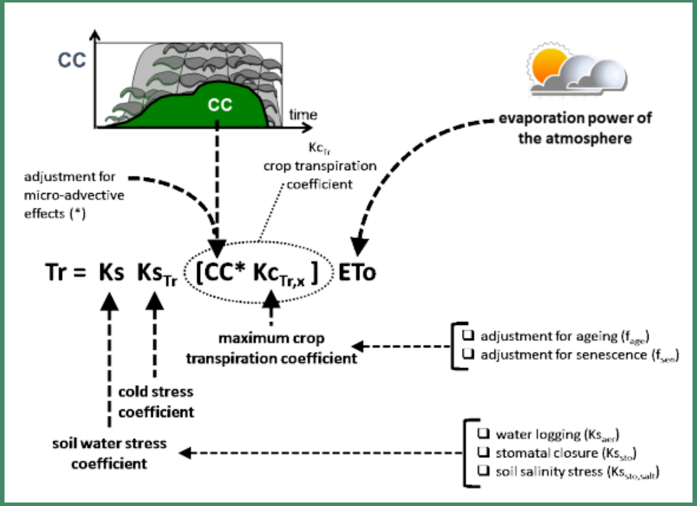


: stress under rain-fed

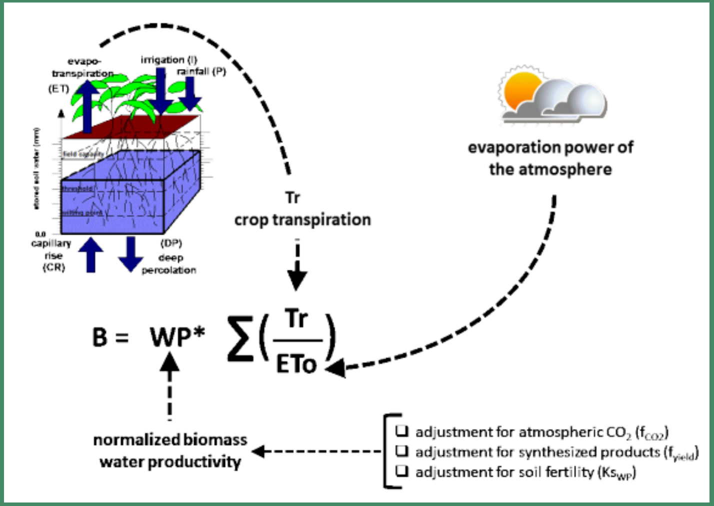
Transpiration and Biomass Production

Using the reference ET and WP*:

- ✓ $Tr = Ks \times Kc_{Tr} \times ETo$
- ✓ $B = WP^* \times \sum (Tr / ETo)$



: calculation scheme for Tr



: calculation scheme for dry AGB

Normalized Water Productivity

Why WP should be normalized?

- ✓ To consider atmospheric CO_2 & climate
- ✓ Importantly, to distinguish C3 and C4 crops

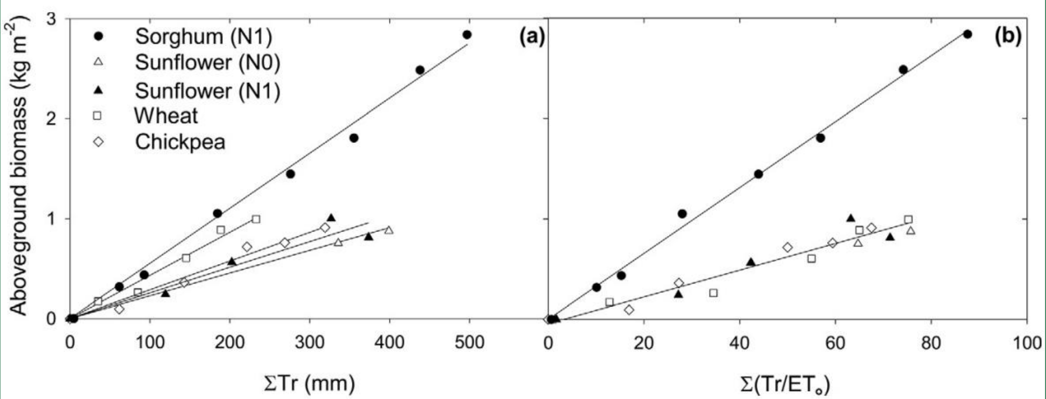


Fig. 2. Relationships (a) between aboveground biomass and cumulative transpiration (∑Tr) and (b) between aboveground biomass and cumulative normalized transpiration for reference-crop evapotranspiration [∑(Tr/ET$_o$)], during the crop cycle of sunflower (under two N levels and up to anthesis), sorghum, wheat, and chickpea (redrawn from Steduto and Albrizio, 2005).

: water productivity for Tr & Tr/ETo

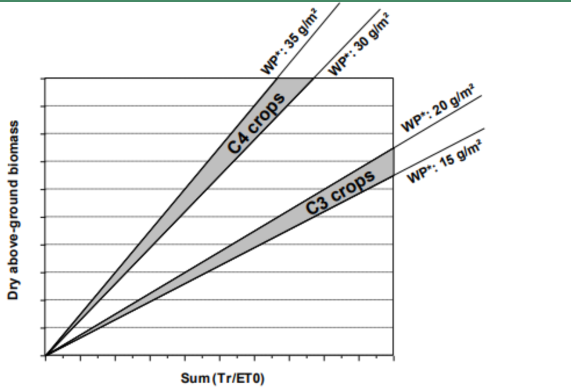


Figure 3.11b – The relationship between the dry above-ground biomass and the total amount of water transpired for C3 and C4 crops after normalization for CO_2 and climate (ET$_o$)

: ranges of WP* for C3 & C4 crops

Structure of Crop Yield Estimation

Using the Harvest Index (HI):

✓ Reference HI + adjustment factor

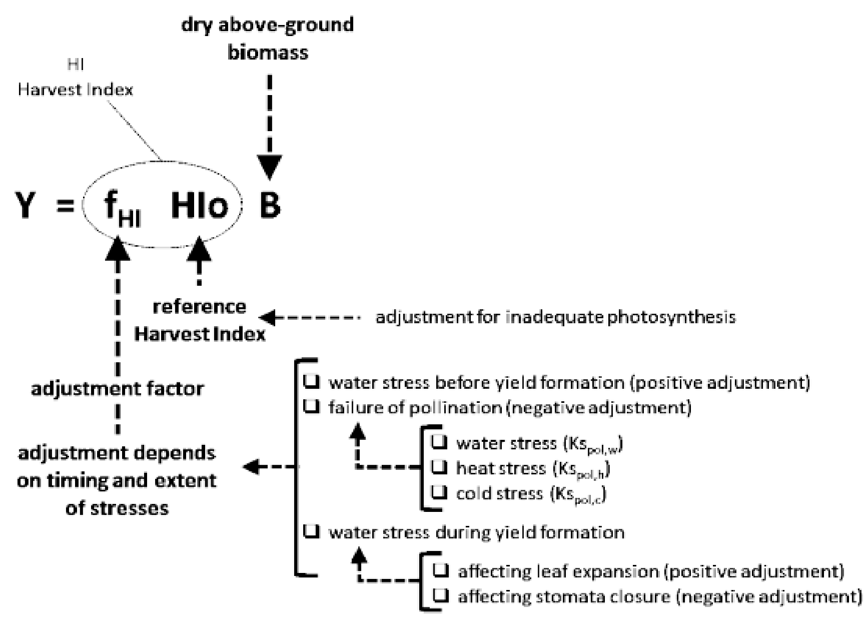
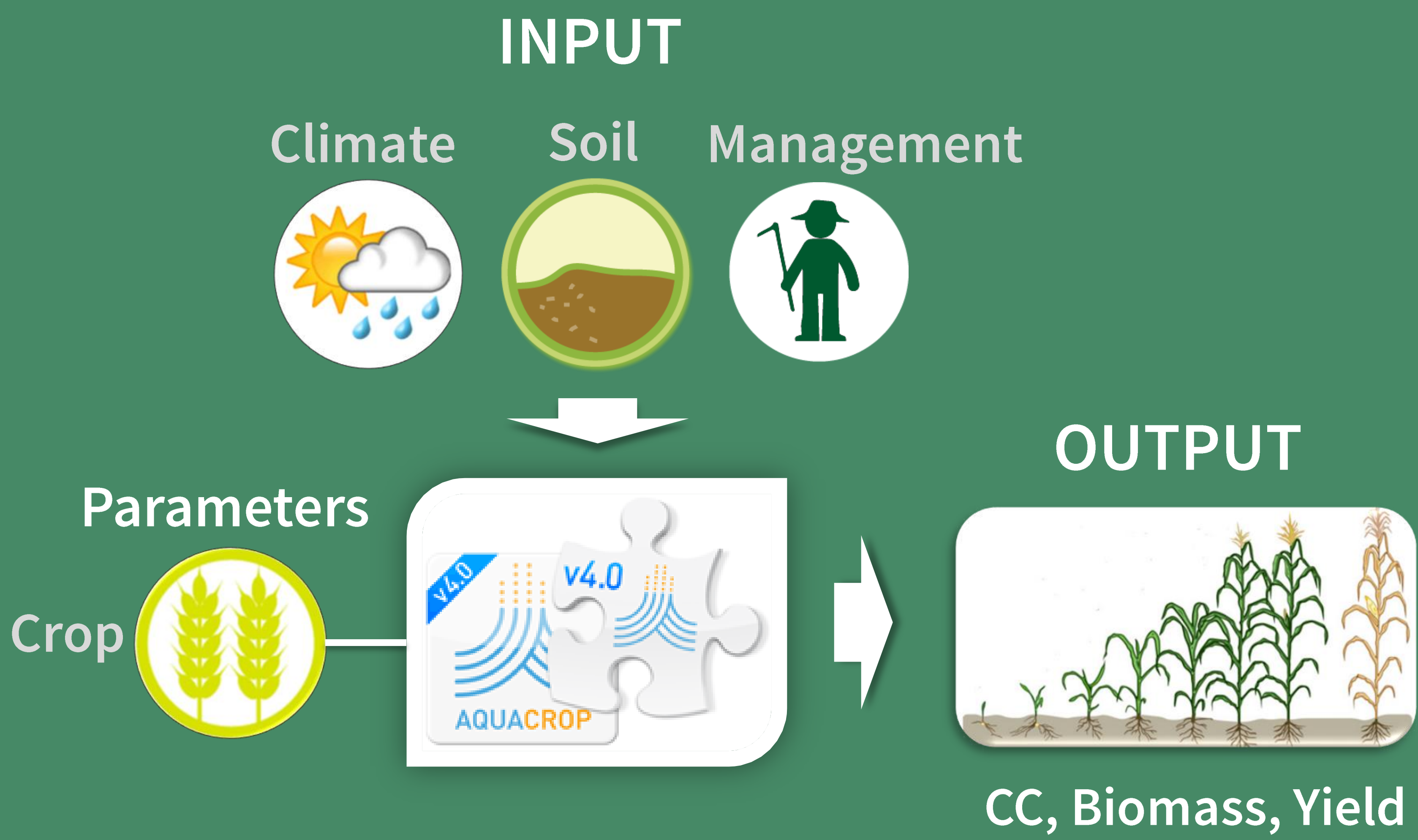
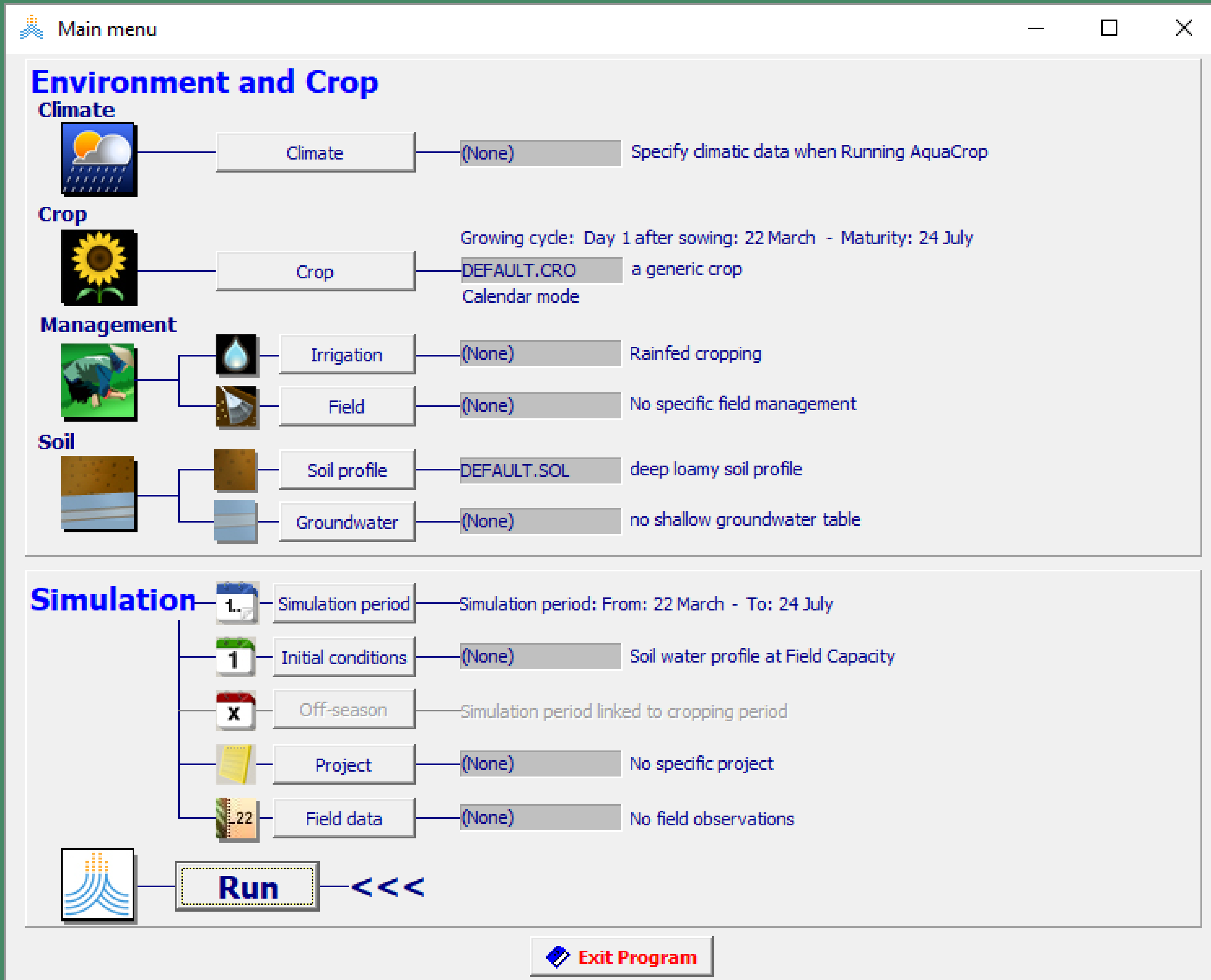


Figure 3.12a – Calculation scheme in AquaCrop for dry yield (Y)

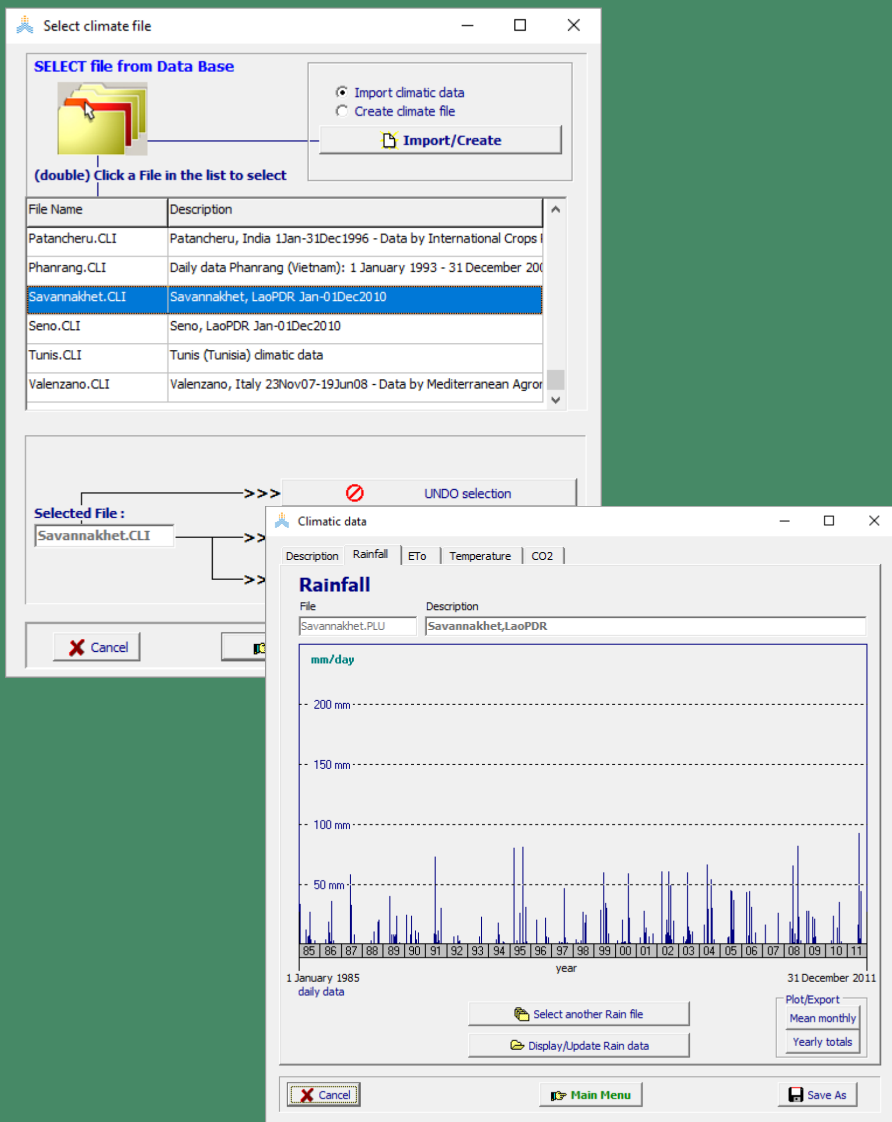
FAO AquaCrop Model



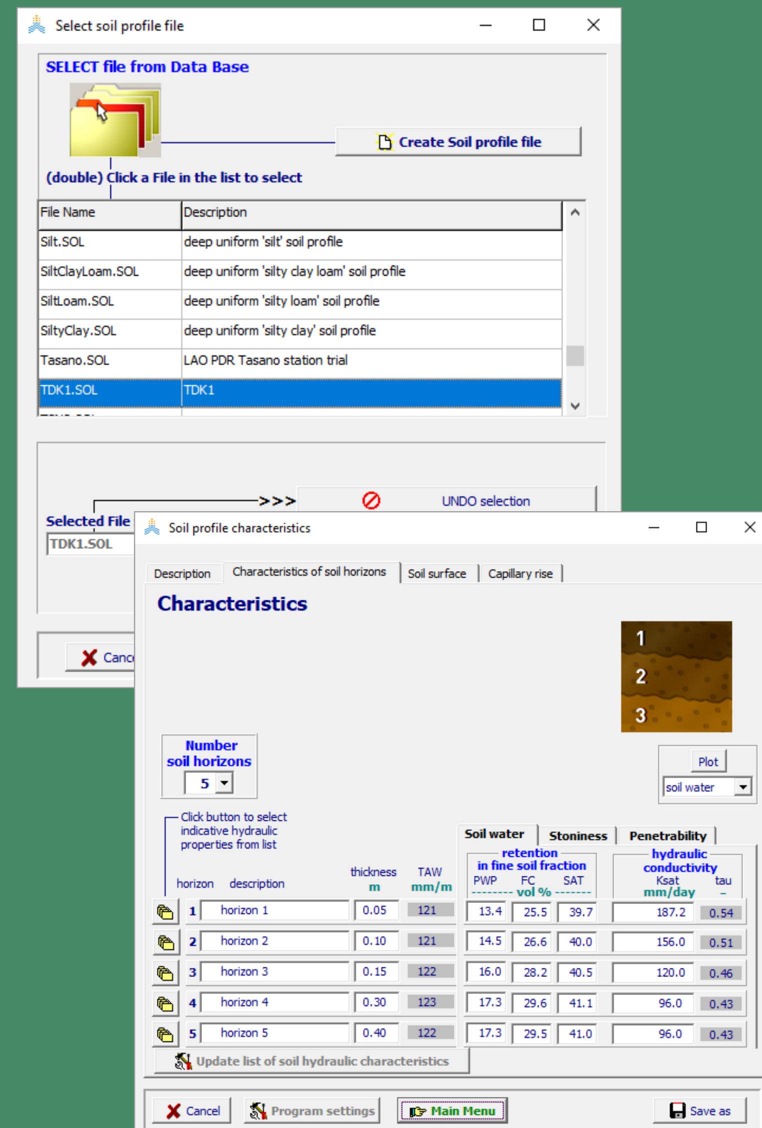
Let’s do some practices using your datasets!


Main menu
Environment and Crop
Climate
Climate
(None)
Specify climatic data when Running AquaCrop
Crop
Growing cycle: Day 1 after sowing: 22 March - Maturity: 24 July
Crop
DEFAULT.CRO
a generic crop
Calendar mode
Management
Irrigation
(None)
Rainfed cropping
Field
(None)
No specific field management
Soil
Soil profile
DEFAULT.SOL
deep loamy soil profile
Groundwater
(None)
no shallow groundwater table
Simulation
Simulation period
Simulation period: From: 22 March - To: 24 July
Initial conditions
(None)
Soil water profile at Field Capacity
Off-season
Simulation period linked to cropping period
Project
(None)
No specific project
Field data
(None)
No field observations
Run
<<<
Exit Program

Climate



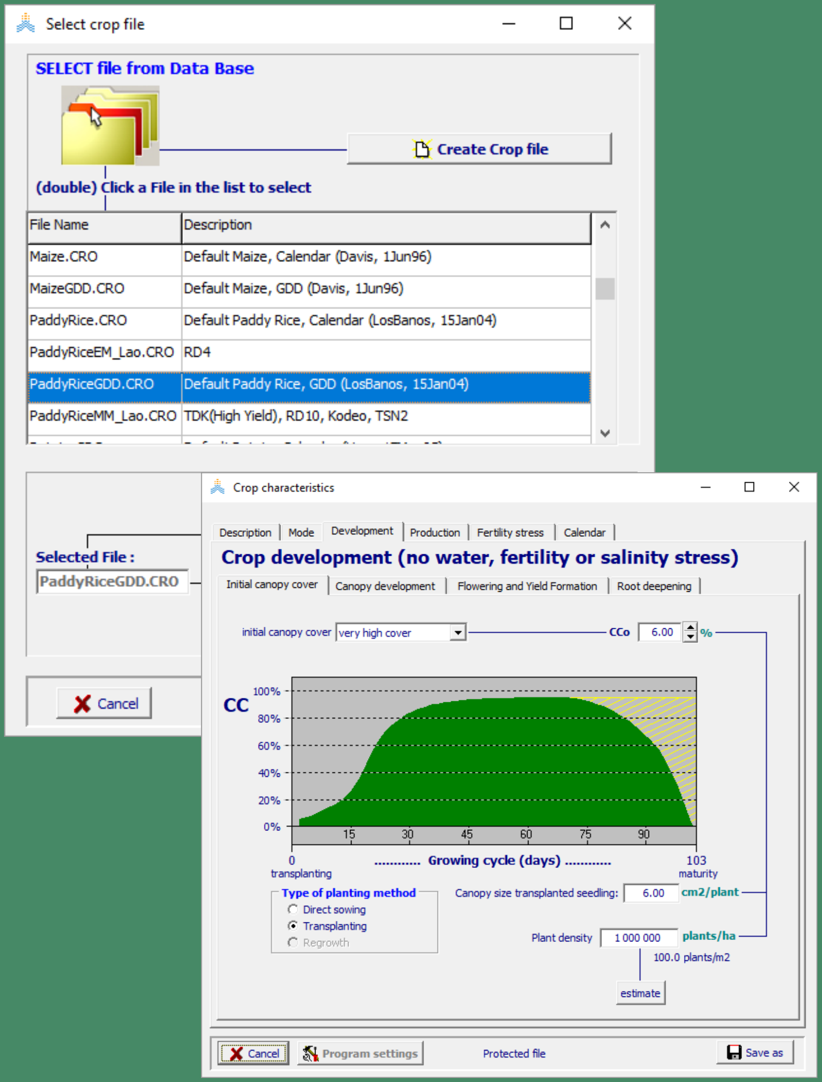
Soil



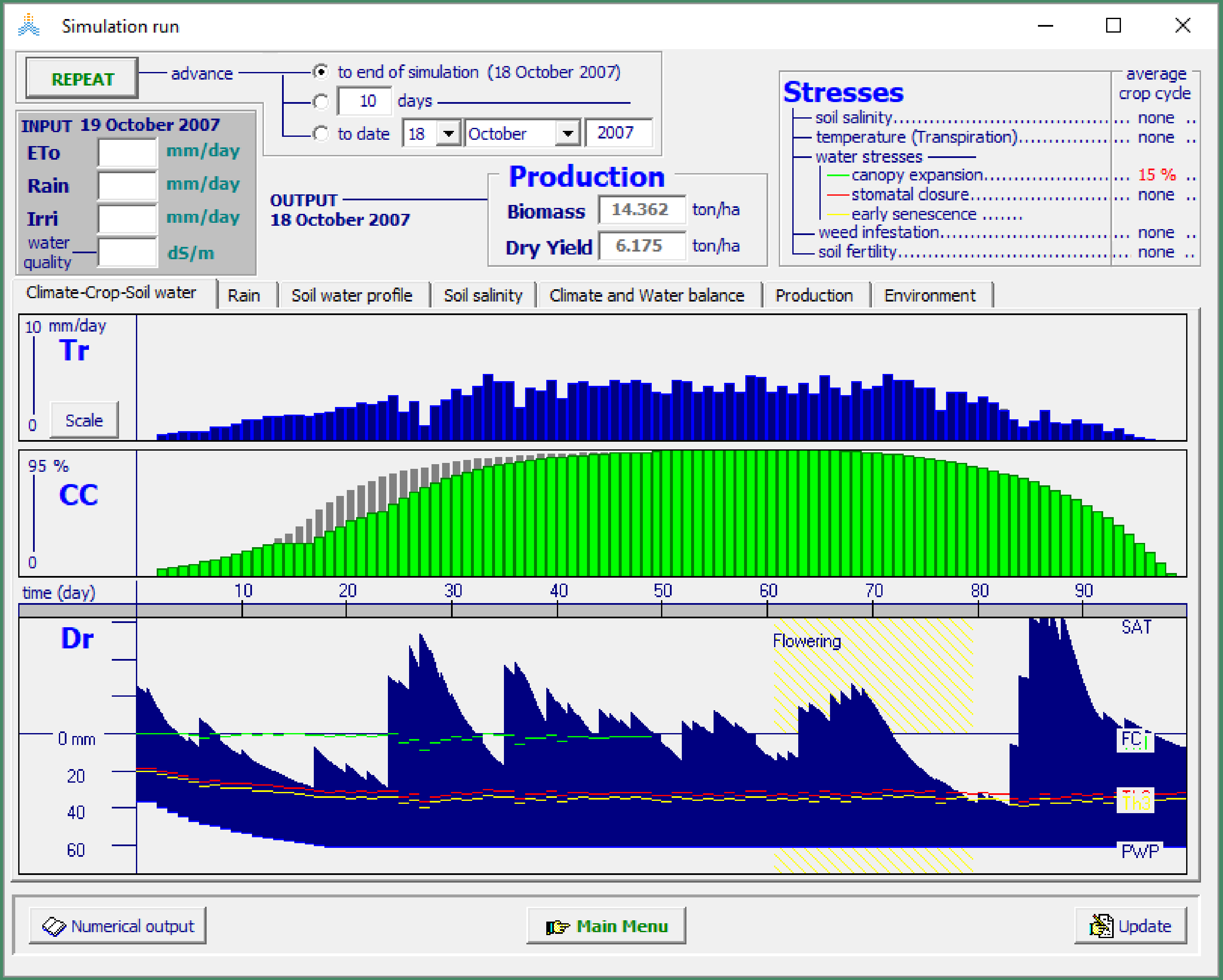
Management

Paddy Rice (Jul/11/2007)

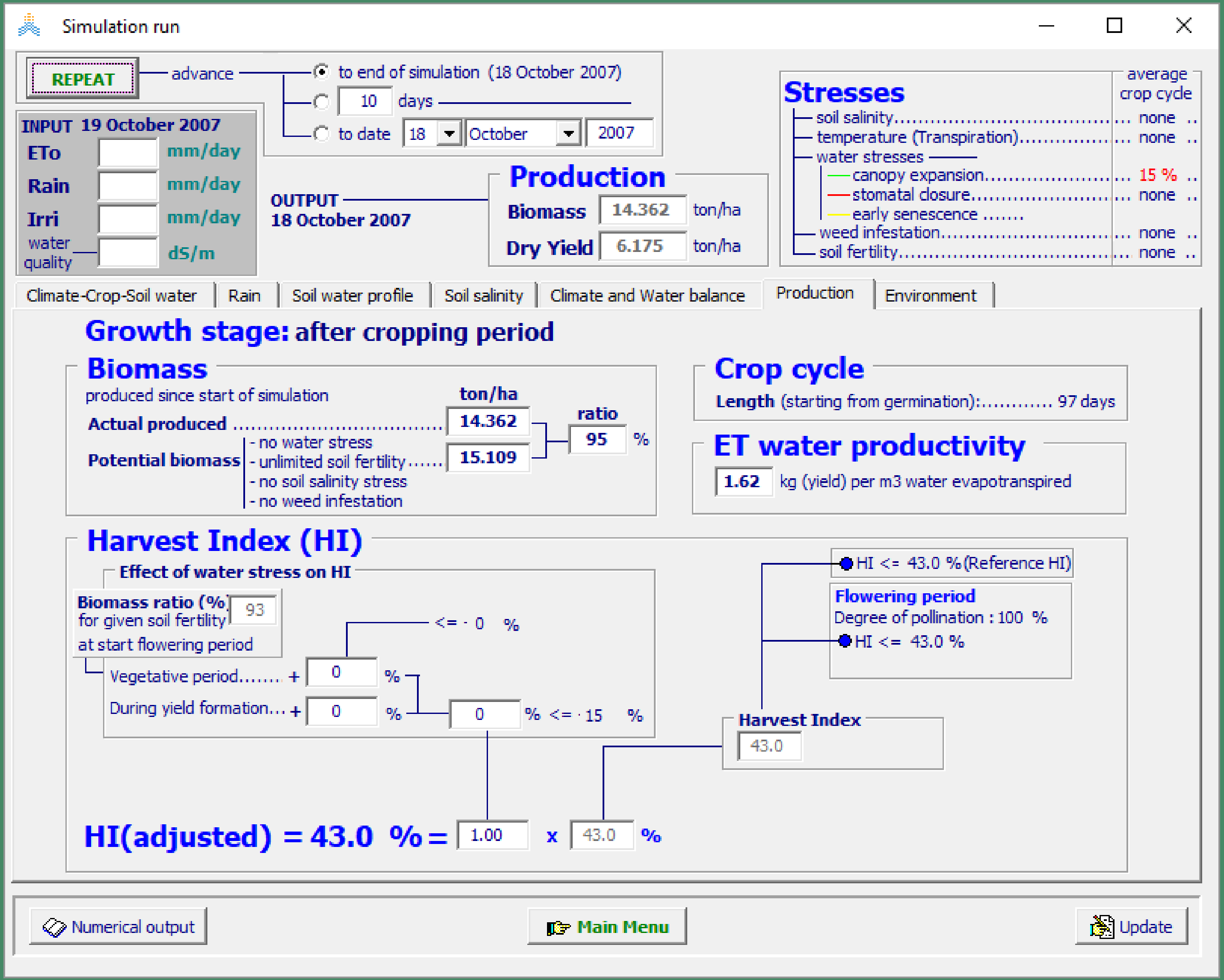
No irrigation (rainfed)
No fertility stress



By Clicking the “Run” Button!



By Clicking the “Run” Button!



Rice productivity in Thavone et al.(2014):

Table 2
Model validation for grain yield for early, medium, and late genotype groups over two rice cropping seasons 2007 and 2008 in Savannakhet province, Laos.

Statistics	2007 season				2008 season		
	Early	Medium	Late	All	Early	Medium	All
Number of samples	10	36	7	53	9	39	48
Bias (kg ha^{-1})	650	92	169	208	198	246	151
Coefficient of correlation (*r*)	0.59	0.58	0.57	0.54	0.75	0.49	0.54
	($p > 0.05$)	($p < 0.01$)	($p > 0.05$)	($p < 0.01$)	($p < 0.05$)	($p < 0.01$)	($p < 0.01$)
Index of Agreement (IA)	0.48	0.73	0.97	0.69	0.78	0.62	0.67

Note: There was no yield analysis for late maturity variety in 2008 due to only a few farms planted this maturity type.

Table 3
Rice yield (kg ha^{-1}) at two fertilizer rates ($N–P_2O_5–K_2O$ kg ha^{-1}), farmer practice and estimated rate required to target grain yield of 5000 kg ha^{-1}, at eight locations [Phonhong (PH), Tulakhom (TK), Champhone (CP), Sakeun (SK), Beungxe (BX), Donekhor (DK), Saphai (SP), Vatsay (VS)] across three provinces in Laos in 2010/11 dry season. The bottom rows show estimated fertilizer rates ($N–P_2O_5–K_2O$) required for the target yield of 5000 kg ha^{-1} and observed field conditions.

	Vientiane		Savannakhet			Champassak			Mean
	PH	TK	CP	SK	BX	DK	SP	VS	
Farmer practice yield	3067	3750	2260	5525	3023	4747	5437	3561	3921
Target yield	4417	4894	3057	5566	3607	5072	5509	3977	4512
Fertilizer rate	110-63-34	91-62-10	121-62-0	100-60-7	94-52-39	106-63-36	113-57-30	84-61-0	
Field issues			W		W	FYM	FYM	W, S	

W: weed problem; FYM: additional nutrient input of farm-yard manure; S: water stress.

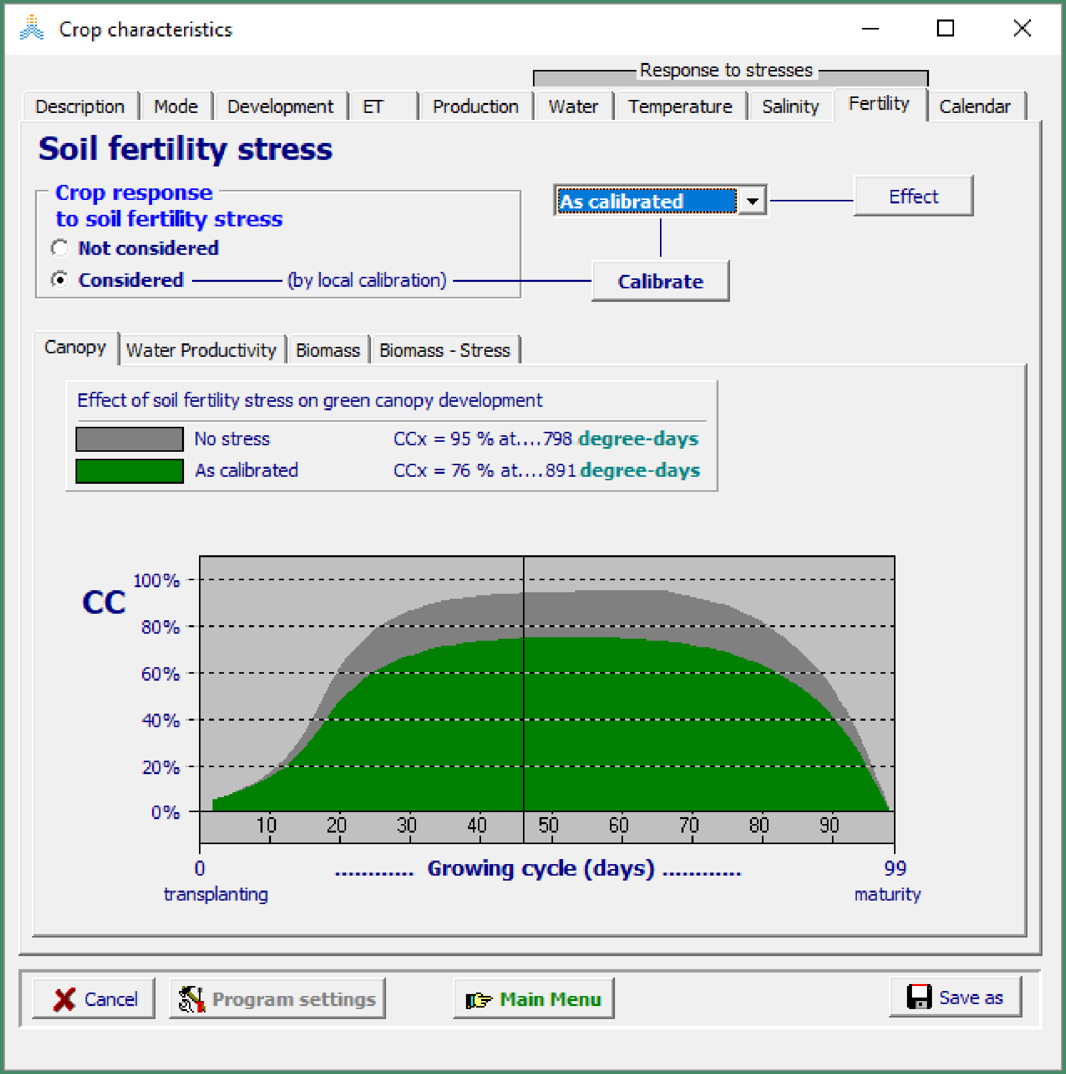
Table 4
Comparison of grain yield (kg ha^{-1}) in nutrient omission trials (a) simulated in this study and (b) observed by Linquist and Sengxue (2001), and (c) simulated effect of fertilizer rate relative to standard 60N-13P-16 K kg ha^{-1} (multiplier of this rate from 0 to 6 times (0×, 1×, 2×, 3×, 4×, 5×, 6×) the standard rate).

(a) Simulated effect of nutrient omission from the standard fertilizer rate (60 N–13 P–16 K)							
Fertiliser rate (N–P–K)	60–13–16	0–13–16	60–0–16	60–13–0	0–0–0		
Grain yield	2932	1895	2248	2822	1595		
Yield reduction due to nutrient omission		35%	23%	4%	46%		
(b) Observed effect of N omission from the standard fertilizer rate (60 N–13 P–16 K)							
Fertiliser rate (N–P–K)	60–13–16	0–13–16			0–0–0		
Grain yield	3300	2400			2000		
Yield reduction due to N omission		27%			39%		
(c) Simulated effect of fertilizer rate							
Times the standard rate (60 N–13 P–16 K)	0×	1×	2×	3×	4×	5×	6×
Grain yield	1595	2932	3914	4672	5194	5543	5774
Yield increase over the previous rate		84%	33%	19%	11%	7%	4%

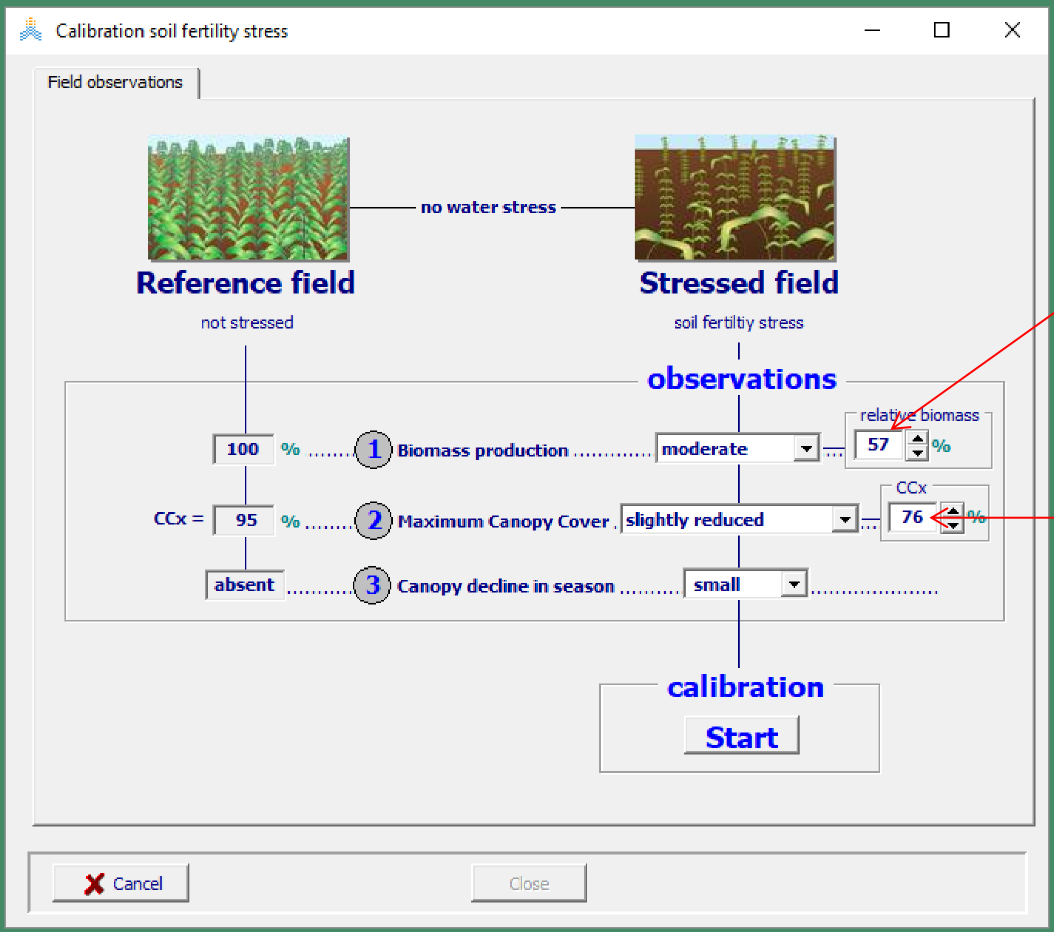
Calibration for rice response to fertility stress:

Rice yield under water stress only = 6.175 ton/ha
Rice yield under water and fertility stresses = 3.5 ton/ha
Relative biomass under fertility stress = 3.5/6.175 = 57%

Calibration for rice response to fertility stress:



Calibration for rice response to fertility stress:



57% of Relative biomass

How can we get this?

Calibration for rice response to fertility stress:

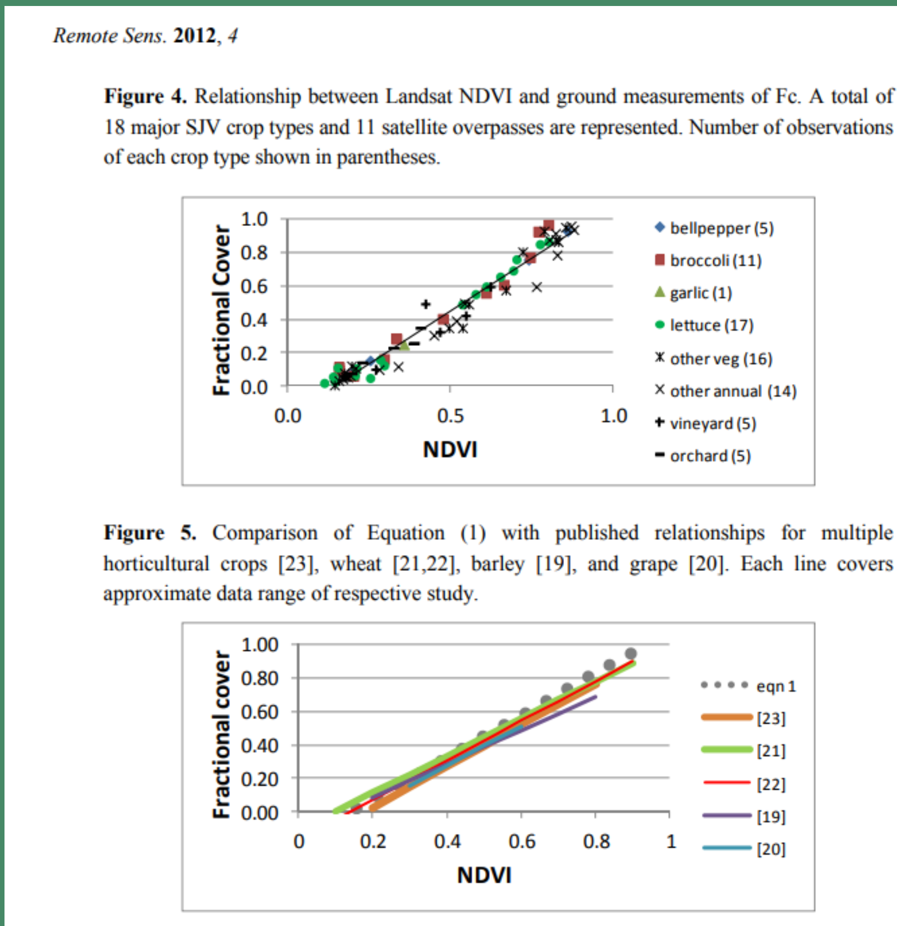
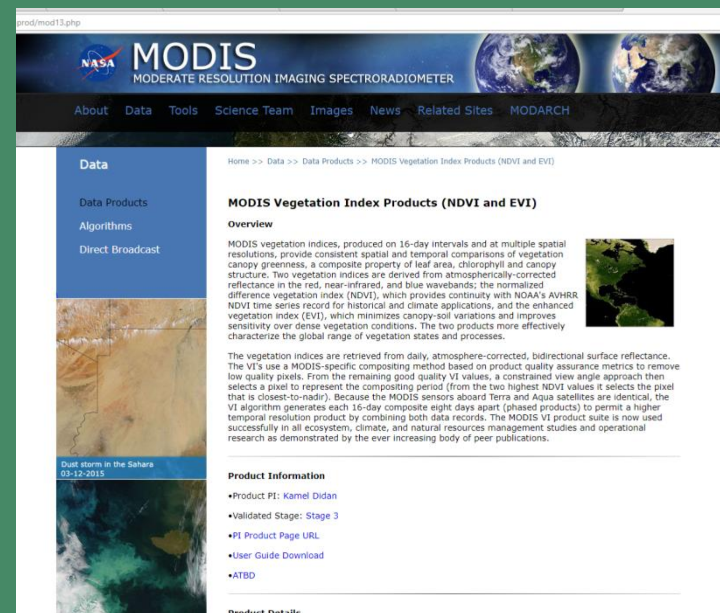

Remote Sens. **2012**, *4*

Figure 4. Relationship between Landsat NDVI and ground measurements of Fc. A total of 18 major SJV crop types and 11 satellite overpasses are represented. Number of observations of each crop type shown in parentheses.

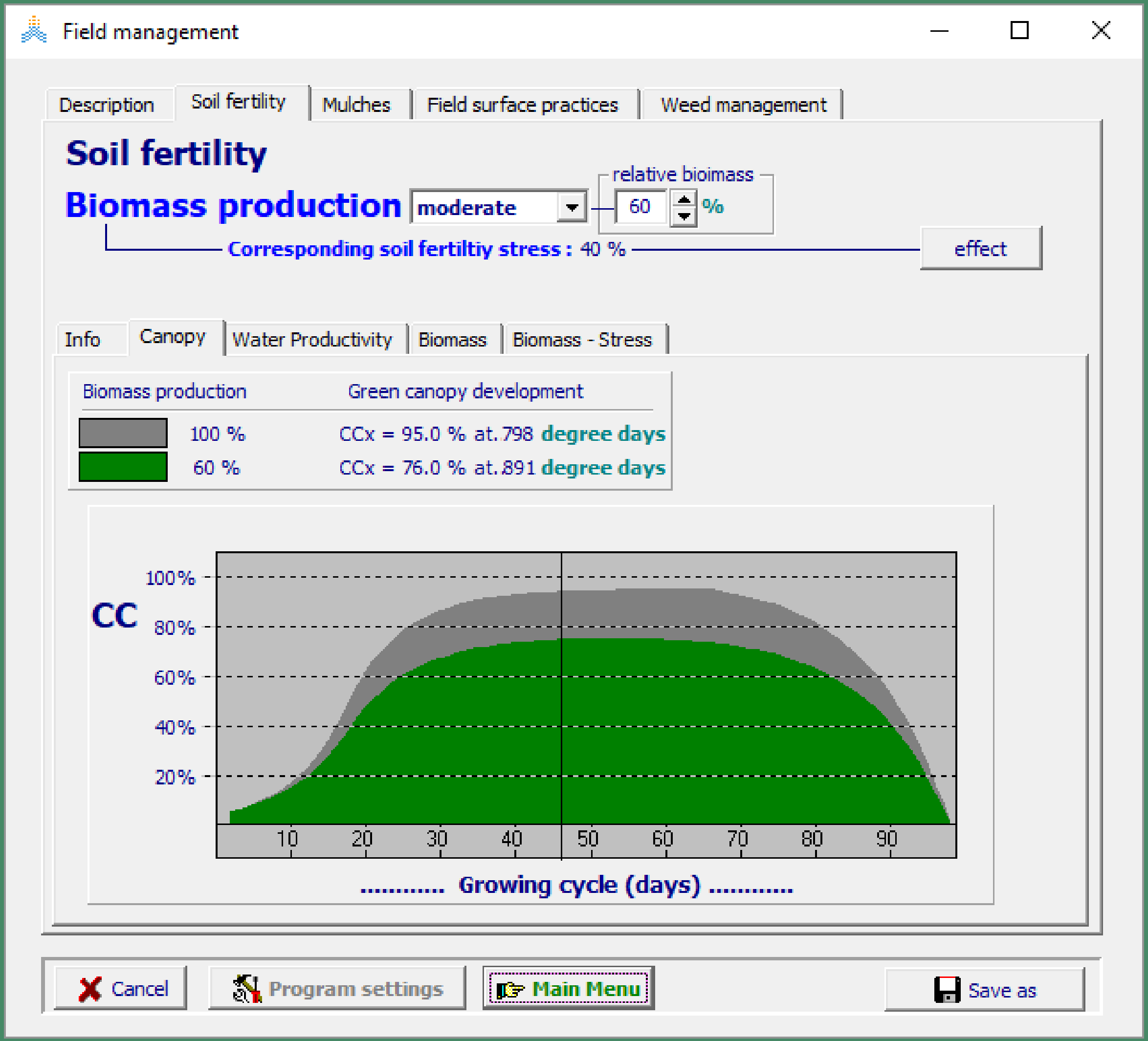
Figure 5. Comparison of Equation (1) with published relationships for multiple horticultural crops [23], wheat [21,22], barley [19], and grape [20]. Each line covers approximate data range of respective study.

< Johnson and Trout, 2012 >

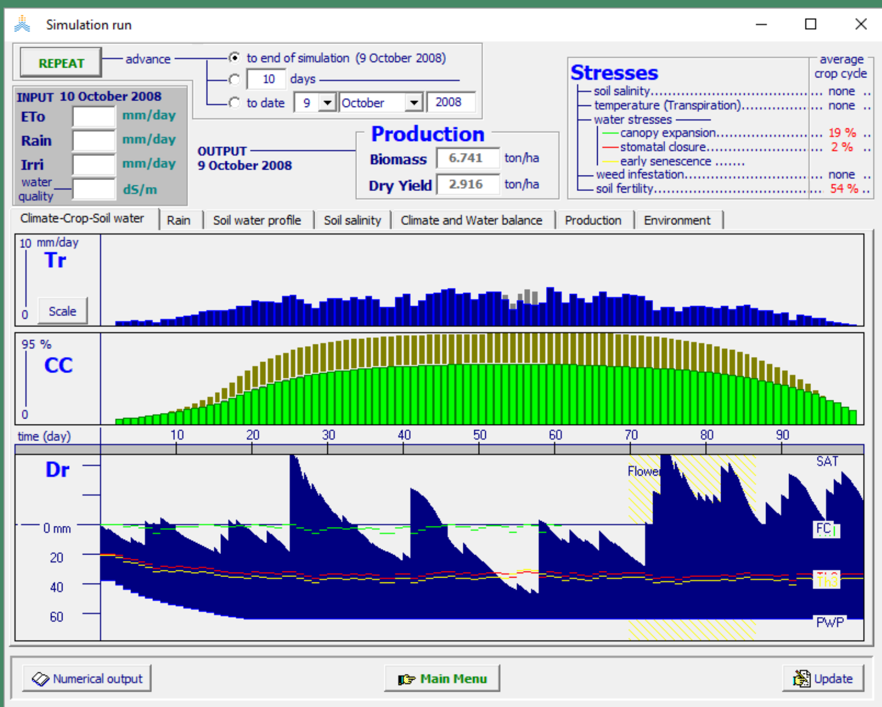


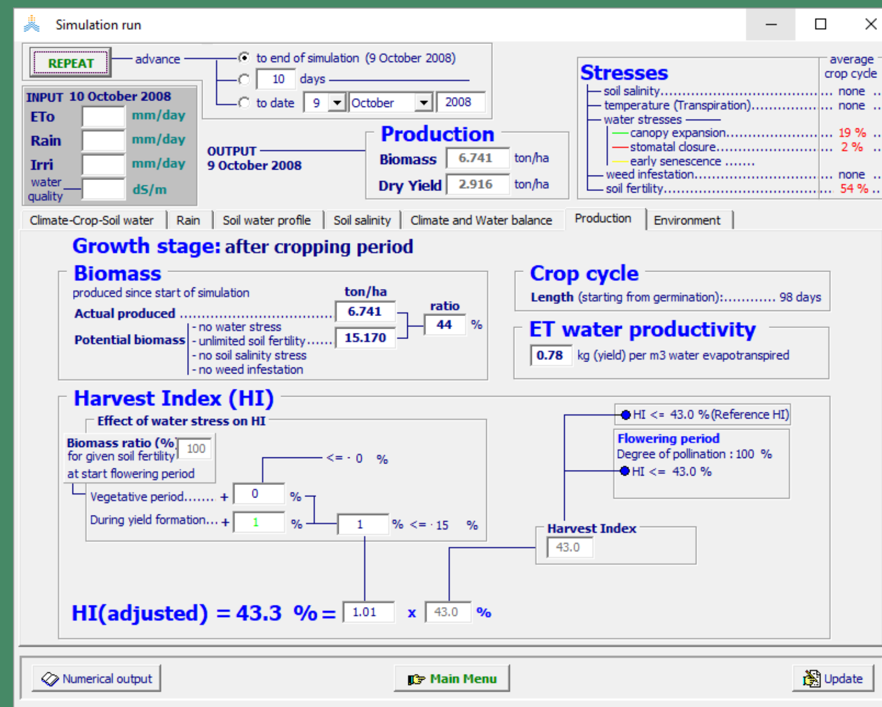
Maximum MODIS NDVI in 2007 → CCx = 76%

Simulation for water & fertility stresses:

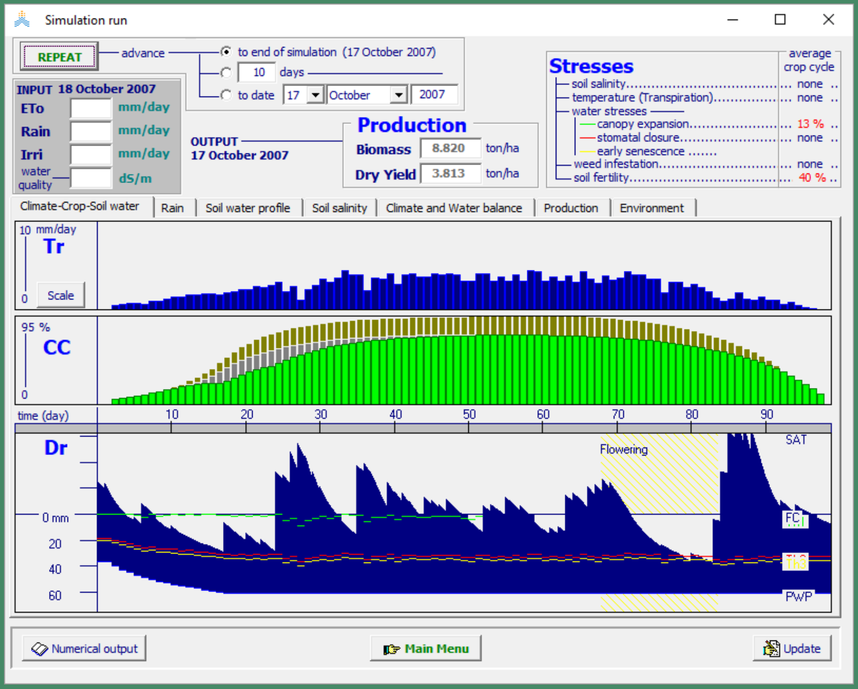


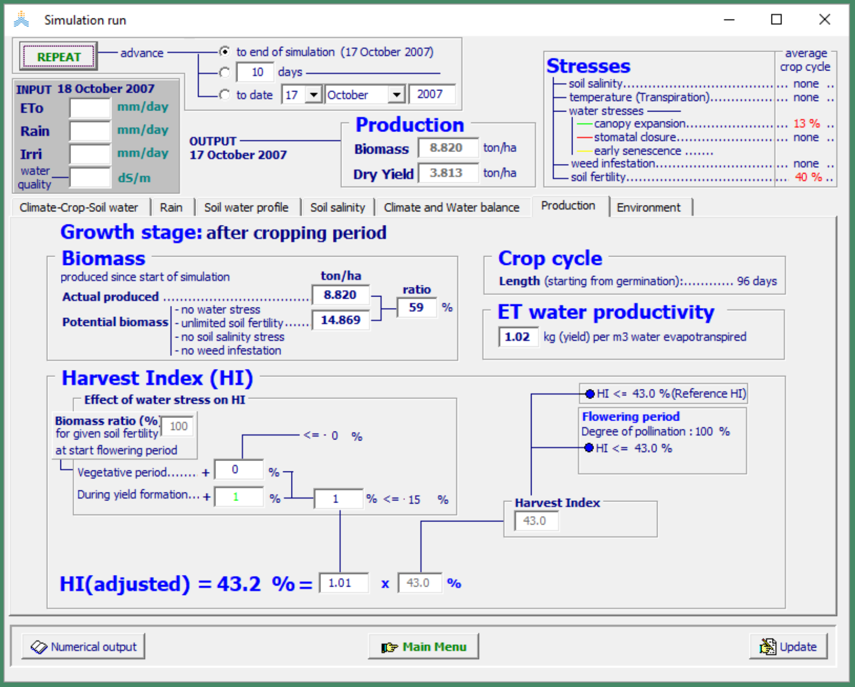
Simulation for water & fertility stresses:





It looks like circling.
But, if you apply the same parameters to other sites…

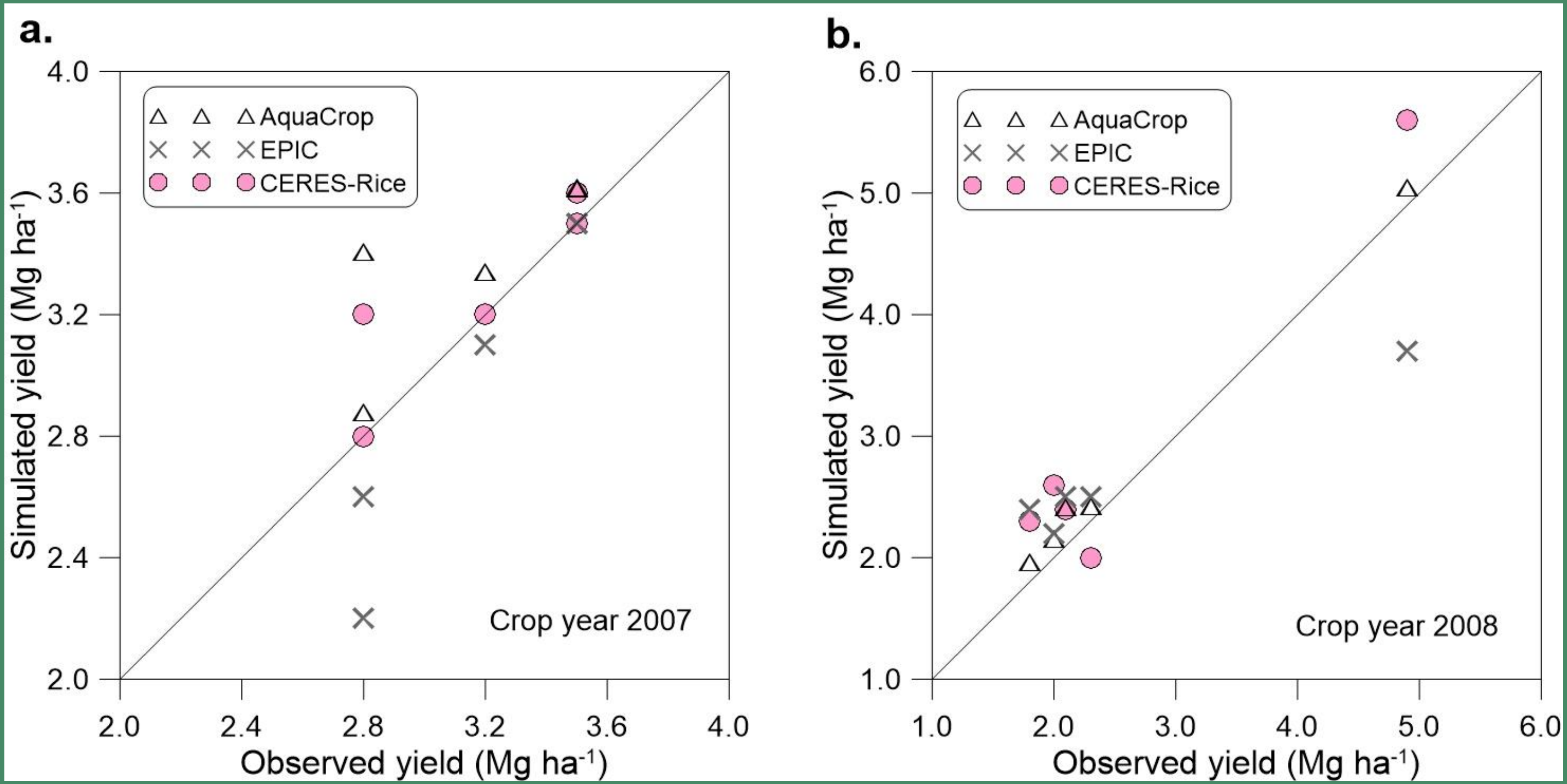




For RD10 in 2008 under 44% relative biomass fertility management

Observed yield = 2.8 ton/ha

It looks like circling.
But, if you apply the same parameters to other sites…



Questions? d.kim@apcc21.org