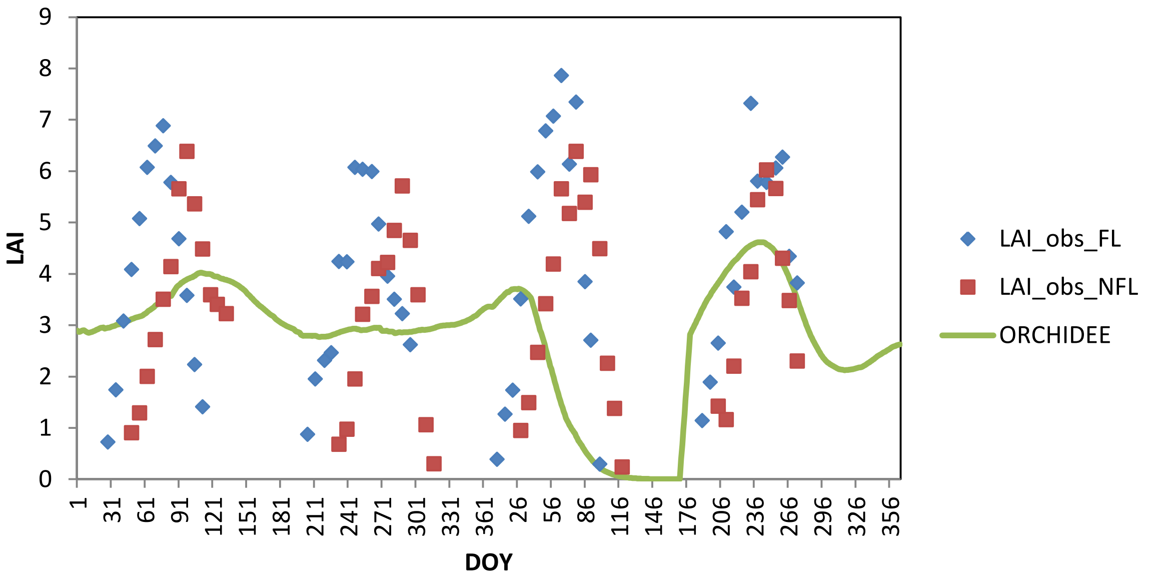
ORCHIDEE-crop

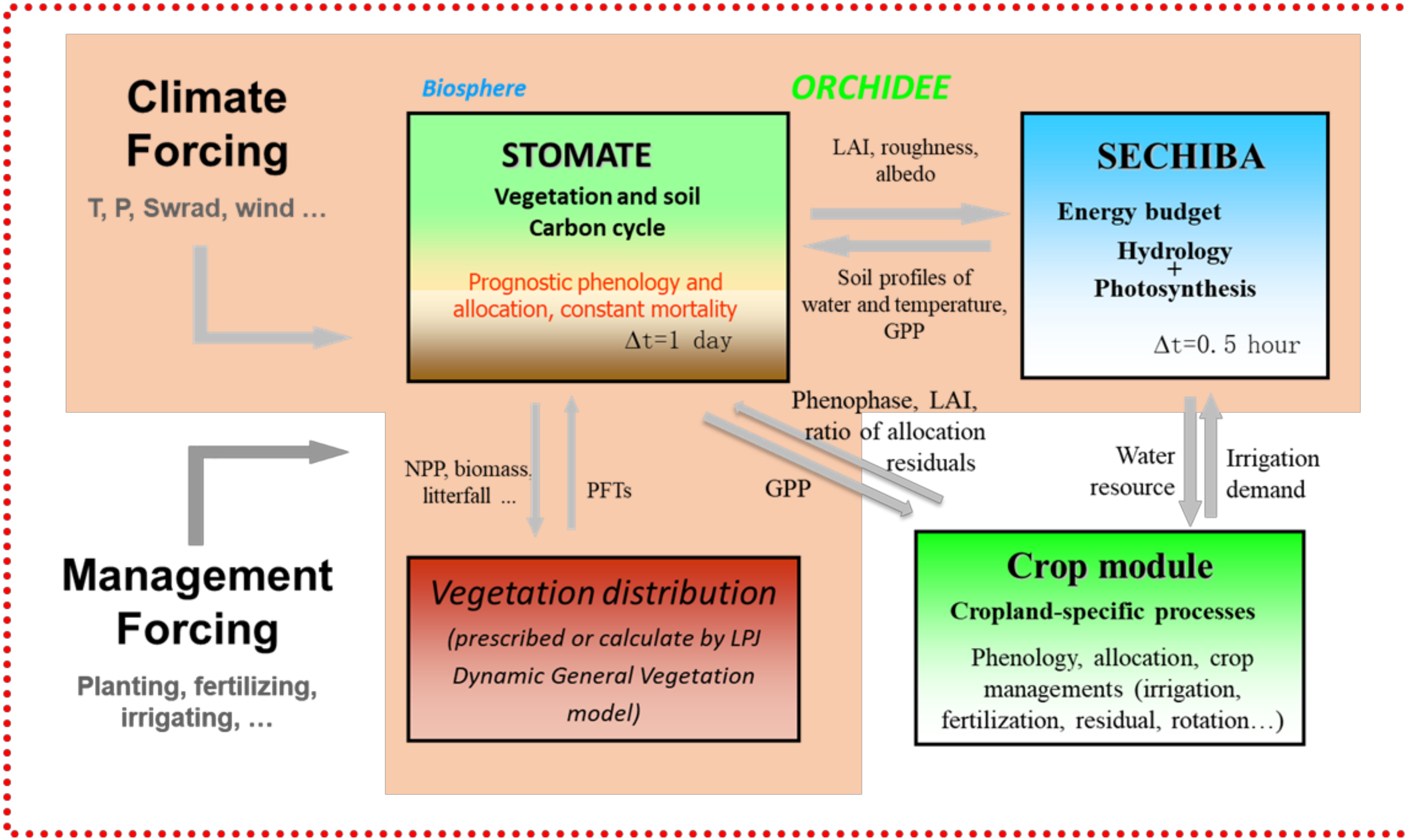
INRA SCIENCE & IMPACT
BIONUT

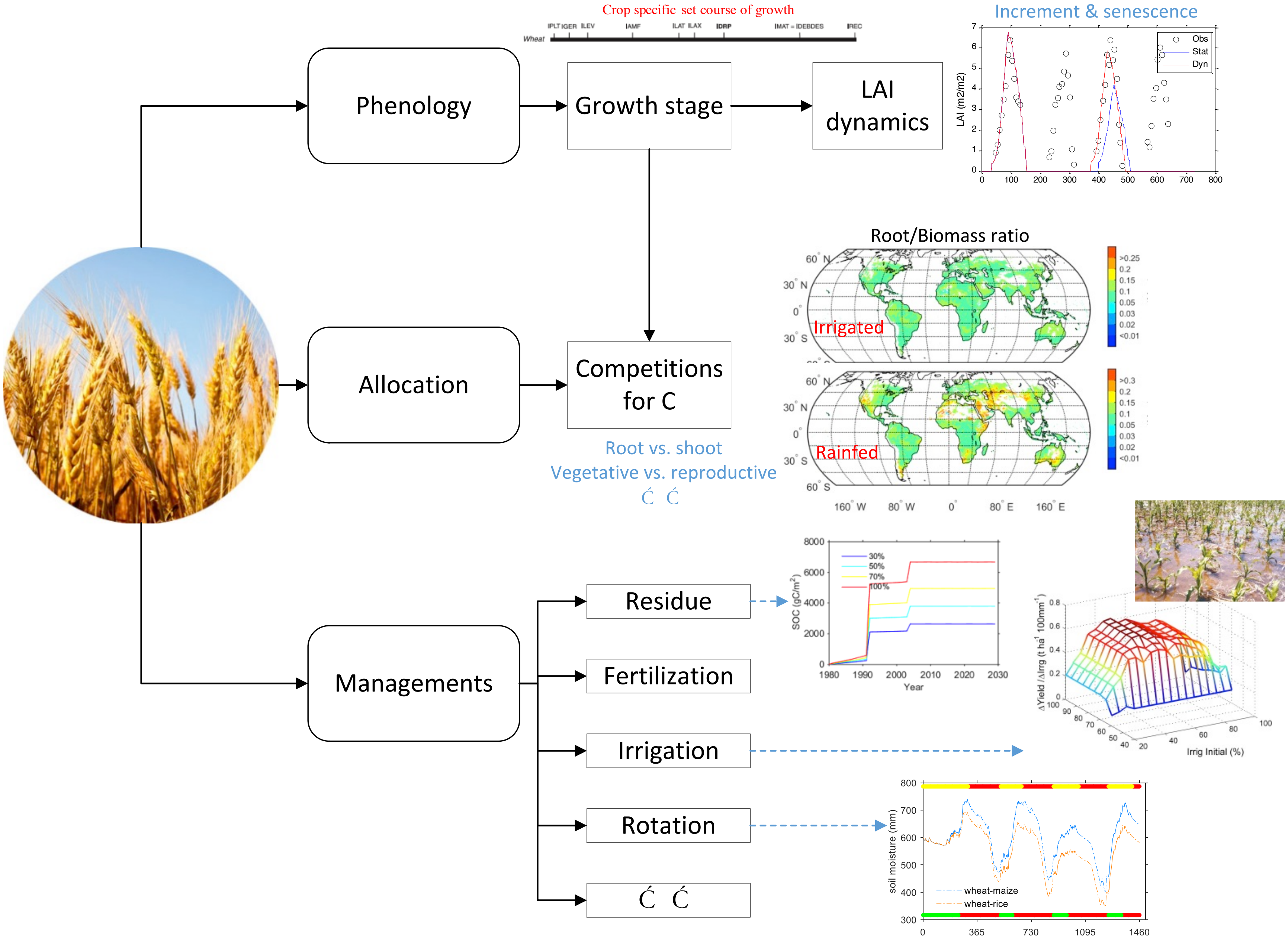
Limitations in simulating croplands by ORCHIDEE

IRRI site (14.2°N, 121.3°E)
Rice field trial



Schematic plot for ORCHIDEE-crop





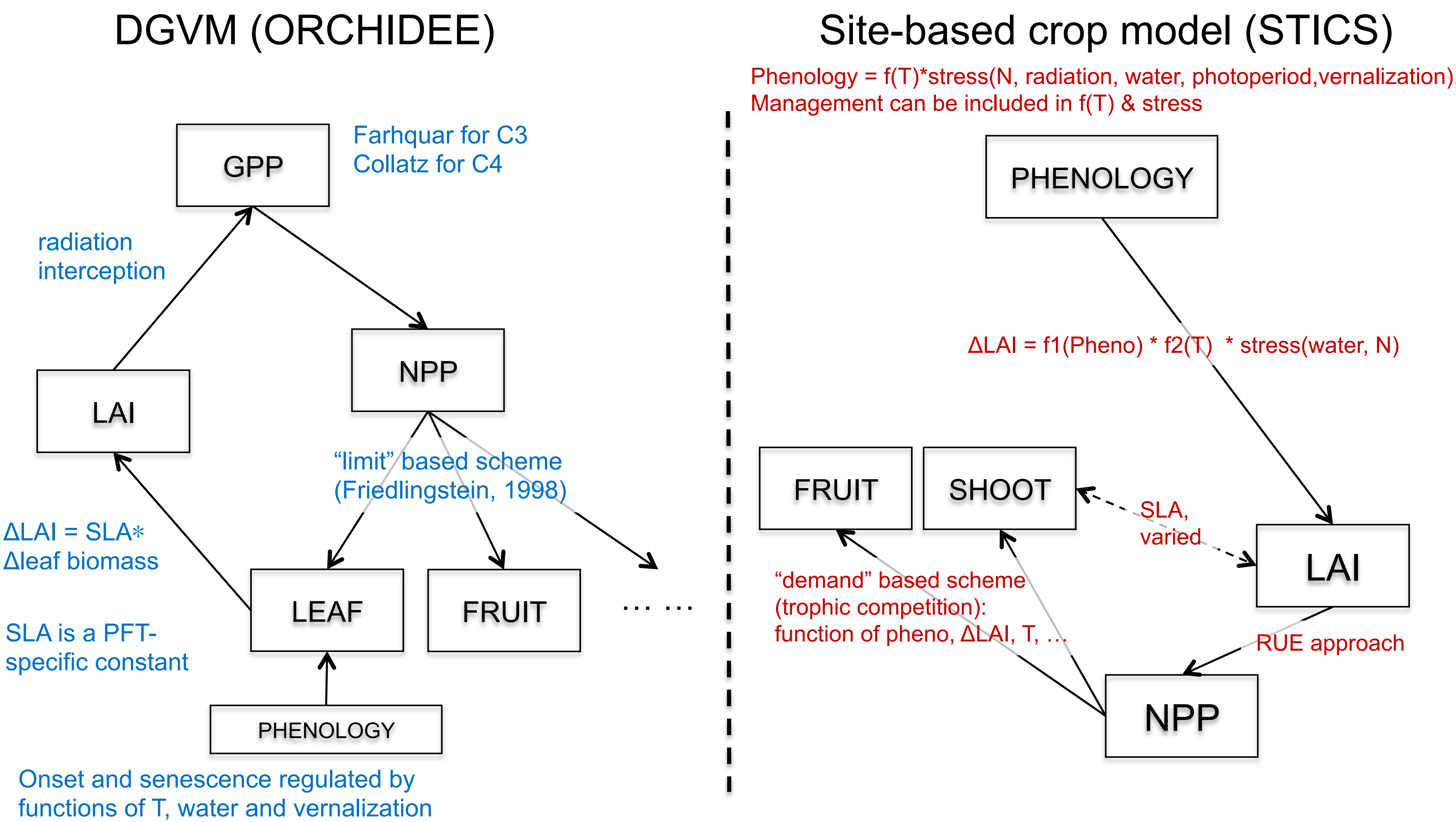
Phenology
Growth stage
LAI dynamics
Crop specific set course of growth
Wheat
Increment & senescence
LAI (m2/m2)
Obs
Stat
Dyn
Allocation
Competitions for C
Root vs. shoot
Vegetative vs. reproductive
Ć Ć
Root/Biomass ratio
Irrigated
Rainfed
160° W
80° W
0°
80° E
160° E
Managements
Residue
Fertilization
Irrigation
Rotation
Ć Ć
SOC (gC/m²)
30%
50%
70%
100%
Year
Irrig Initial (%)
soil moisture (mm)
wheat-maize
wheat-rice

Lists of sub-modules

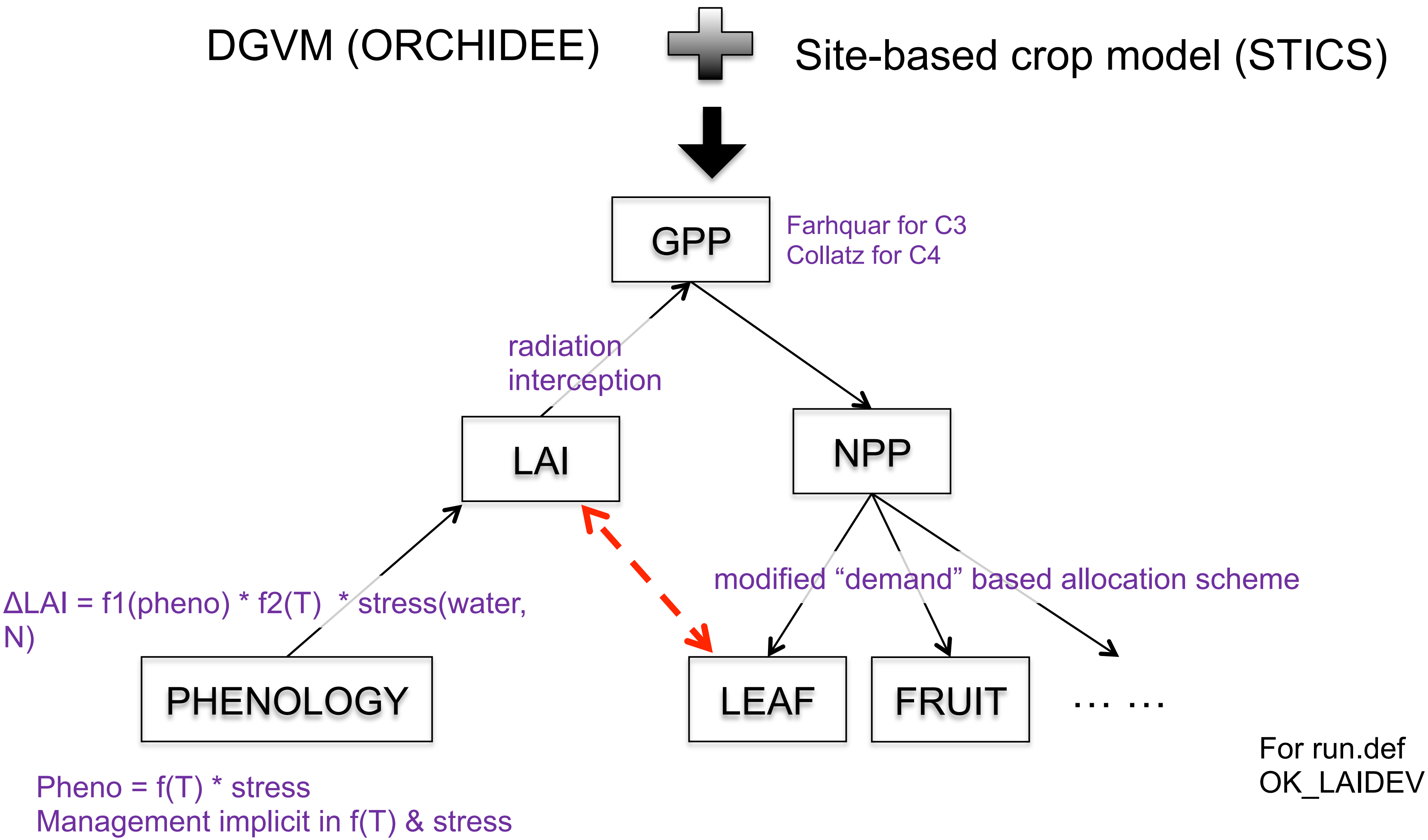
- **Growth dynamic modules**
  - **Phenology**
  - **Allocation**

- Management modules
  - Irrigation
  - Fertilization
  - Rotation
  - Residue management

growth cycle simulation



ORCHIDEE CROP growth cycle simulation



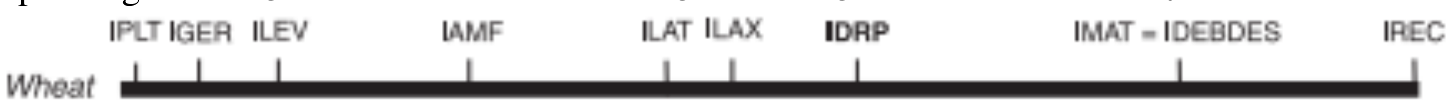
This approach also lead to problems that we have two engines that drives the growth cycle, which have to be harmonized

Phenology progressing

$$\text{Growth } Unit = f(T) \times \delta_p \times \delta_v \times (\varepsilon \times \min(\delta_n, \delta_w) + 1 - \varepsilon) \quad (Eq.1)$$

The phase of the growth is a joint function of temperature, precipitation, vernalization demand, nitrogen & water stress

planting leafing grain-filling maturity harvest



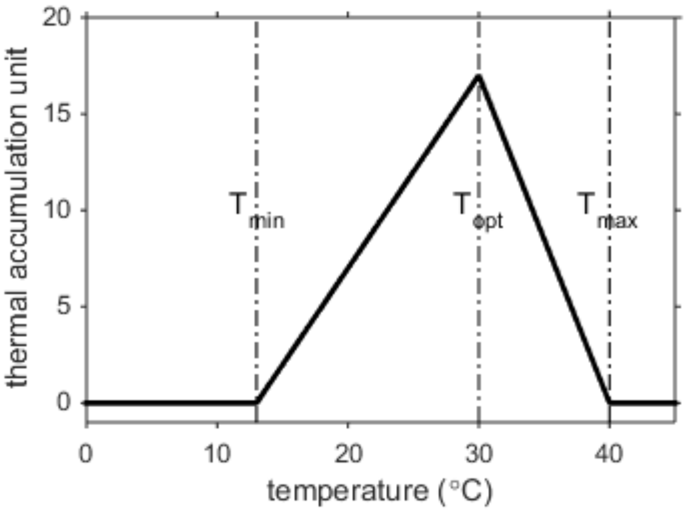
germination

LAI as a function of phenology

For ORCHIDEE-crop, LAI is no longer diagnostic of leaf biomass increment * SLA, but a prognostic variable

$$\Delta LAI_{inc} = f(dev) \times f(T) \times f(stress)$$

$$\Delta LAI_{sen} = f(GDD) \times f(stress)$$



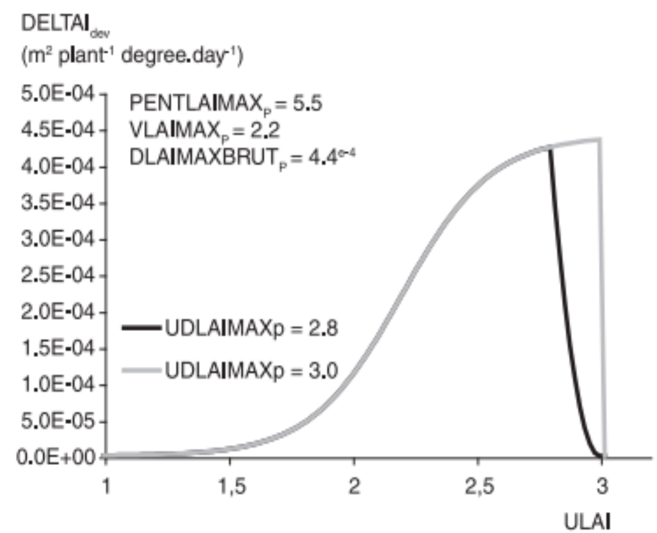
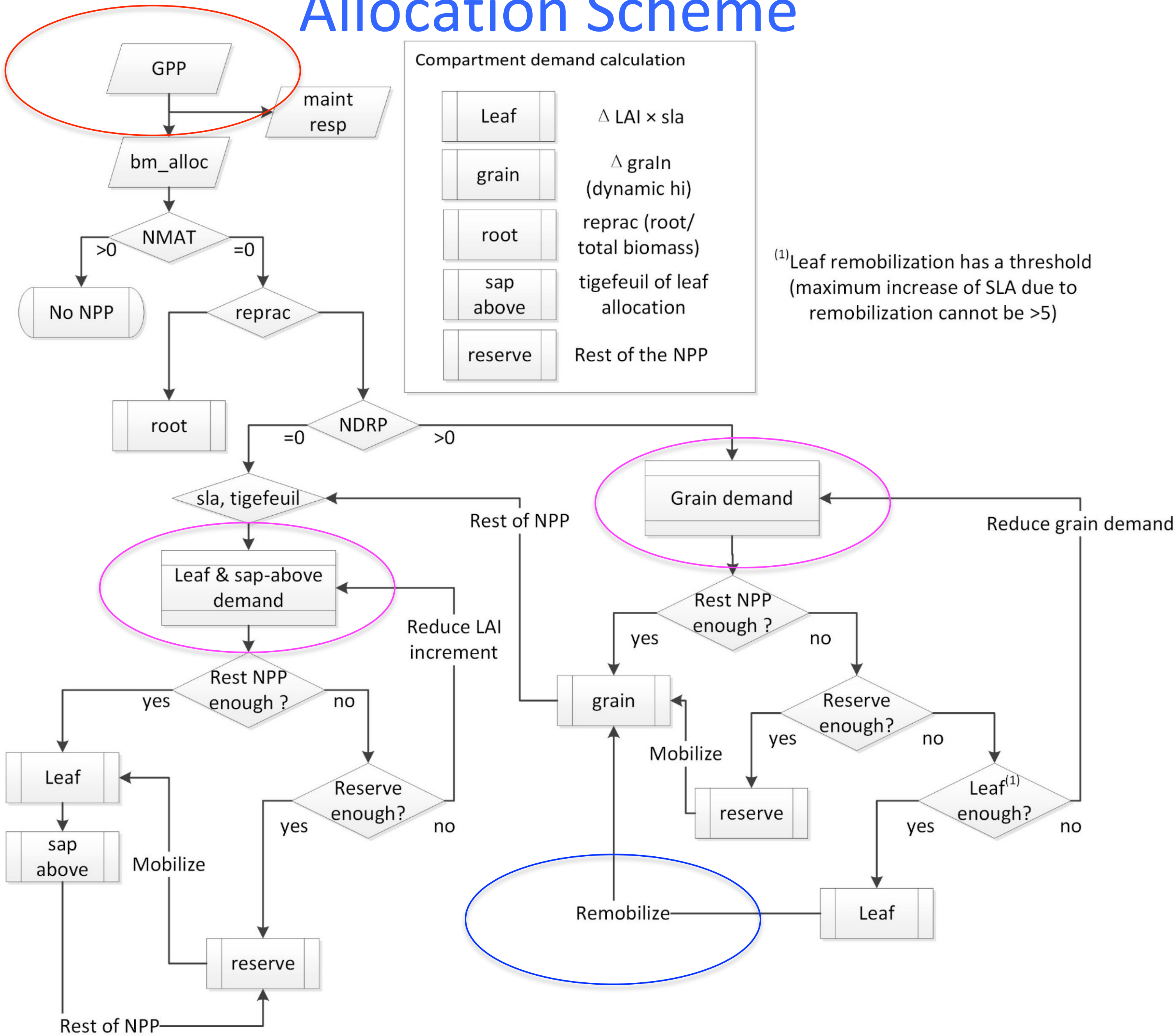
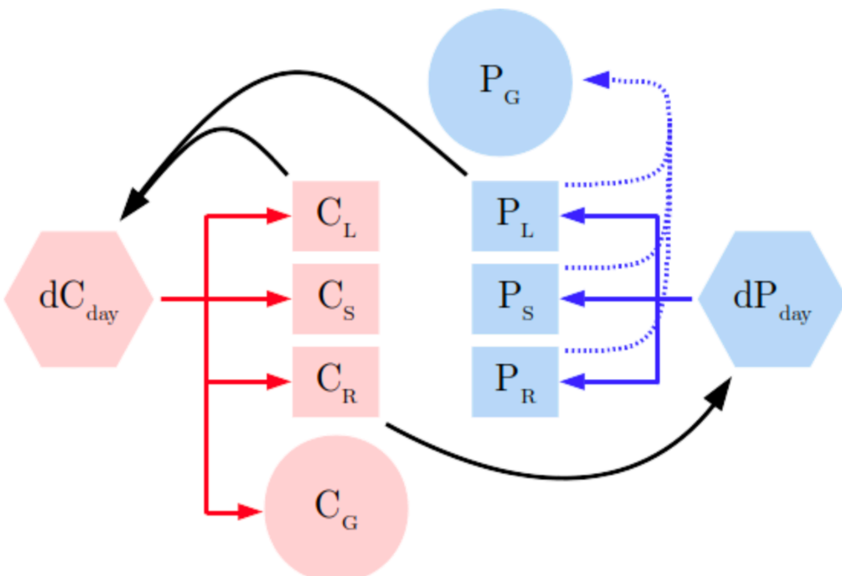


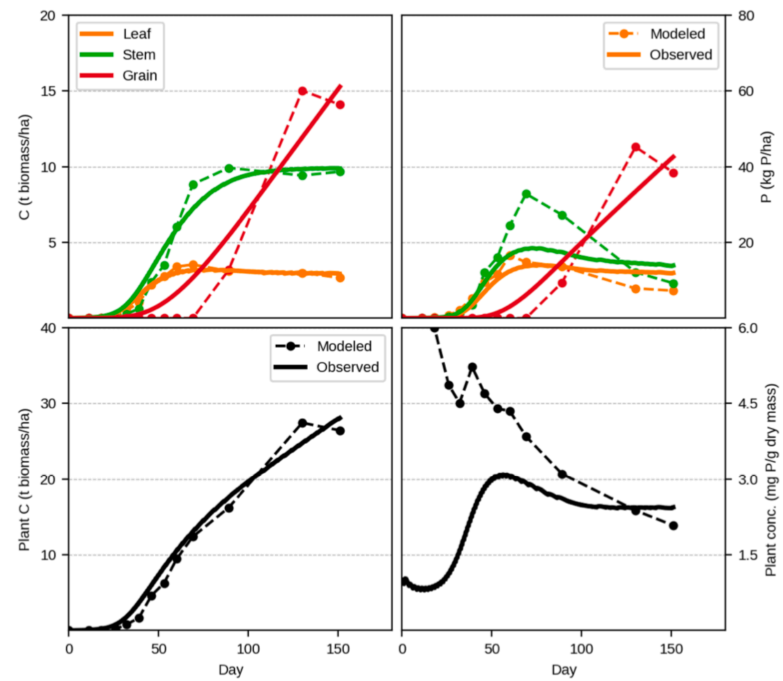
Figure 3.2. Leaf growth rate as a function of phasic development with the parameterization corresponding to wheat crop as given in Singels and Jagger (1991) with two hypotheses for leaf growth slowing at ILAX through the parameter $UDLAIMAX_p$ and consequences for the LAI curve shape.

Allocation Scheme



Optimal allocation

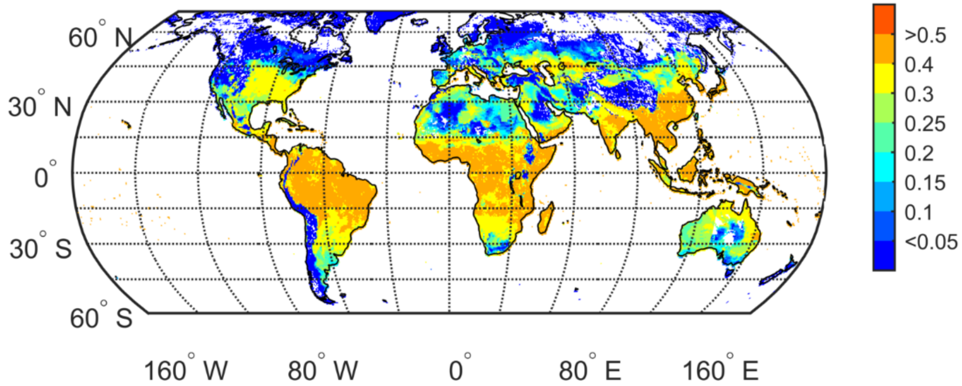




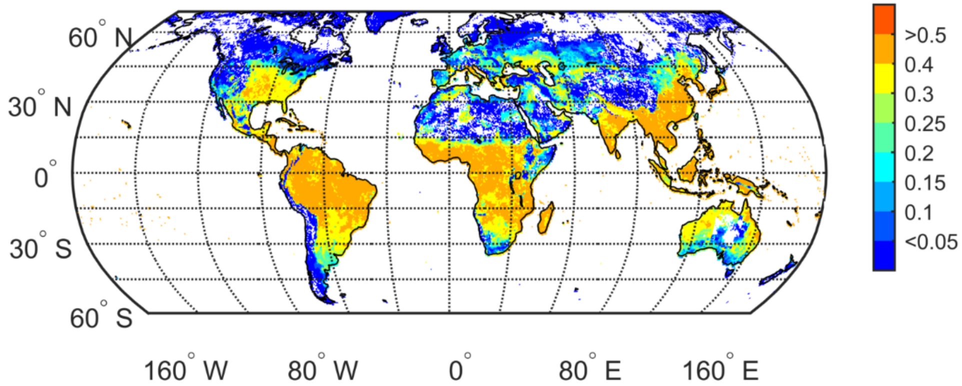
Conceptual model developped with INRA
No LAI phenology constraints (only grain filling requirement)
Linear programming to optimize daily plant growth rate given organ stoichiometry
Tested in ORCHIDEE to optimize Vcmax & allocation

Harvest Index

Irrigated

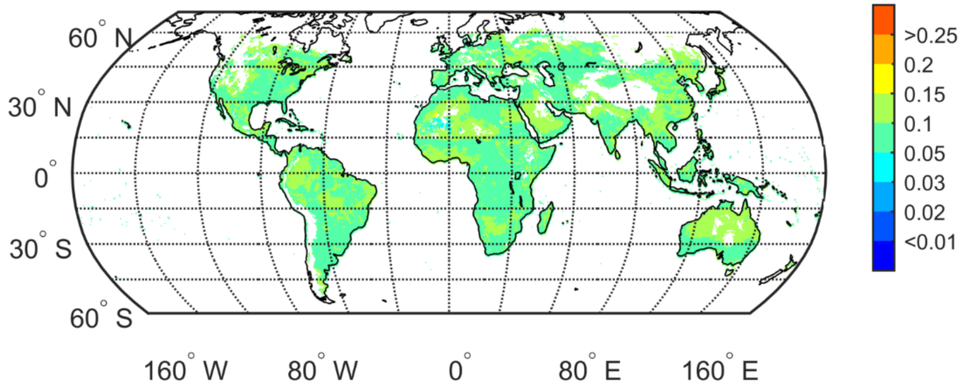


Rainfed

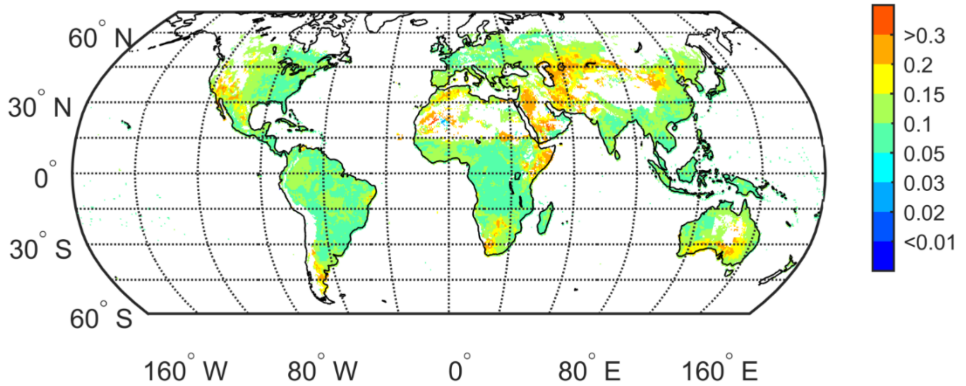


Root/shoot ratio

Irrigated

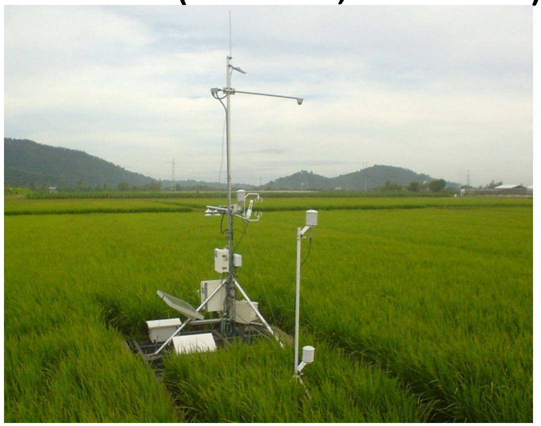


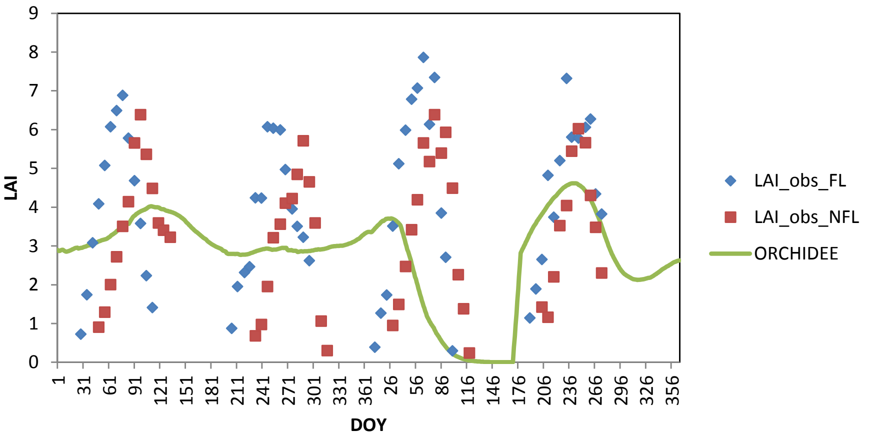
Rainfed

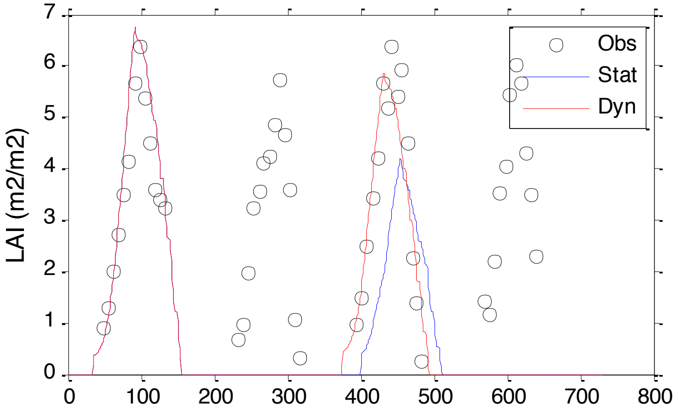


One step ahead

IRRI site (14.2°N, 121.3°E)

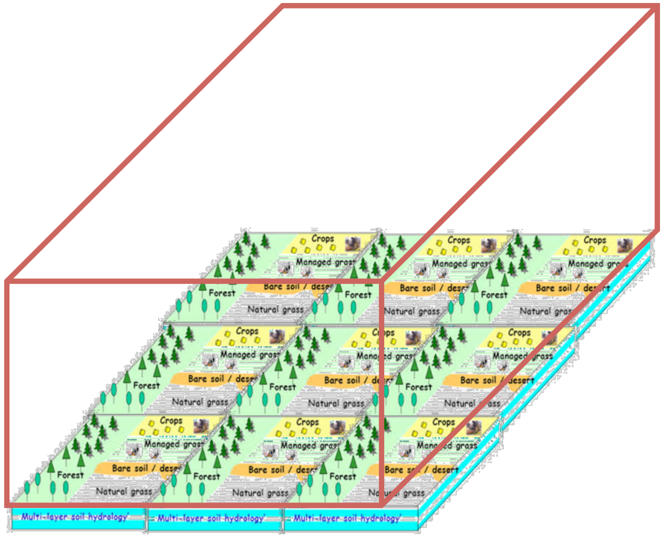




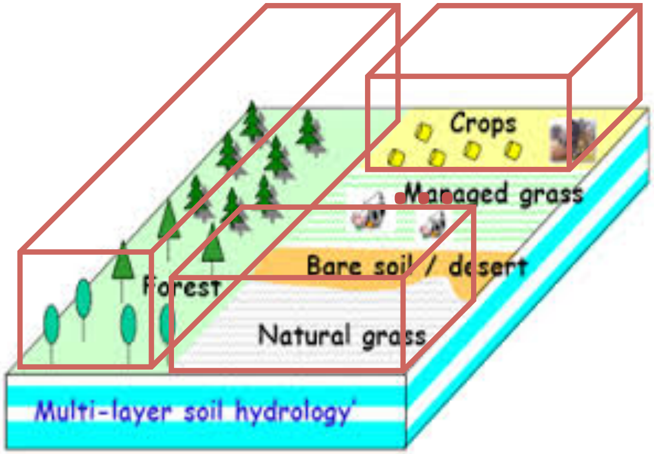


Why PFT-specific water & energy budget needed?

CASE A (default)

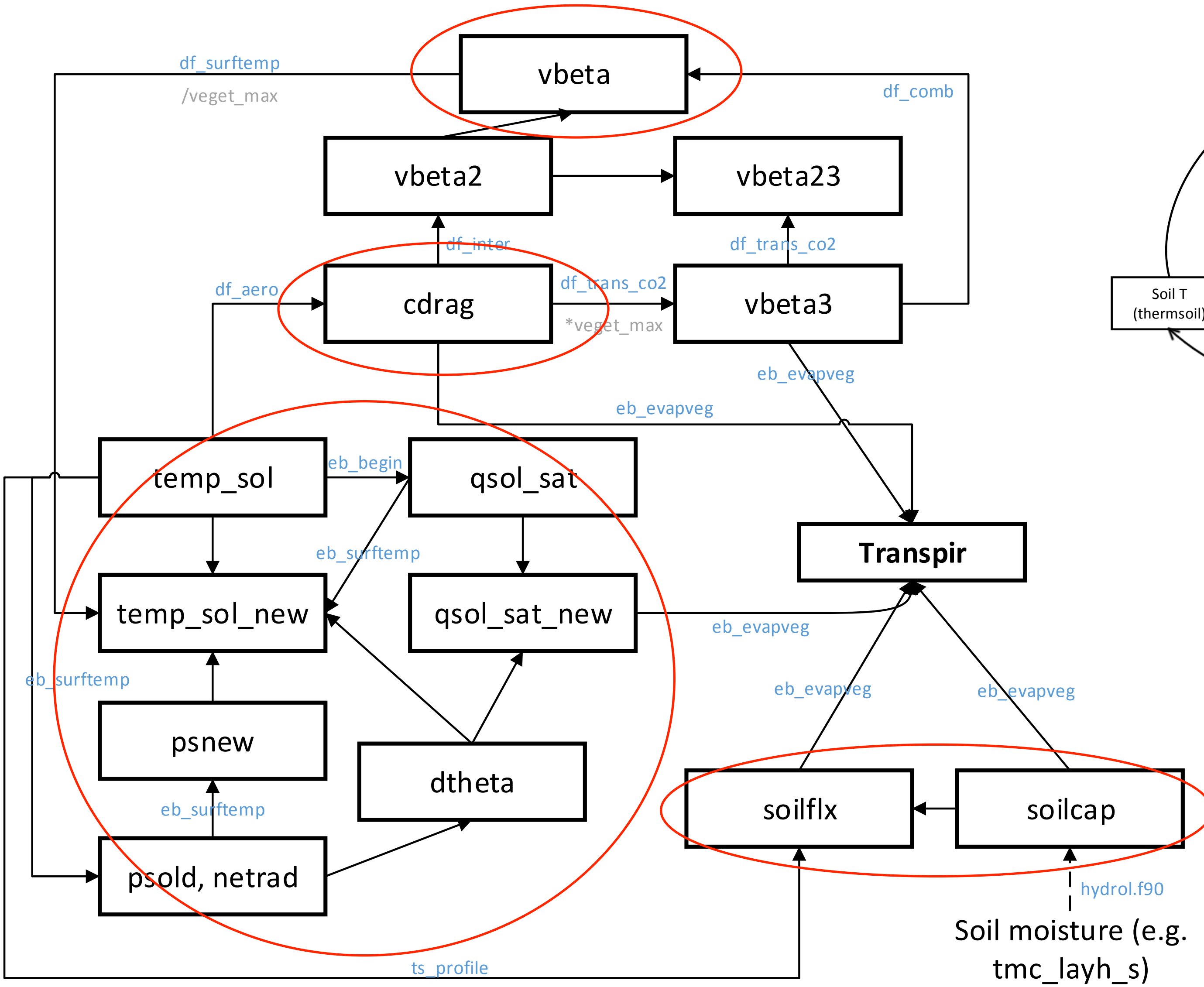


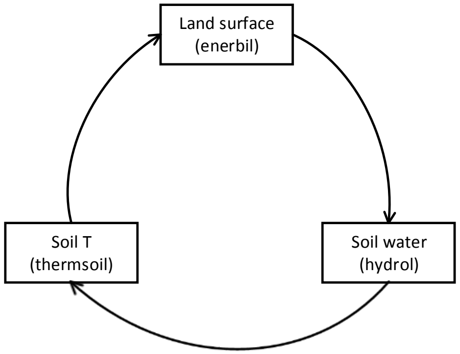
CASE B



Croplands usually applies to Case B, which is not previously supported

The variables made PFT-specific





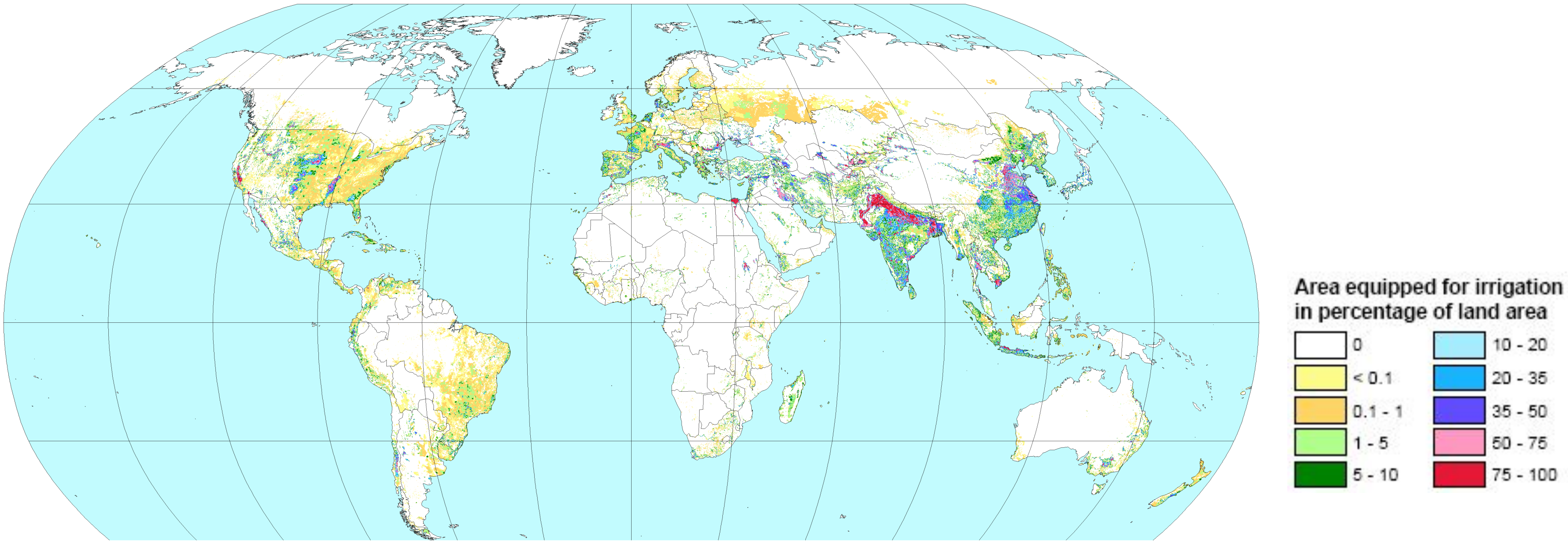
Abbreviations: eb_ = enerbil_ , df_ = diffuco_ , ts_ = thermosoil_

Lists of sub-modules

- Growth dynamics modules
  - Phenology
  - Allocation

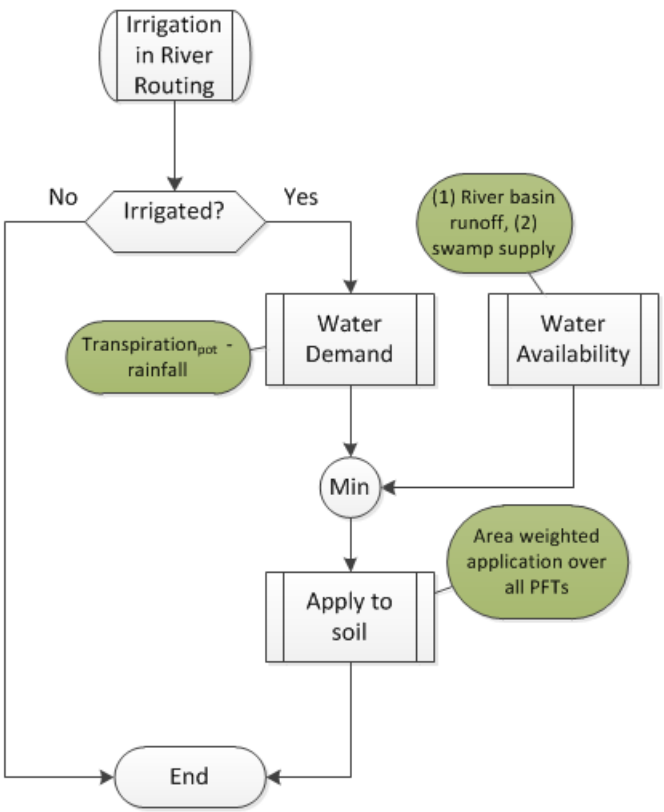
- **Management modules**
  - **Irrigation**
  - **Fertilization**
  - **Rotation**
  - **Residue management**

Global irrigation extent



Courtesy from GMIA v5

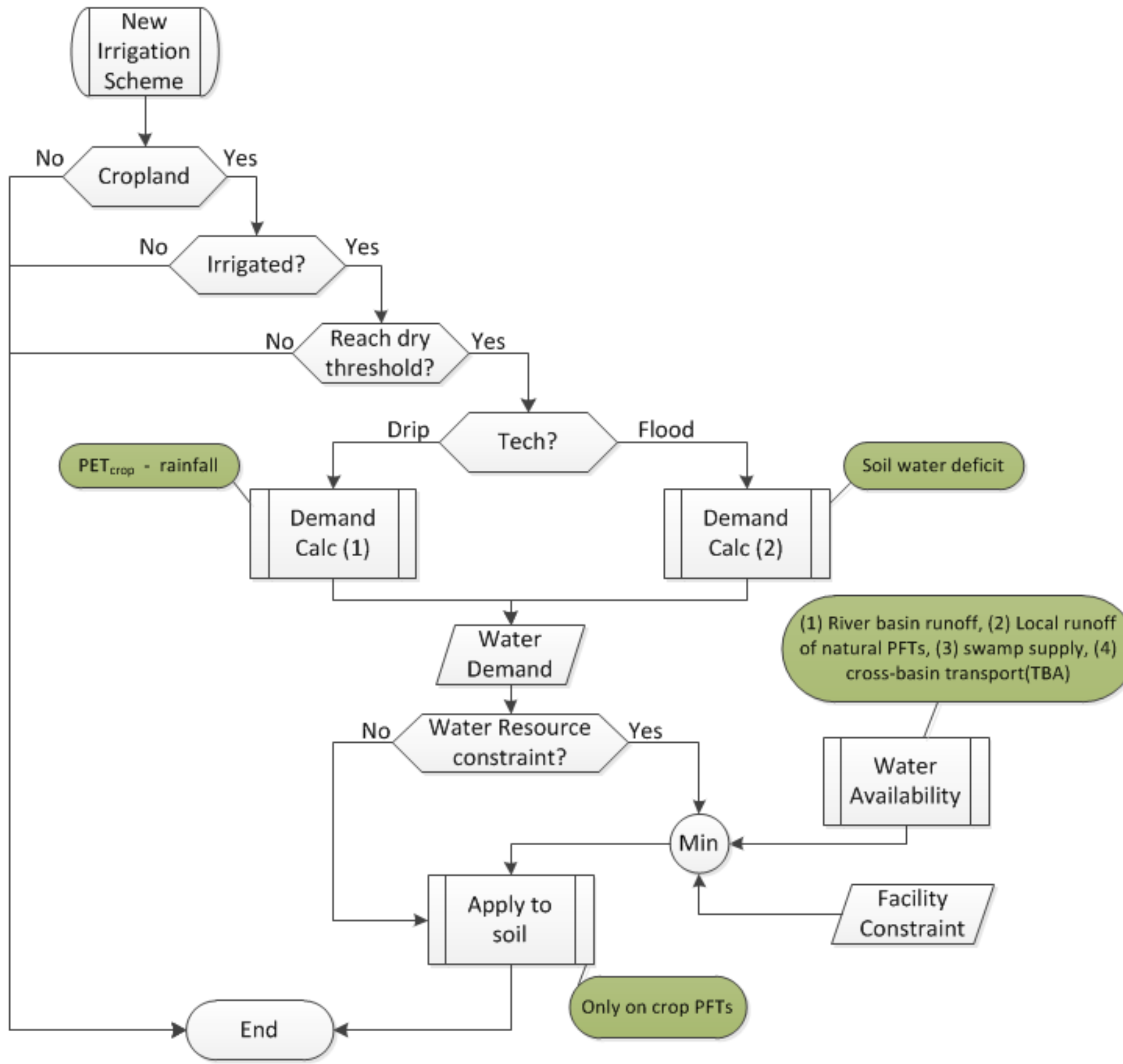
ORCHIDEEstandard irrigation scheme



- Only activated with river routing
- Water demand & applications over all PFTs
- Considering only potential transpiration, not PET (always deficit even irrigated)
- no room for varying irrigation technologies/strategies

ORCHIDEEcrop irrigation scheme

- Addressing:
  - Where?
  - When?
  - How much?
  - How?



Irrigation methods & Tech constraints (how)

Some key parameter: IRRIG_DRIP, IRRIG_DOSMAX

Flooding

- Demand = Soil water deficit (irrig_fulfill * SWHC - SWC)

SWHC: soil water holding capacity
SWC: soil water content

Drip

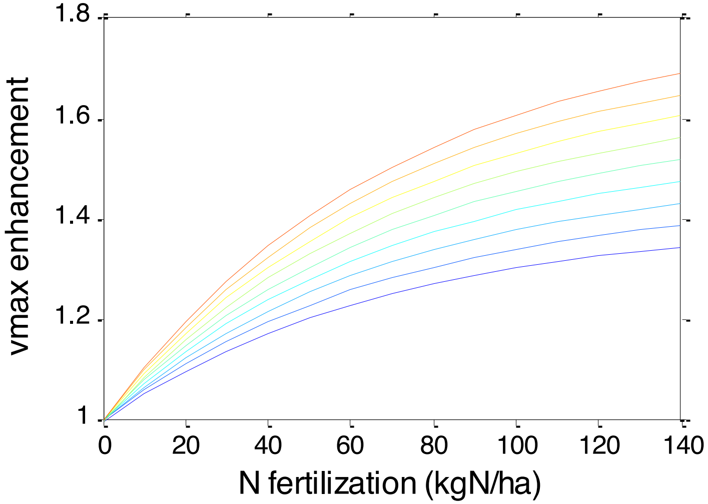
- Demand = PET_{crop} - rainfall

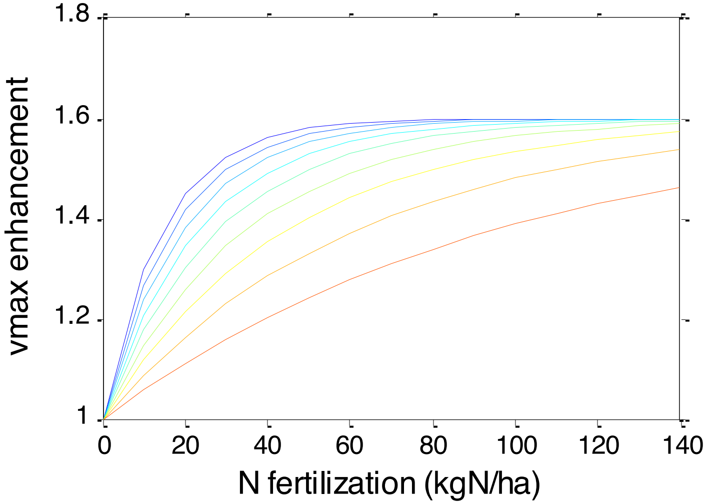
N response function

- Nfac = 1 + Neff - Neff*(pa^(Nfert./pb));

- Three parameters to optimize:
  - Neff (maximum enhancement of N fertilizer)
  - pa (how fast the N response saturated)
  - Vcmax25 (intrinsic Vcmax at 25 ^{o}C)

fertilization





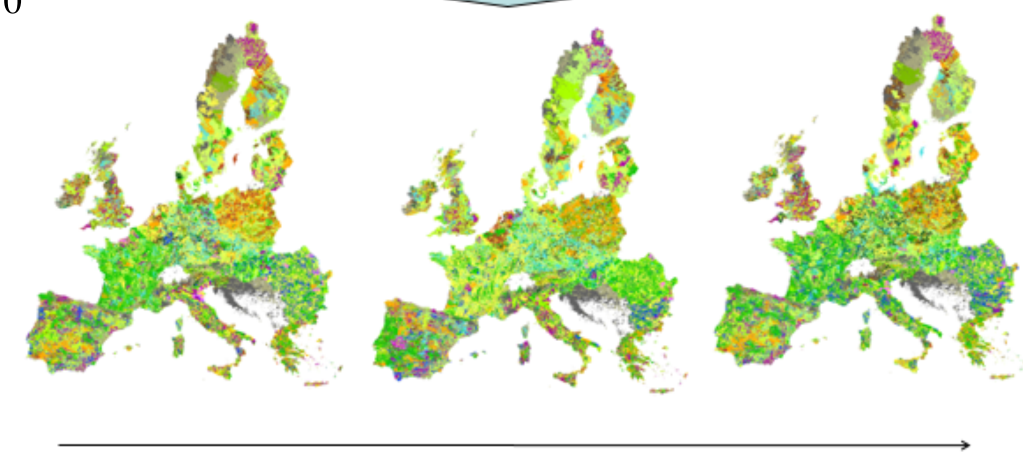

```
NITROGEN_USE = y
FIX_NFERT = y
SP_AVENFERT = 0.0, 0.0, 0.0, 10.0, 10.0, 10.0
NEFFMAX=0, 0, 0, 0.65, 0.65, 2.51
NSATRAT=0, 0, 0.91, 0.91, 0.68
VCMAX25=40, 70, 70, 70, 70, 46.2

##NFERT_FILE = /home/satellites8/speng/Xuhui/data/Fert_IFA_FAO.nc
##NFERT_FILE = /home/satellites8/speng/Xuhui/data/Fert_ISIMIP_harm.nc
```

Crop rotation/multi-cropping

time

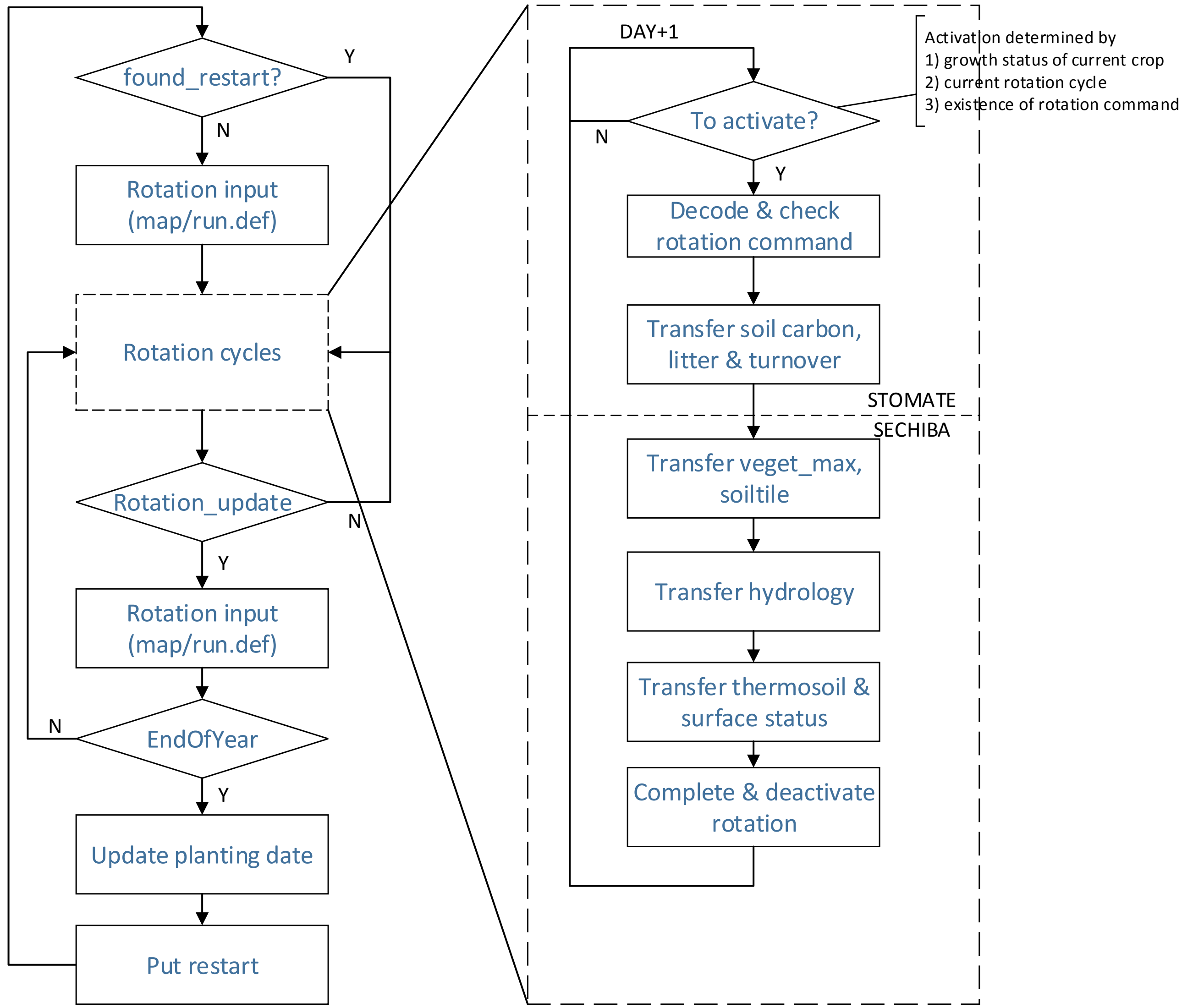
Germany	Greece	Italy	Espania	United King.	Poland
POTA	PULS	DWHE	RAPE	RAPE	WBAR
WRYE	WBAR	WSWH	WBAR	OATS	RAPE
MAIZ	MAIZ	MAIZ	MAIZ	SETA	WRYE
WRYE	WBAR	WSWH	SUNF	SBAR	OCER
MAIZ	MAIZ	MAIZ	WBAR	SETA	SBAR
SBAR	WBAR	WSWH	MAIZ	SBAR	WRYE
RAPE	MAIZ	MAIZ	SUNF	RAPE	MAIZ
WRYE	WBAR	PARI	WBAR	SBAR	SSWH
MAIF	MAIZ	SETA	RAPE	SETA	MAIZ
WRYE	WBAR	MAIZ	WBAR	SBAR	SSWH
MAIF	MAIZ	WSWH	MAIZ	SETA	MAIZ
POTA	WBAR	MAIZ	SUNF	SBAR	SSWH
SBAR	MAIZ	WSWH	WBAR	RAPE	MAIZ
RAPE	POTA	MAIZ	RAPE	WBAR	SSWH
WRYE	MAIZ	WSWH	WBAR	SETA	MAIZ
MAIF	WBAR	MAIZ	MAIZ	SBAR	SSWH
WRYE	MAIZ	WSWH	SUNF	SETA	MAIZ
MAIF	WBAR	MAIZ	WBAR	SBAR	SSWH
WSWH	MAIZ	WSWH	MAIZ	RAPE	MAIZ
RAPE	POTA	MAIZ	SBAR	WBAR	SSWH
WSWH	MAIZ	WSWH	RAPE	PULS	MAIZ
MAIF	WBAR	MAIZ	WBAR	WBAR	SSWH
WSWH	MAIZ	PARI	SUNF	PULS	POTA
MAIF	WBAR	SETA	SBAR	WBAR	WRYE
WSWH	MAIZ	MAIZ	SUNF	RAPE	OCER
WRYE	POTA	PARI	SBAR	WBAR	SSWH
MAIF	MAIZ	SETA	RAPE	PULS	SUGB
SBAR	WBAR	MAIZ	WBAR	WBAR	SSWH
RAPE	MAIZ	WSWH	SUNF	PULS	POTA
MAIF	WBAR	MAIZ	SBAR	WBAR	WRYE

Wattenbach et al., 2010

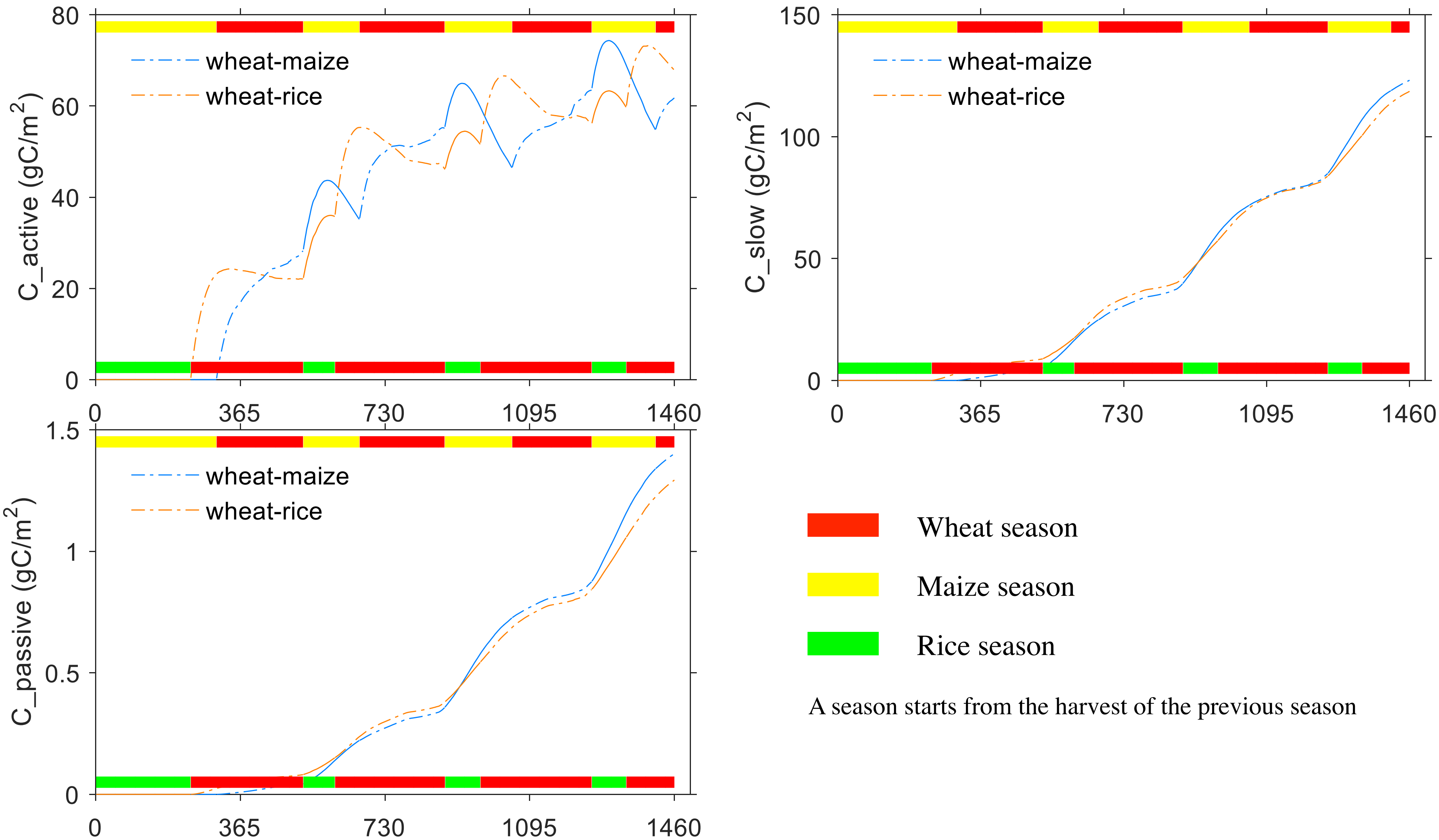


time

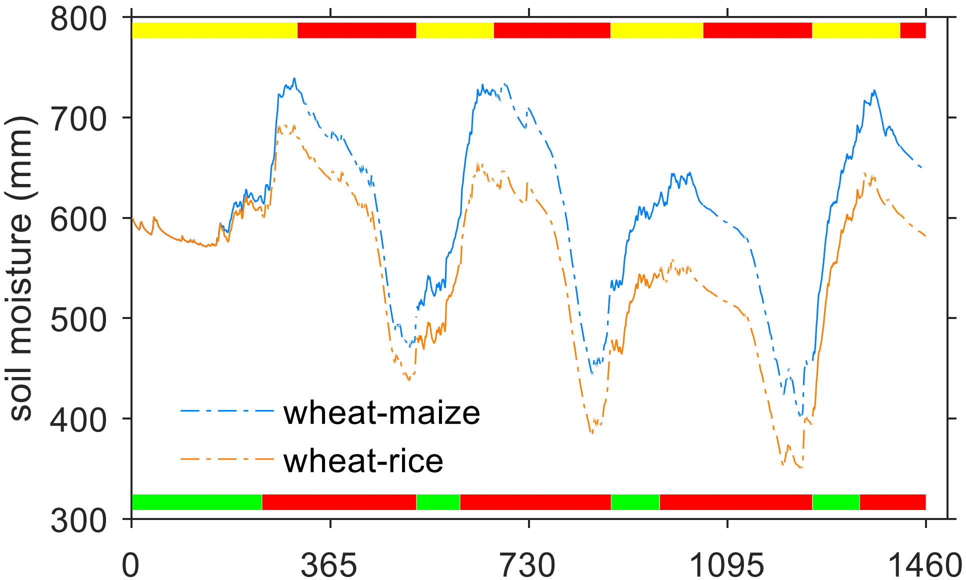
The flowchart for crop rotation/multi-cropping

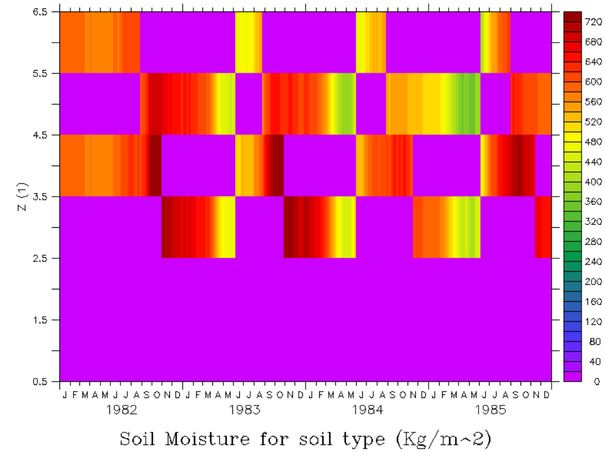


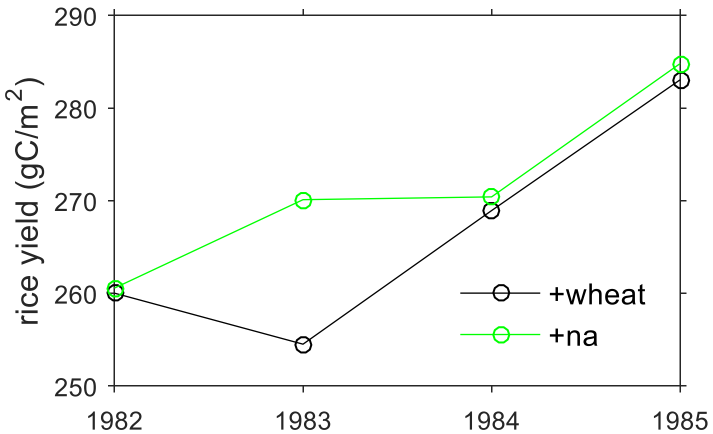
Transfer of litter & soil carbon pools



Transfer of soil moisture







Variables transferred in SECHIBA,

Transferred status variables: veget_max, soiltile

Transferred hydrology variables: moisture of all layers & water to infiltrate next time step

Transferred thermal variables: soil temperature of all layers & conductivity (cgrnd, dgrnd)

Other variables: surface soil temperature (temp_sol_new), heat capacity (soilcap) and heat flux (soilflx)

The data structure

Transfer matrix → Command list

Receptor / Source

Source \ Receptor	1	2	3	4	5	6	7	8
1								
2								
3								
4								
5						50		
6								
7								
8							80	

An integer (i_std, int32) with 7 meaningful digits:

% transfer			source		target	
1	0	0	0	9	1	0

e.g.
500506
800807

Note:
By using percentage transfer, the RMC module is in theory compatible with the LUC module of ORCHIDEE i.e. RMC & LUC can be activated simultaneously (to be tested)

Configuration for rotation

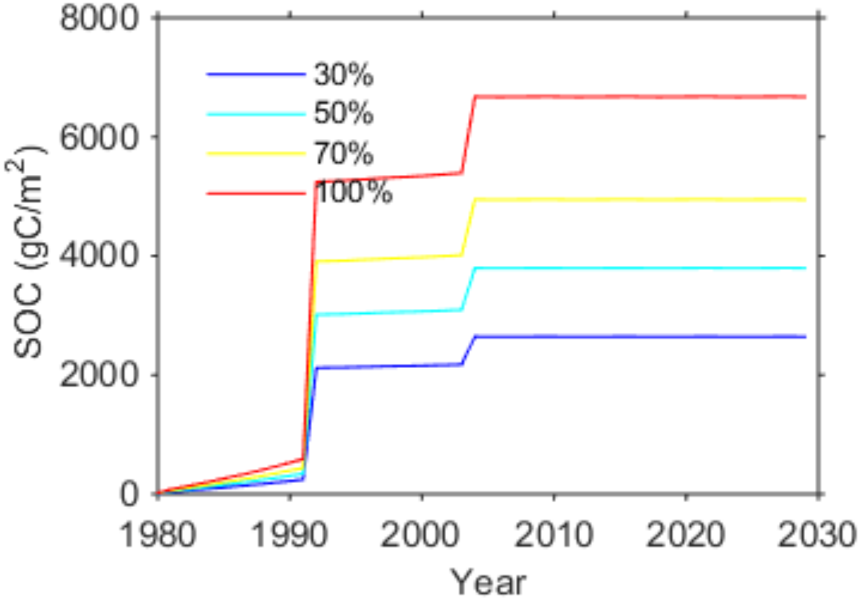
1D

- Planting date for each crop-rotation cycle:
  - SP_IPLT0 = 0, 0, 0, 310, 160, 310, 161
  - SP_IPLT1 = 0, 0, 0, 310, 160, 310, 161
  - NVM_PLNT = y (NVM or MTC PFT)
- No. of rotation cycles:
  - CYC_ROT_MAX = 2
- Rotation command for each cycle:
  - CMDROTATE_1 = 1000504, 1000706, 0
  - CMDROTATE_2 = 1000405, 1000607, 0
- If the planting date needs to be changed within a rotation cycle:
  - DYN_PLNTDT = y
- If rotation system needs to be updated:
  - ROTATION_UPDATE = 10Y

2D

- Planting date for each crop-rotation cycle:
  - IPLT_FILE = iplt.nc
- No. of rotation cycles in each grid:
  - NUMROTATE_FILE = filename1.nc
- Rotation command of each grid:
  - CMDROTATE_FILE = filename2.nc
- Others
  - DYN_PLNTDT & ROTATION_UPDATE can also be set for update frequencies of rotation systems and crop planting date with new maps

Residual management




thank you
danke
рахмат
謝謝
ngiyabonga
teşekkür ederim
Баярлалаа
спасибо
faafetai lava
mersi
barka
welalin
tack
spas
dank je
misaotra
matondo
paldies
grazzi
mahalo
tapadh leat
vinaka
спасибі
blagodaram
gracias
хвала
asante
manana
kiitos
dankie
dhanyavad
nanni
nandri
maururu
köszönöm
hvala
gràcie
bayarlalaa
bedankt
enkosi
dziękuję
akun
dankon
obrigada
tenki
murakoze
djiere dieuf
tau
mochchakkeram
дякую
mamnun
chnorakaloutioun
gràcies
sulpáy
go raibh maith agat
sobodi
dėkuji
obrigado
sukriya
kop khun krap
taiku
arigatô
takk
dakujem
trugarez
mèsi
sagolun
najis tuke
ありがとう
tanemirt
grazie
didi madloba
kam sah hamnida
rahmat
terima kasih
rahmet
diolch
dhanyavadagalu
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мерси
তোমাকে ধন্যবাদ
감사합니다
xiexie
ευχαριστώ
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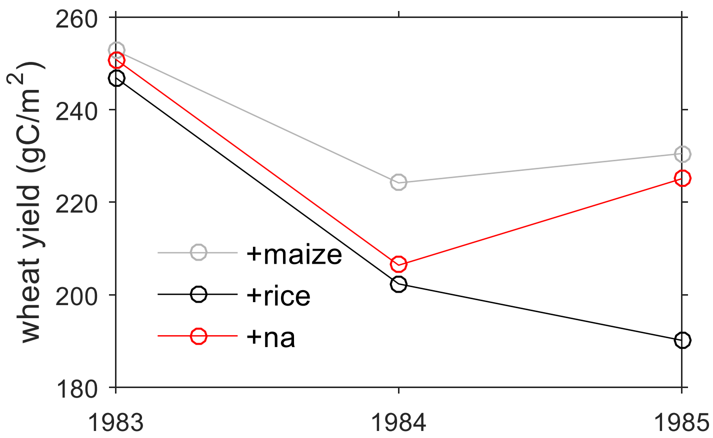
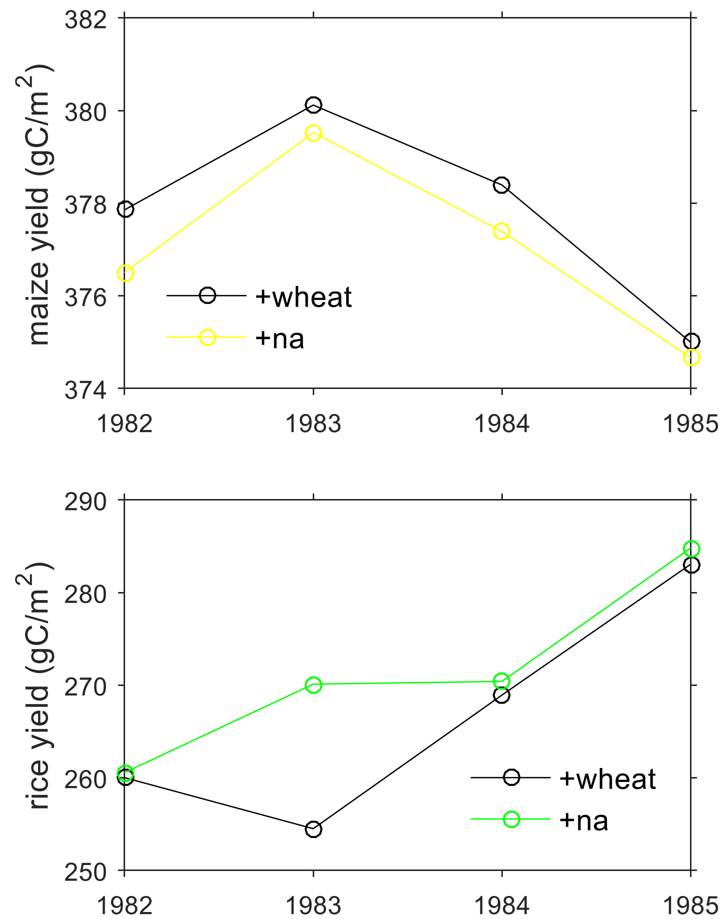
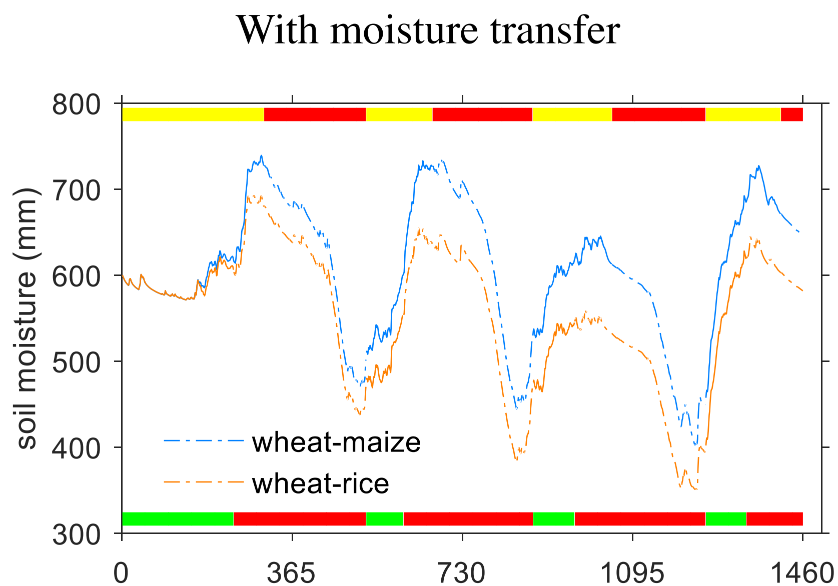
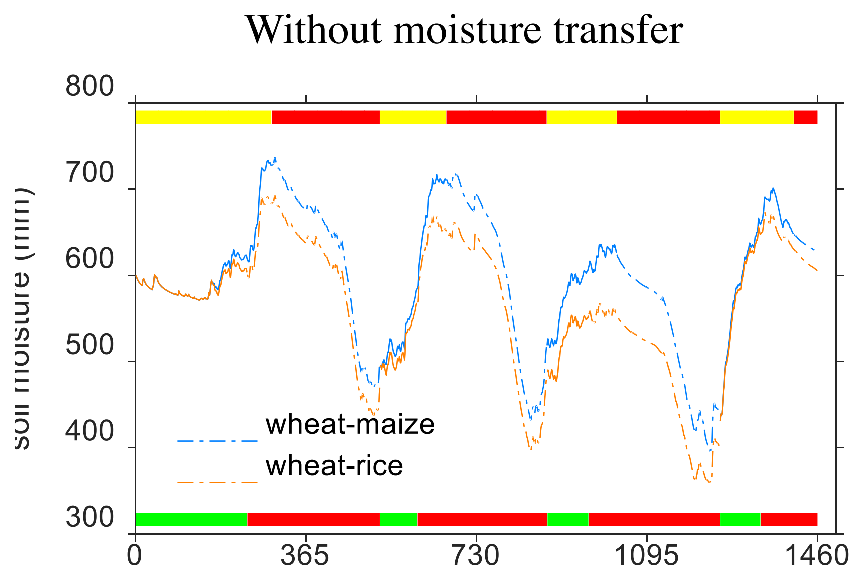
Yield, multiple vs. single cropping

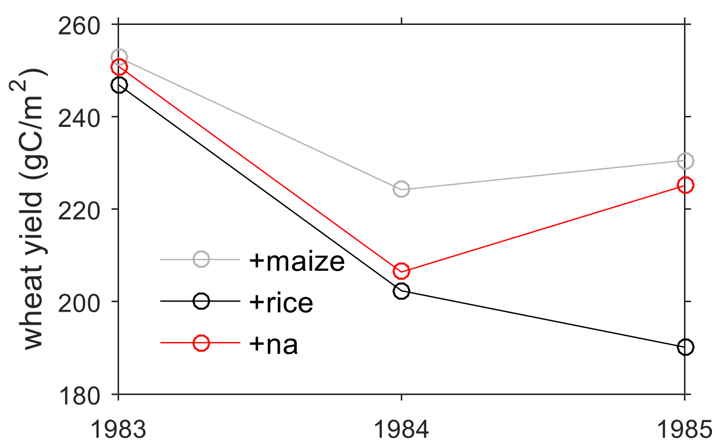


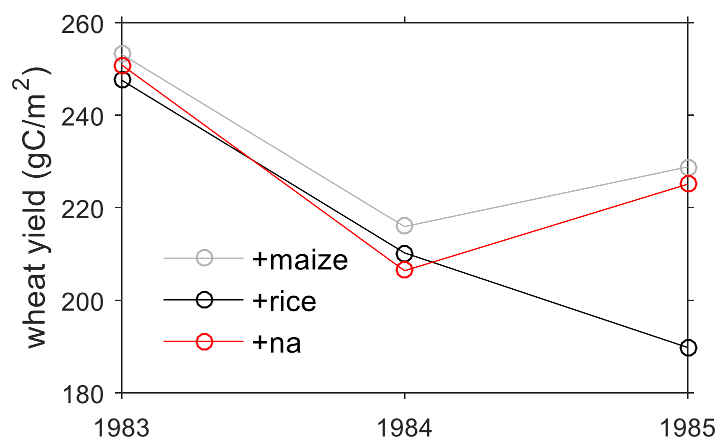


w/ or w/o soil moisture transfer

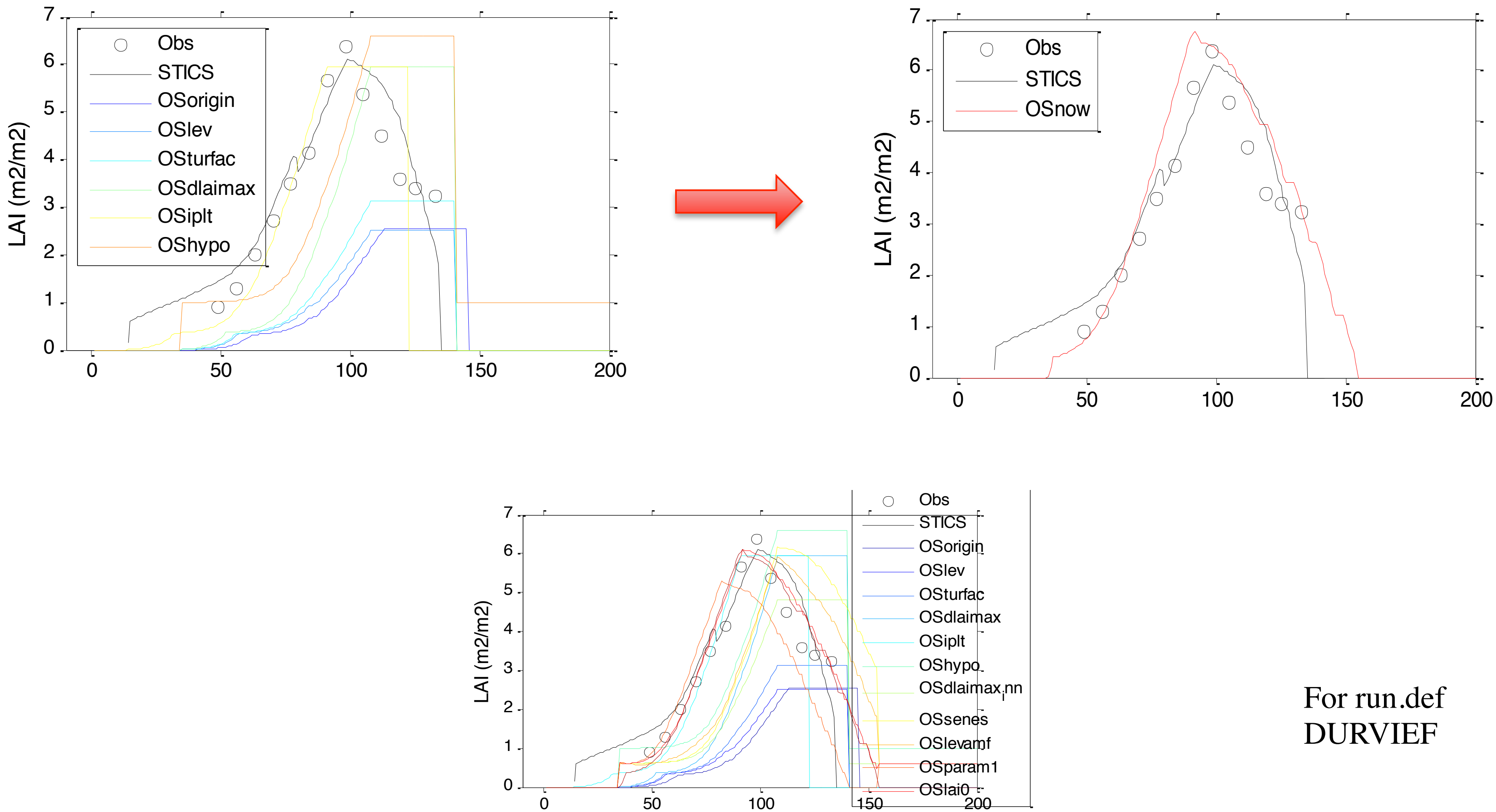








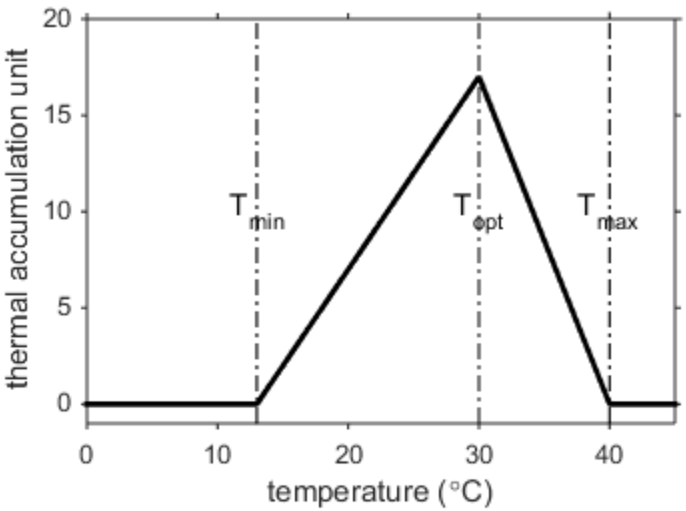
The importance of senescence



For run.def
DURVIEF

Temperature thresholds

Crude but useful



Wang et al., 2019

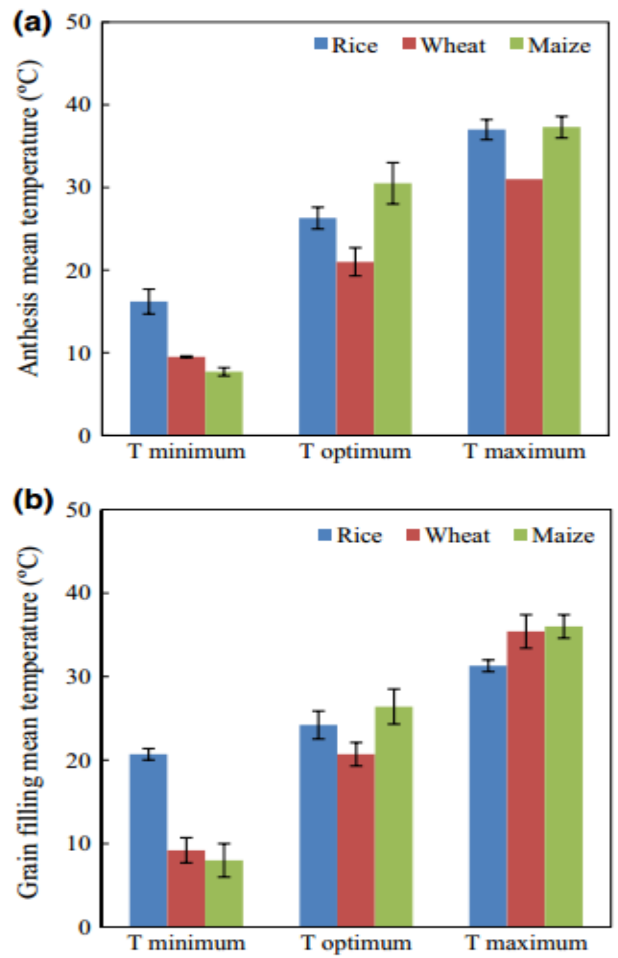
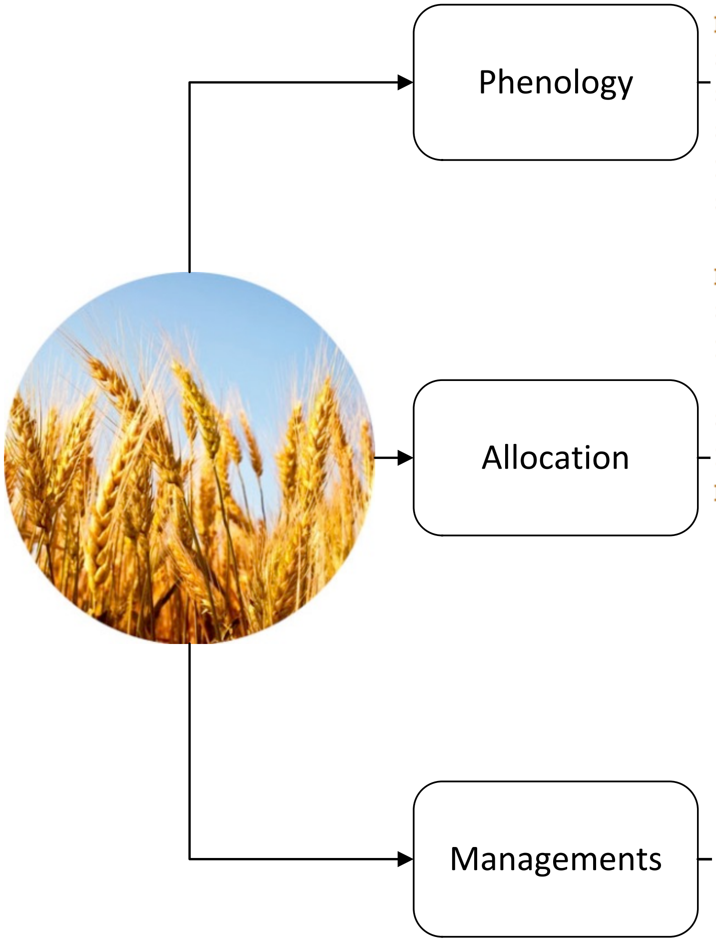


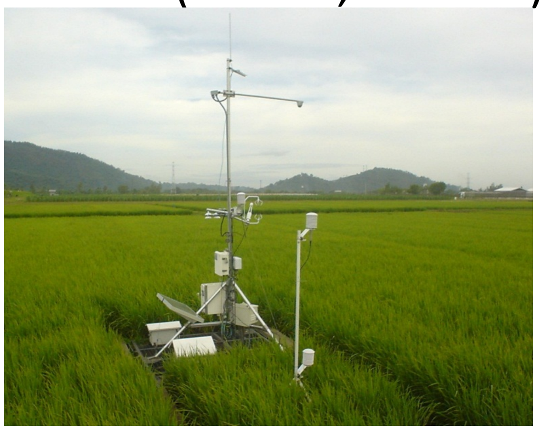
Fig. 2 Rice, wheat and maize (in separate columns with SE). (a) Mean minimum, optimum and maximum temperatures for anthesis, (b) Mean minimum, optimum and maximum temperatures for grain filling.

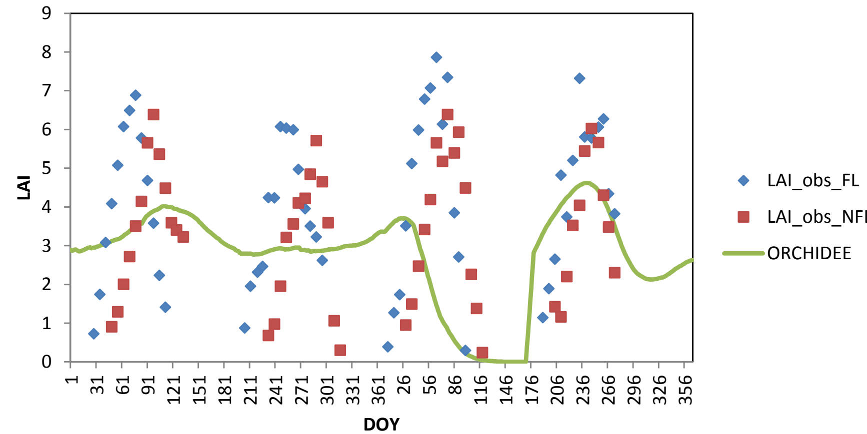
Sanchez et al., 2015

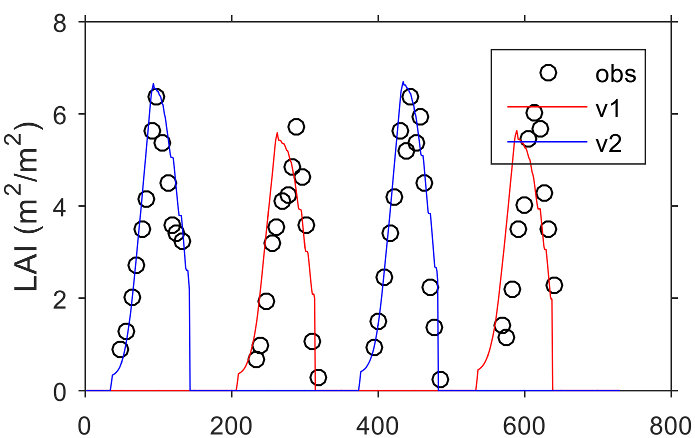


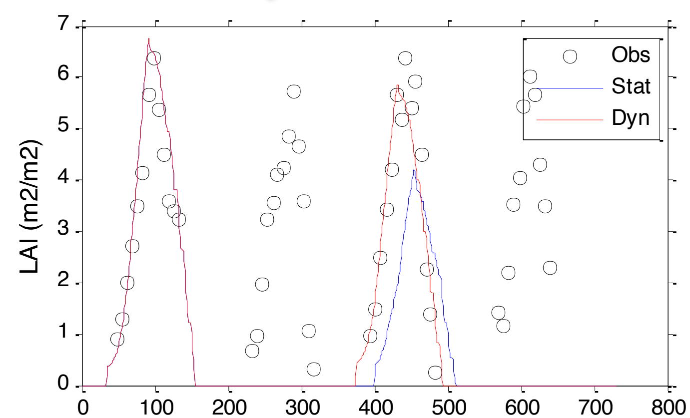

```
NVM = 14
##NVM = 13
##PFT_TO_MTC = 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 14, 13, 14
### wheat maize wheat rice
PFT_TO_MTC = 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
##PFT_TO_MTC = 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13

NSTM = 6
#PREF_SOIL_VEG = 1, 2, 2, 2, 2, 2, 2, 2, 2, 3, 4, 5, 6
PREF_SOIL_VEG = 1, 2, 2, 2, 2, 2, 2, 2, 2, 3, 3, 4, 5, 6

#specific rice-induced change in parameters
IS_C4 =  n, n, n, n, n, n, n, n, n, n, n, n, y, n
NATURAL =  y, y, y, y, y, y, y, y, y, y, y, n, n, n
```

IRRI site (14.2^{o}N, 121.3^{o}E)

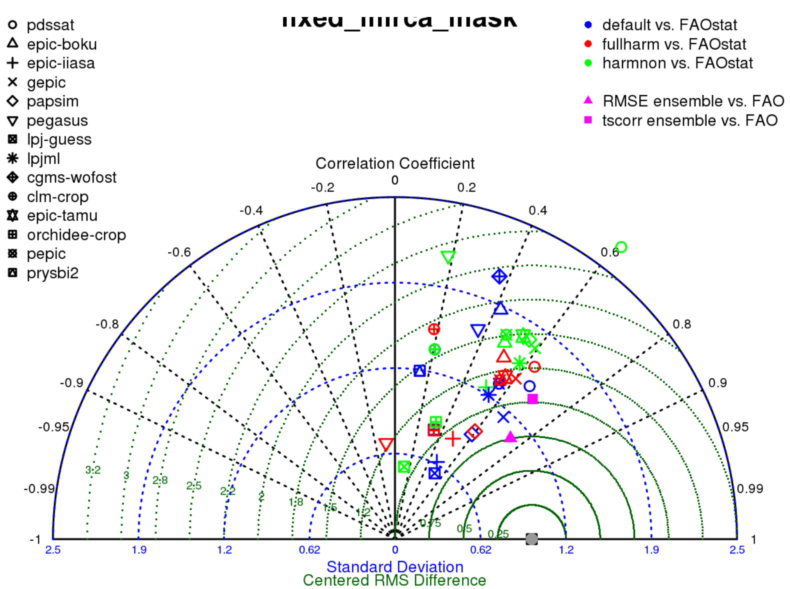




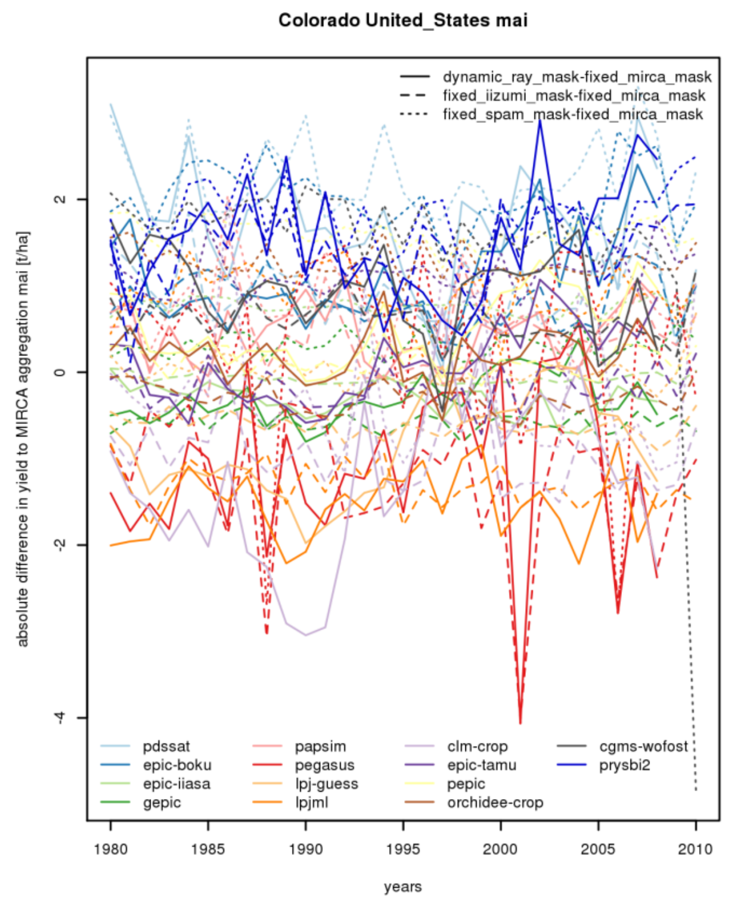




Global gridded crop models

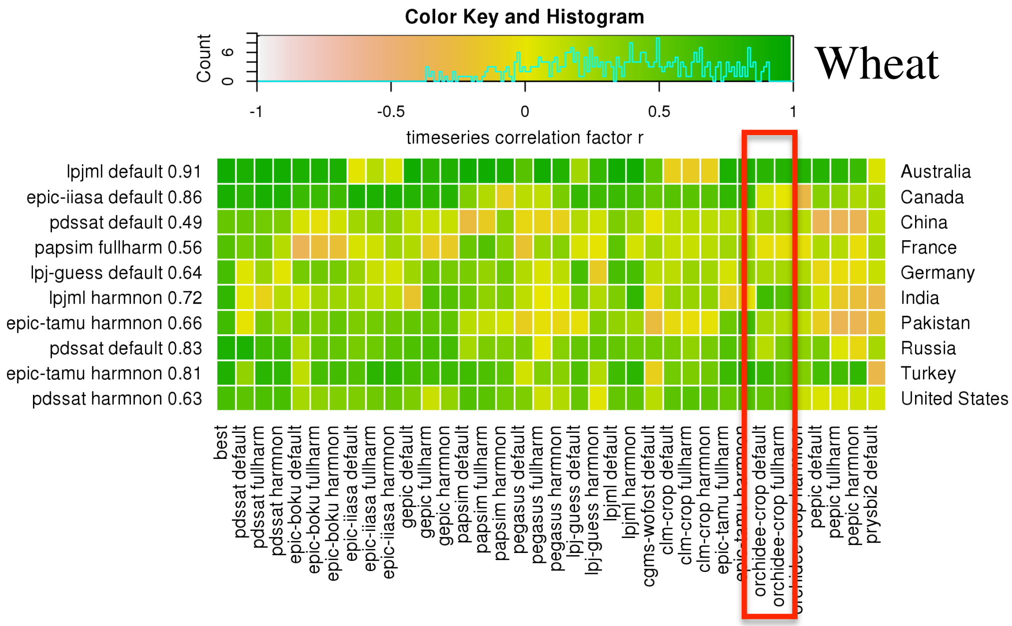


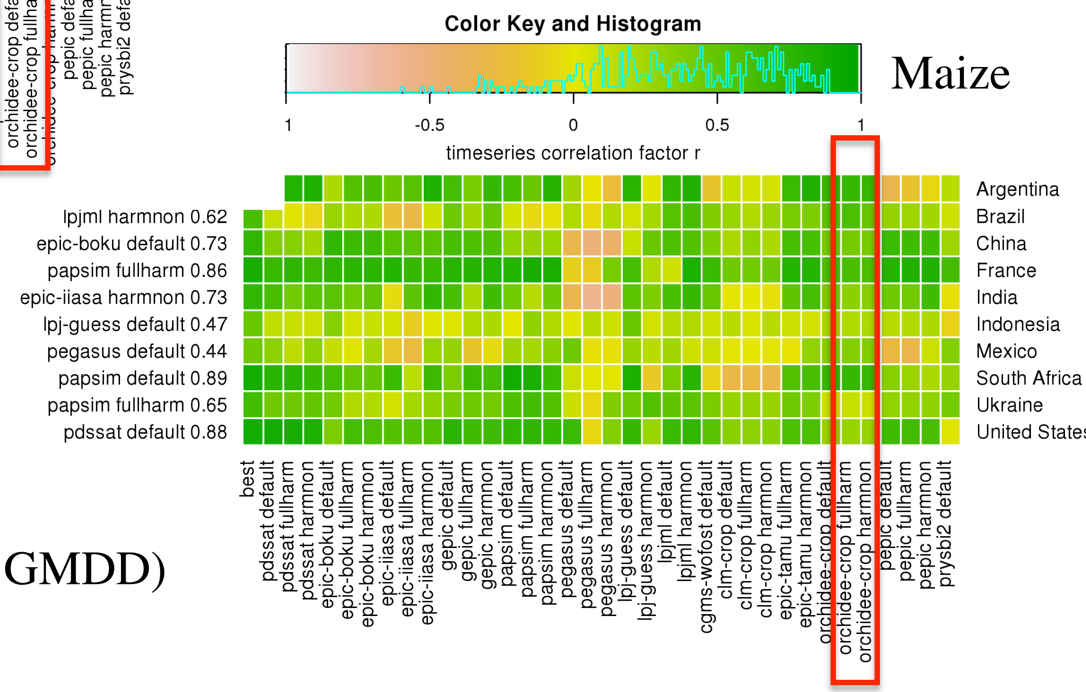
Model evaluations (Muller et al., 2016 GMD)



Porwollik et al., 2016 EJA

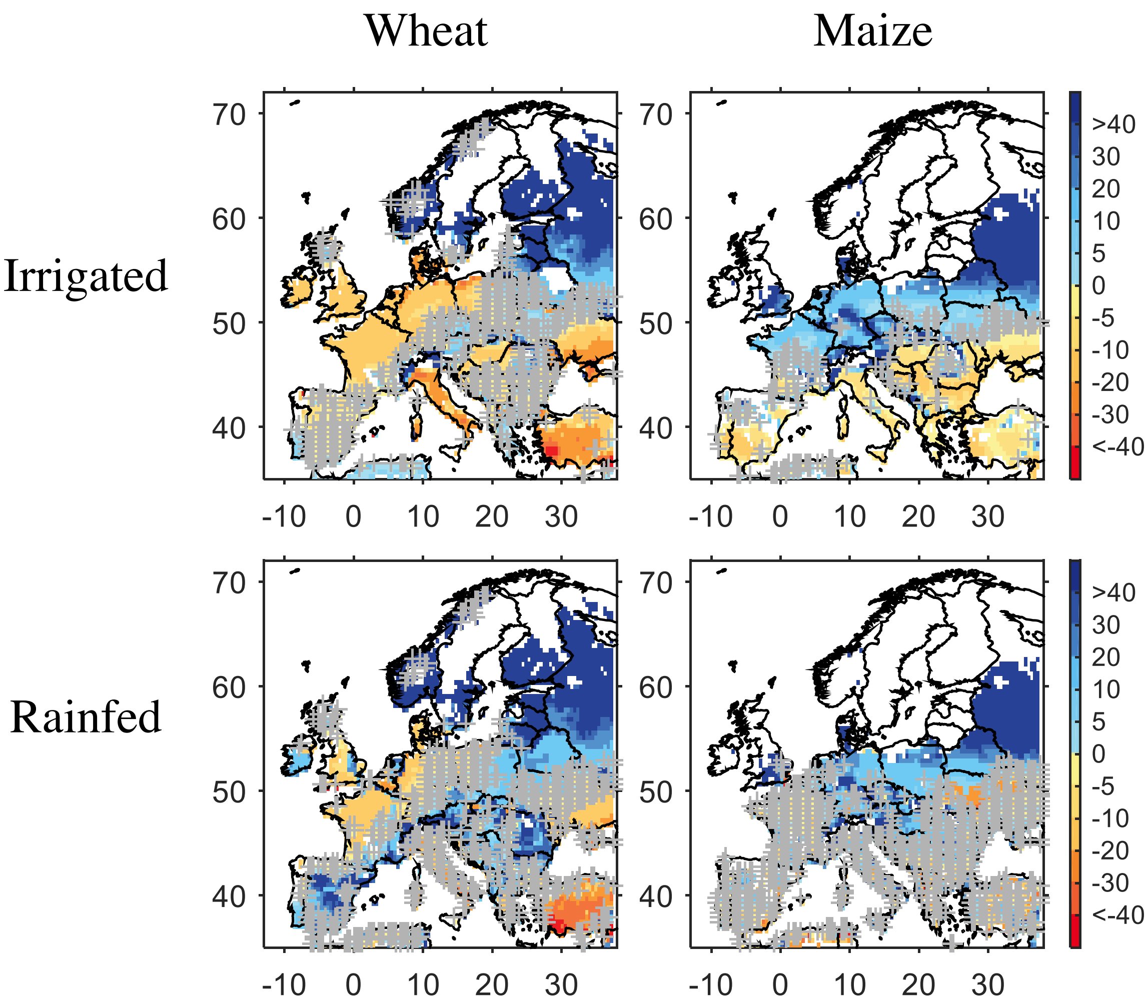
Model Evaluation





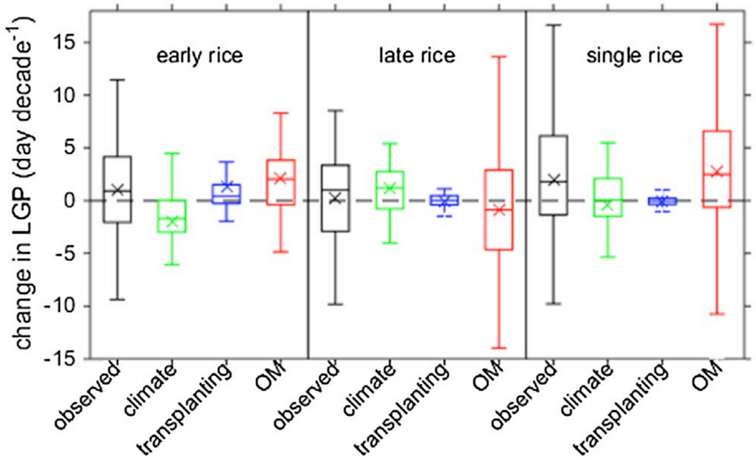
(Muller et al., 2016 GMDD)

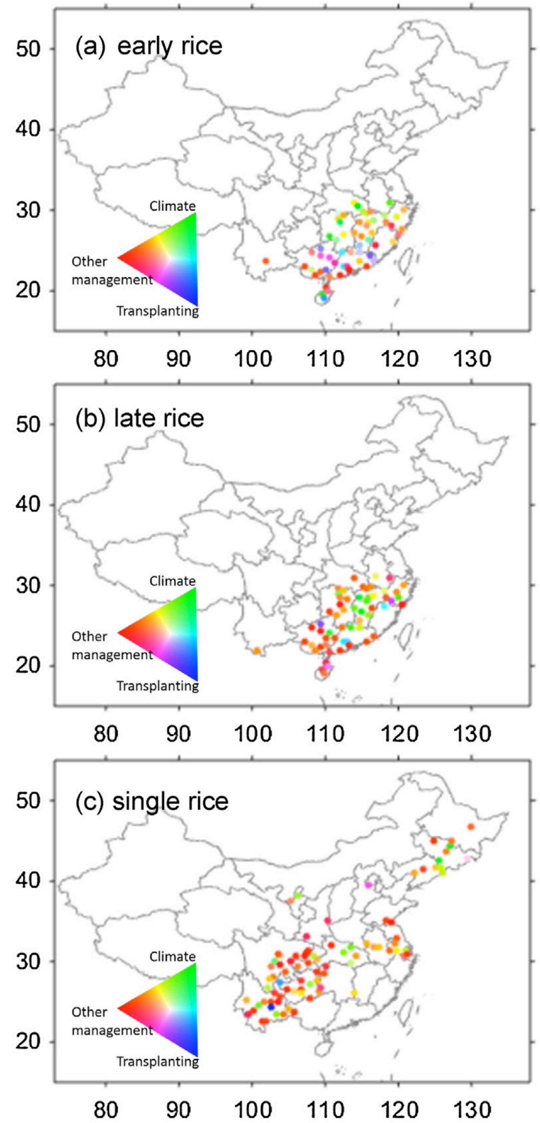
Impact of climate change on European cropland



- The impact of 4K warmer climate on European croplands (HELIX)
- The impact of 2K warmer climate on European croplands (IMPACT2C)

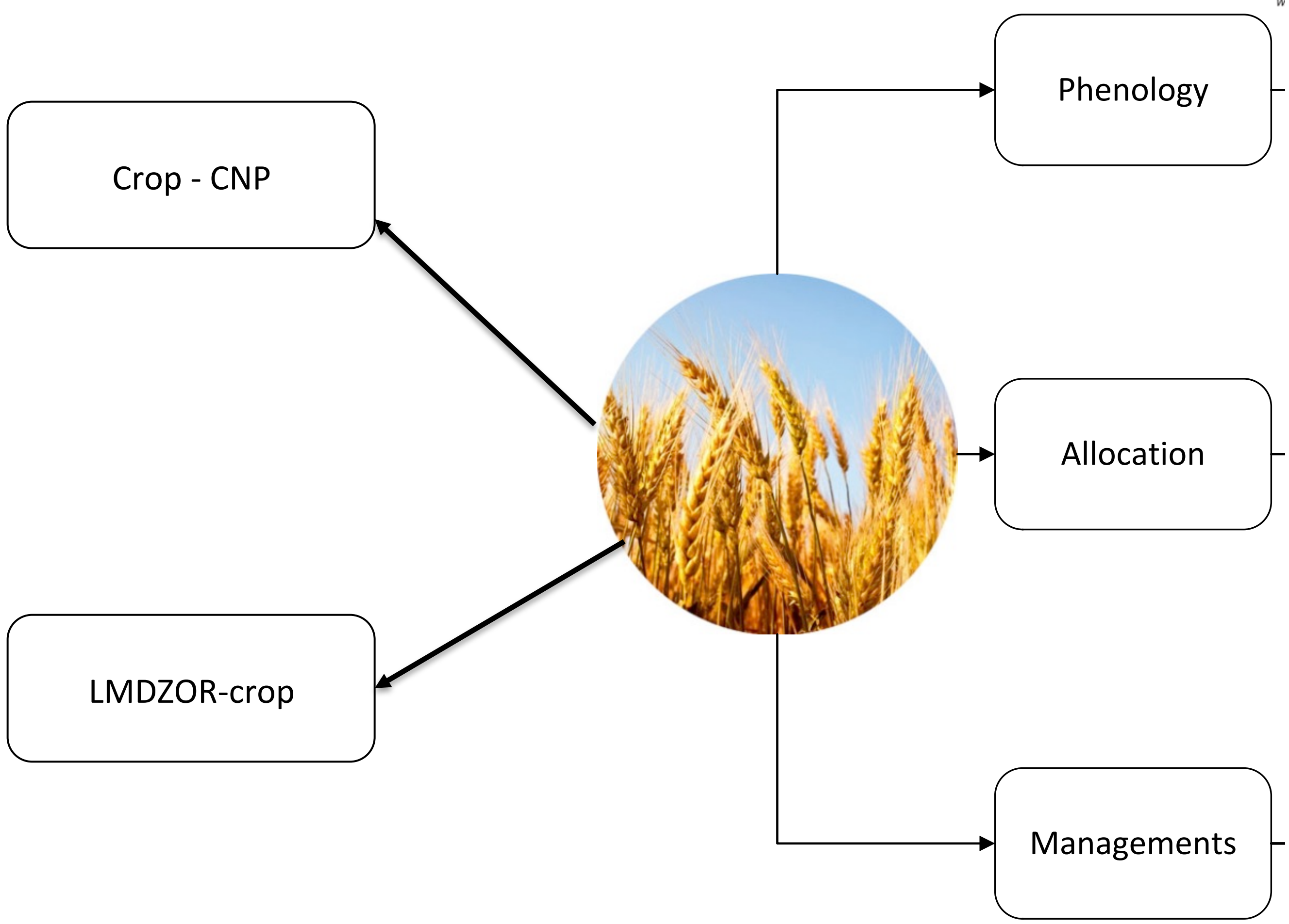
Detection & attribution





(Wang et al., 2017 AFM)

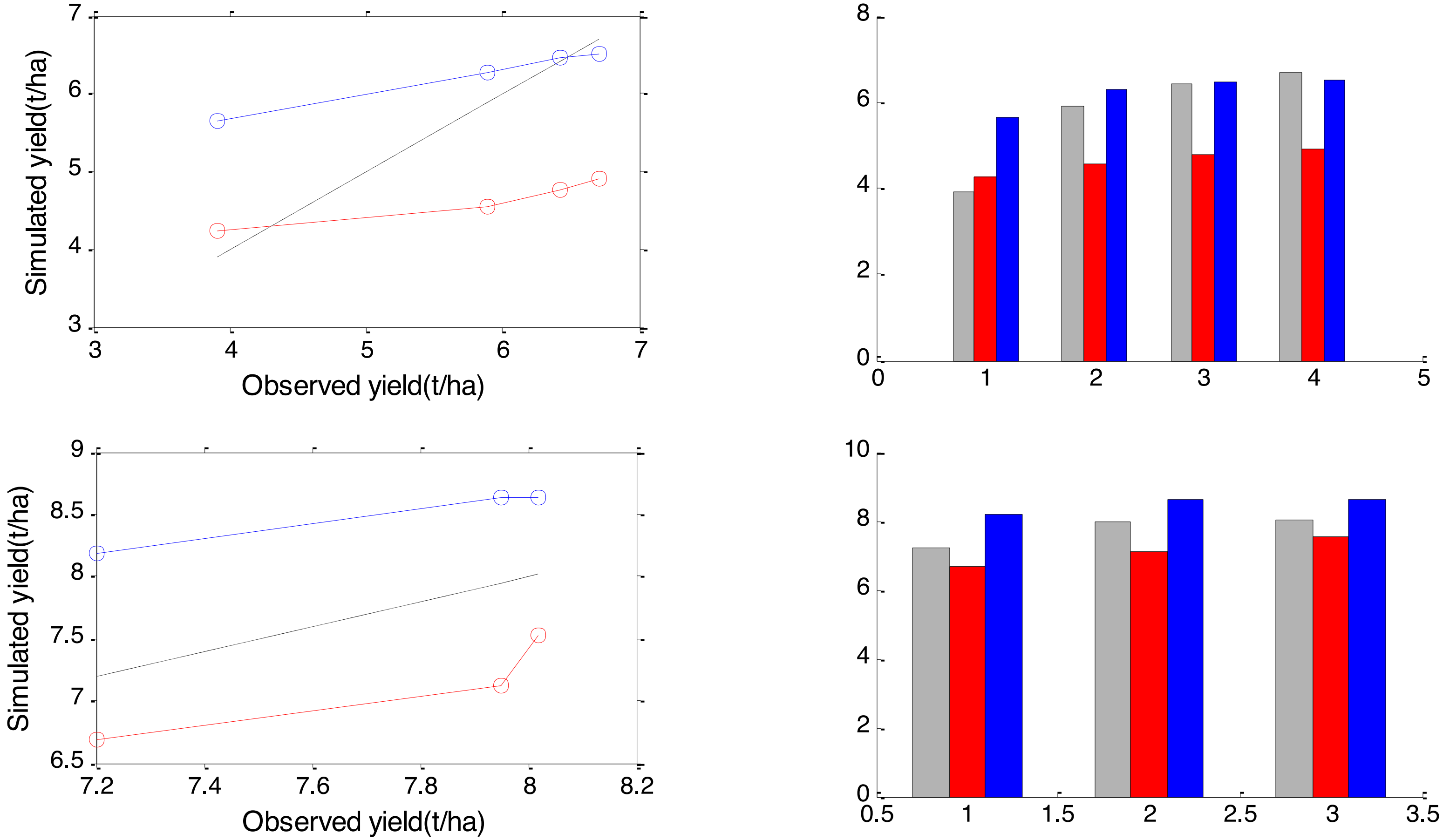
The outlook of ORCHIDEE-crop



opt1

Constrain
Vcmax25>40

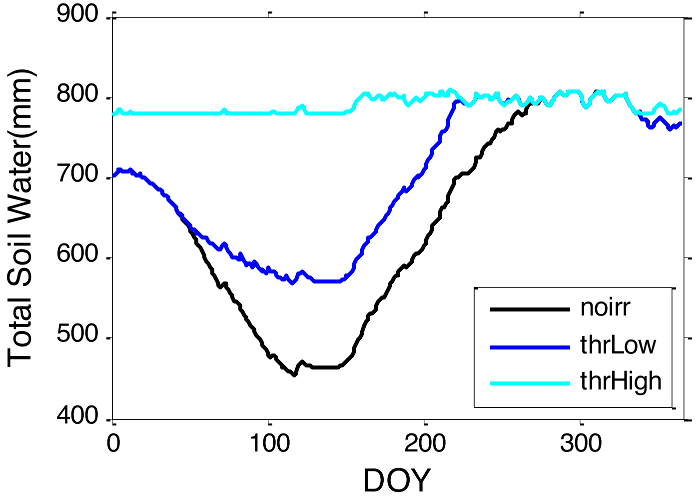
Prior set:		Posterior set:	
Neff	0.65	Neff	2.51
Pa	0.91	Pa	0.68
Vcmax25	70	Vcmax25	46.2



When?

Key parameter: IRRIG_THRESHOLD

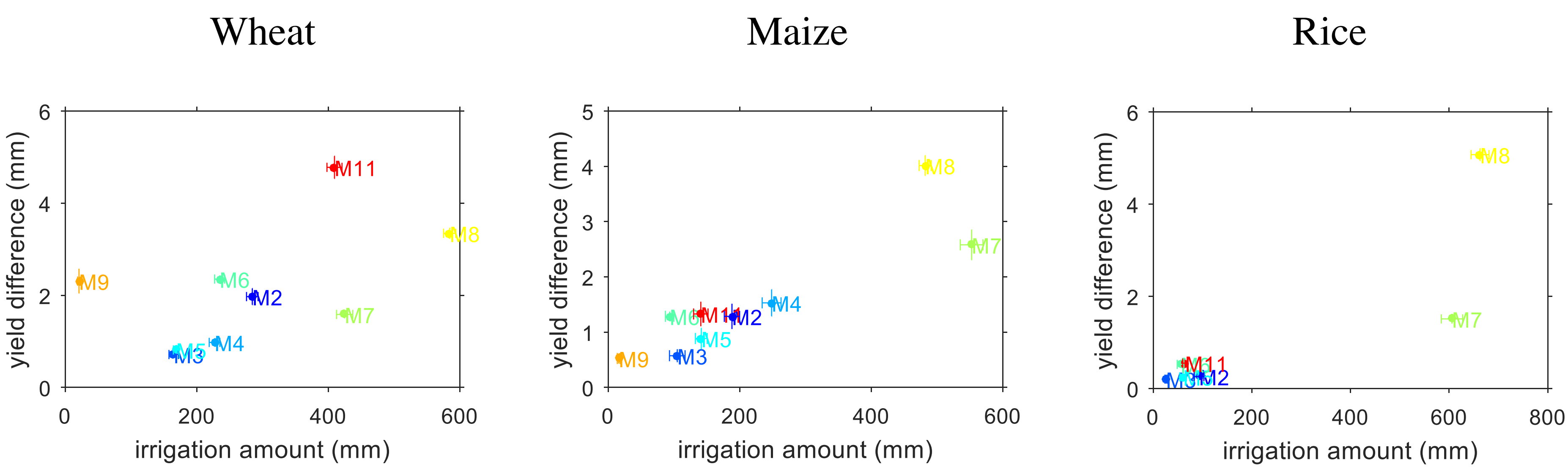
Threshold (% of vegetation growth stress) to which we start irrigation



Irrigation related settings

```
HYDROL_CWRR = y
RIVER_ROUTING = n
DO_IRRIGATION = n
DO_FULLIRR = y
CHECK_WATERBAL = n
IRRIG_THRESHOLD = 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1.0, 1.0, 1.0, 1.0
IRRIG_FULFILL = 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1.0, 1.0, 1.0, 1.0
#IRRIG_DOSMAX = 5.0
IRRIG_DOSMAX = 20.0
#IRRIG_DOSMAX = 10.0
IRRIG_DRIP = n
```

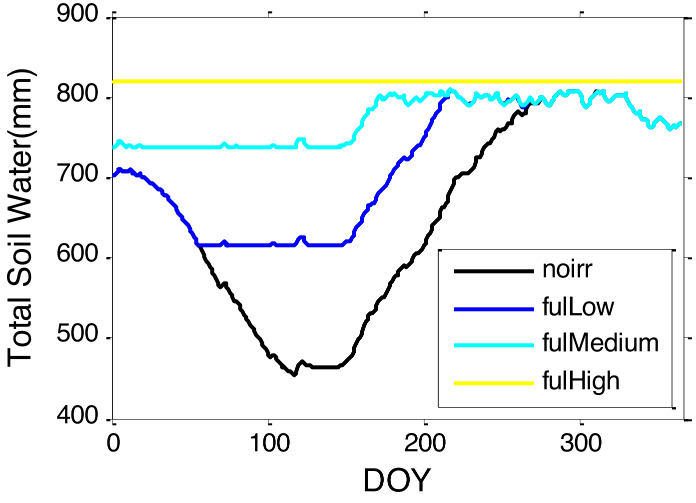
Relationship with irrigation demand



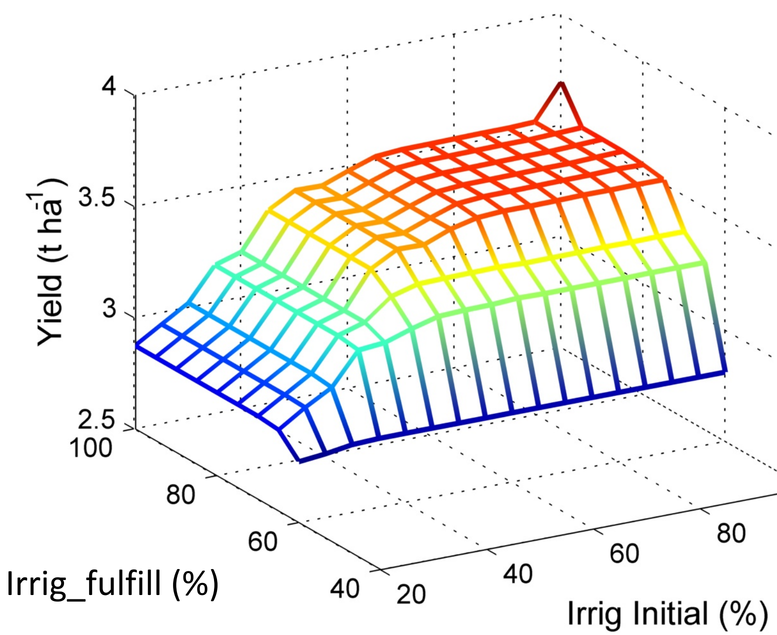
How much?

Key parameter: IRRIG_FULFILL

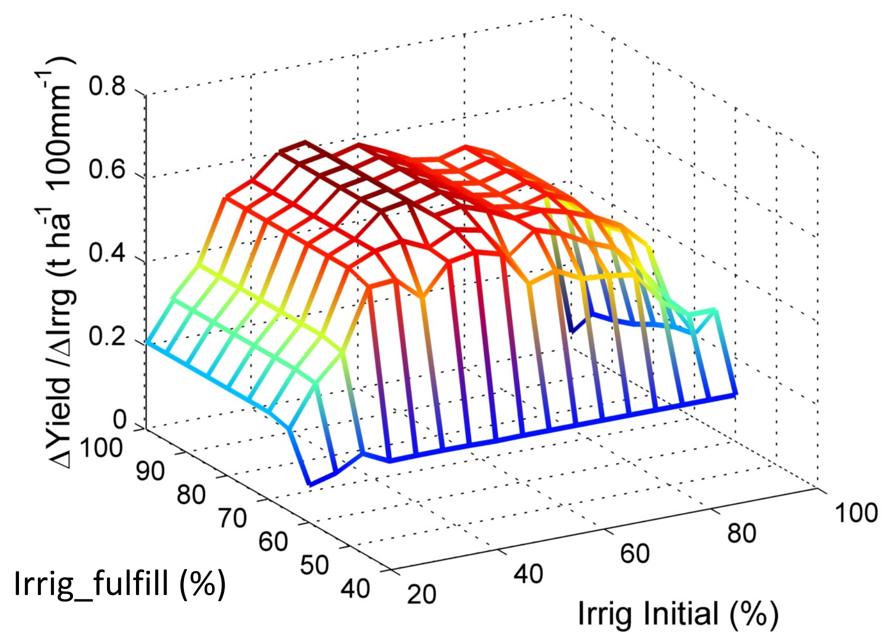
Threshold (% of soil water holding capacity) to which we saturate the soil



Yield ~ irrigation

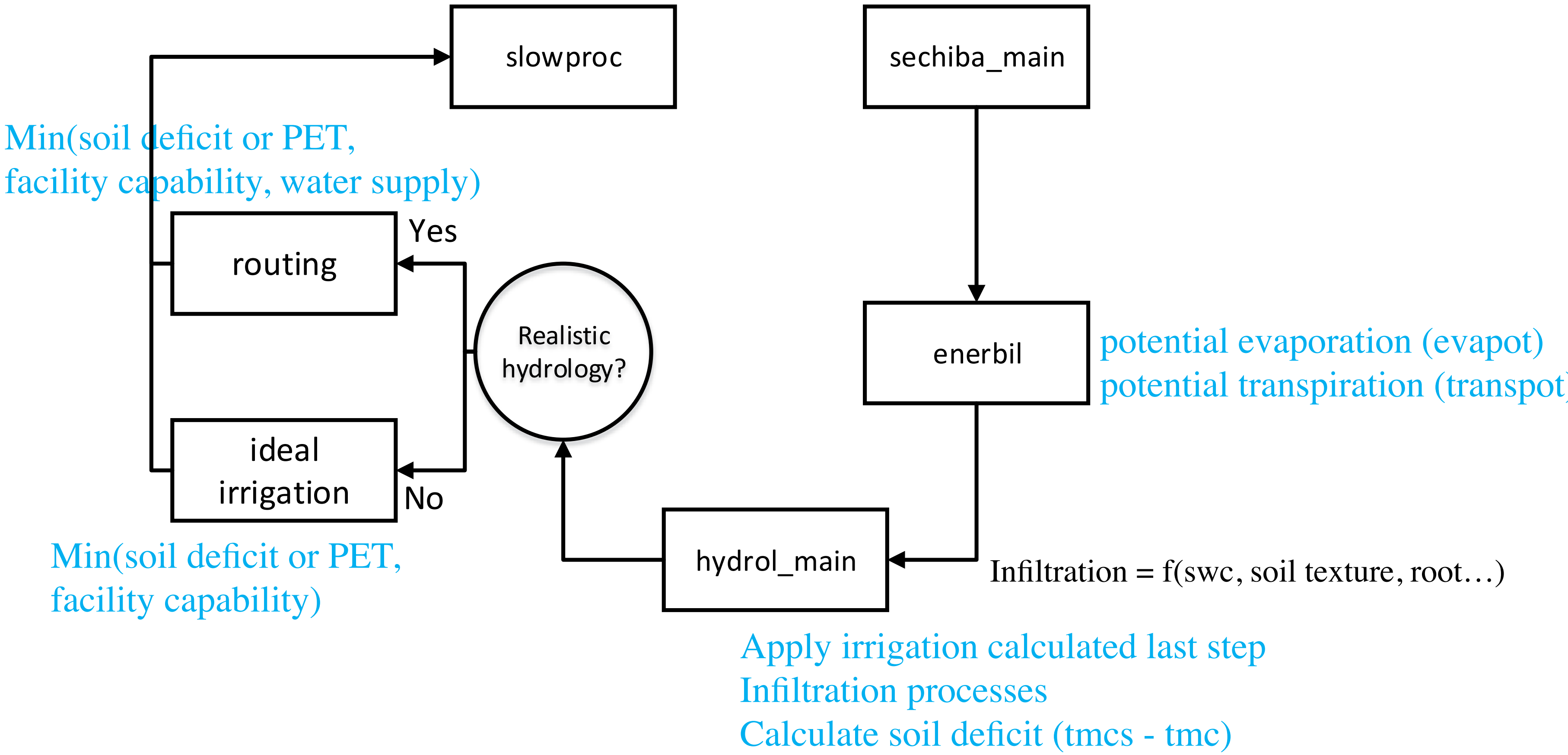


Irrigation Efficiency ~ irrigation



Irrigation Efficiency (t/ha/100mm) =
dYield/dIrrigationWater

On the SECHIBA



For run.def
DO_FULLIRR

tmc: total column moisture content
tmcs: total column moisture content when saturated