Spatiotemporal dynamics of crop phenology and crop yield: The influence of climate variability in the Upper Blue Nile basin

Welcome

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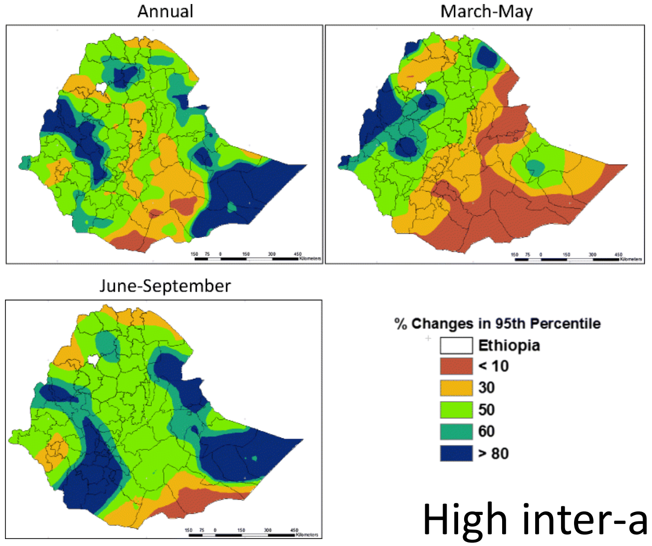
Background of the study

- Agriculture is the most important sector in Ethiopia
  - Employing 85%, contributing 42% of GDP,& 90% of export (CSA, 2018)
- Crop production influenced by anthropogenic and natural factors
- Studies understanding crop growth, drivers and yield is important

- ✓ Fragmented & small plot size
- ✓ Mixed land use system
- ✓ Complex topography



Gummadi, 2018

High inter-annual & seasonal variability

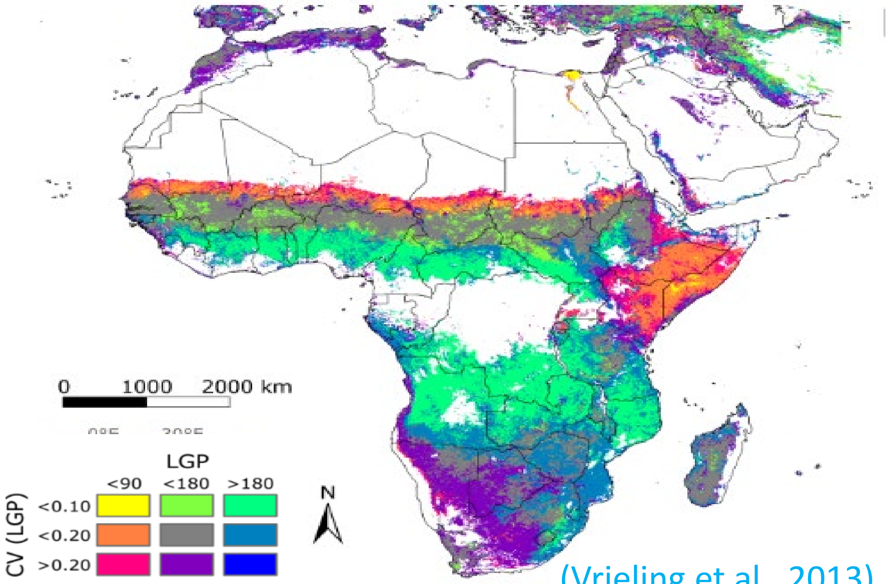
Lack of reliable data

Meshesha, 2018

Phenology and yield estimation a challenge

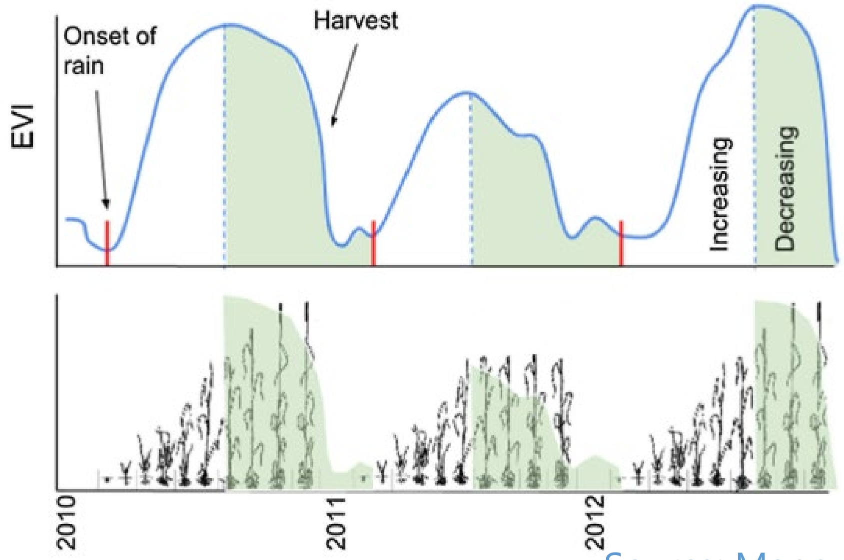
Problem Statement

- Phenology indicator of environmental change and productivity
- Seasonal phenological parameters (SOS, EOS, LOS)



(Vrieling et al., 2013)

Vegetation-climate relation



Source: Mann, 2017

Yield estimation

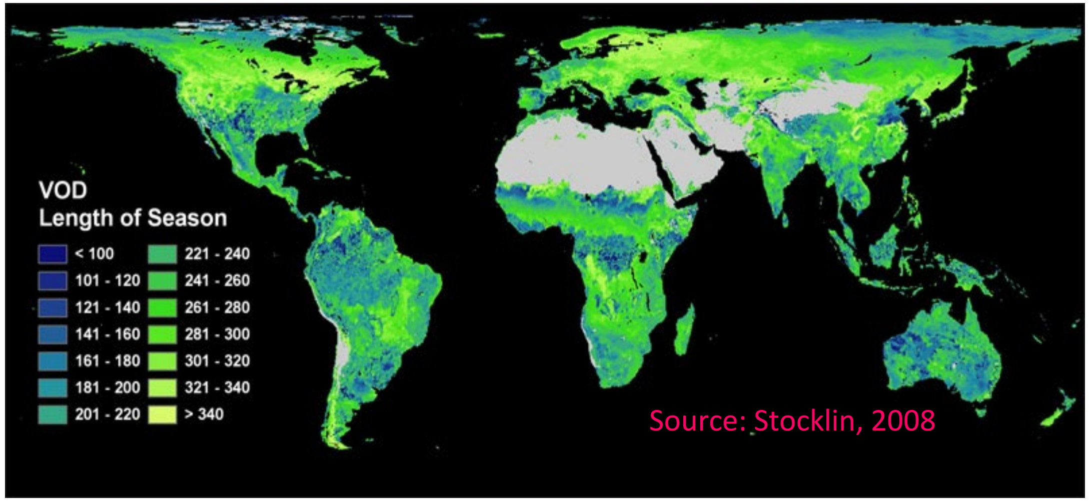
Crop yield estimation for food security

Gaps

- Literature studies shows various efforts on climate change and variability
  - Phenology – climate studies are limited
  - Inconsistent and divergent phenology-climate trend
  - Most focus on length of the growing season
- Data is the main constraint, remote sensing can be a valuable resource

But..

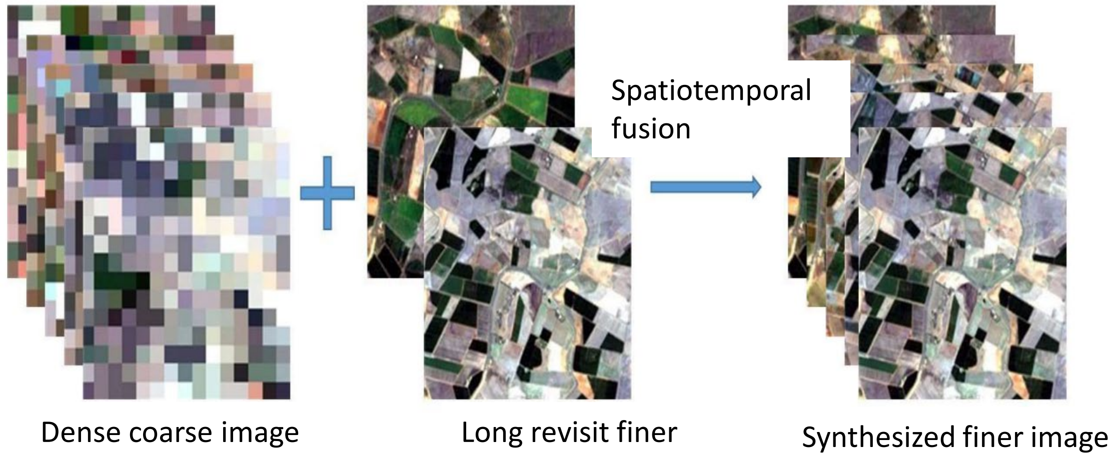
- Available remote sensing data has also limitations
  - Temporally frequent and spatially higher resolution data is required
- Spatiotemporal data fusion could be a solution

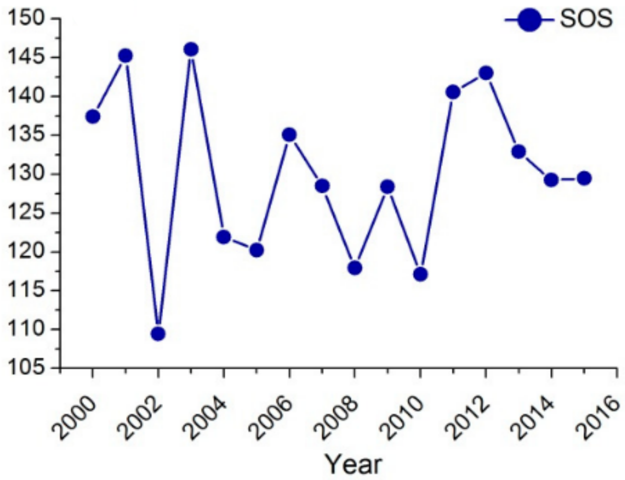


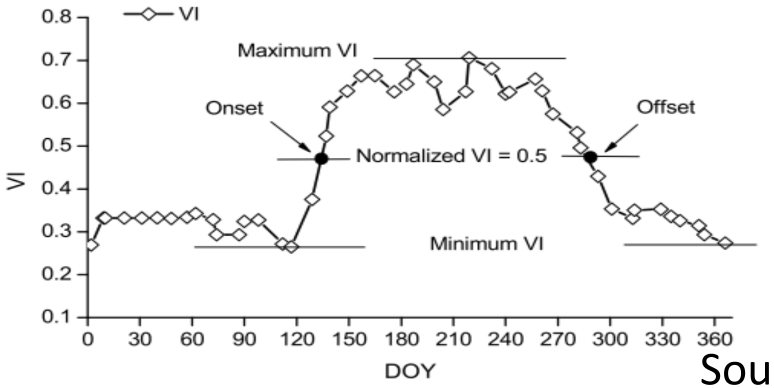
Source: Stocklin, 2008

Objectives of the study

- The general objective is to understand the spatiotemporal dynamics of vegetation phenology and the influence of climate variability on crop yield using image fusion approach in Lake Tana Basin



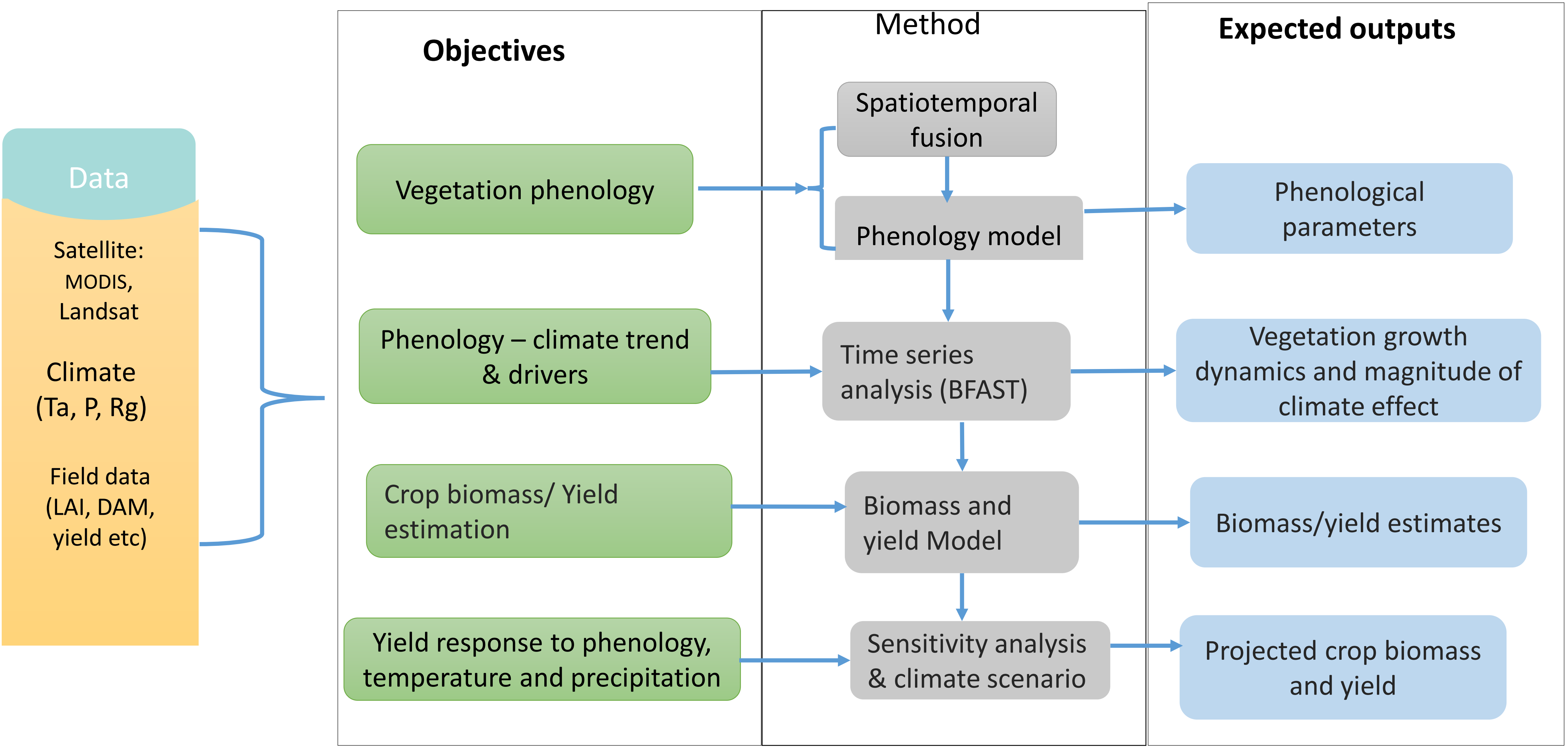




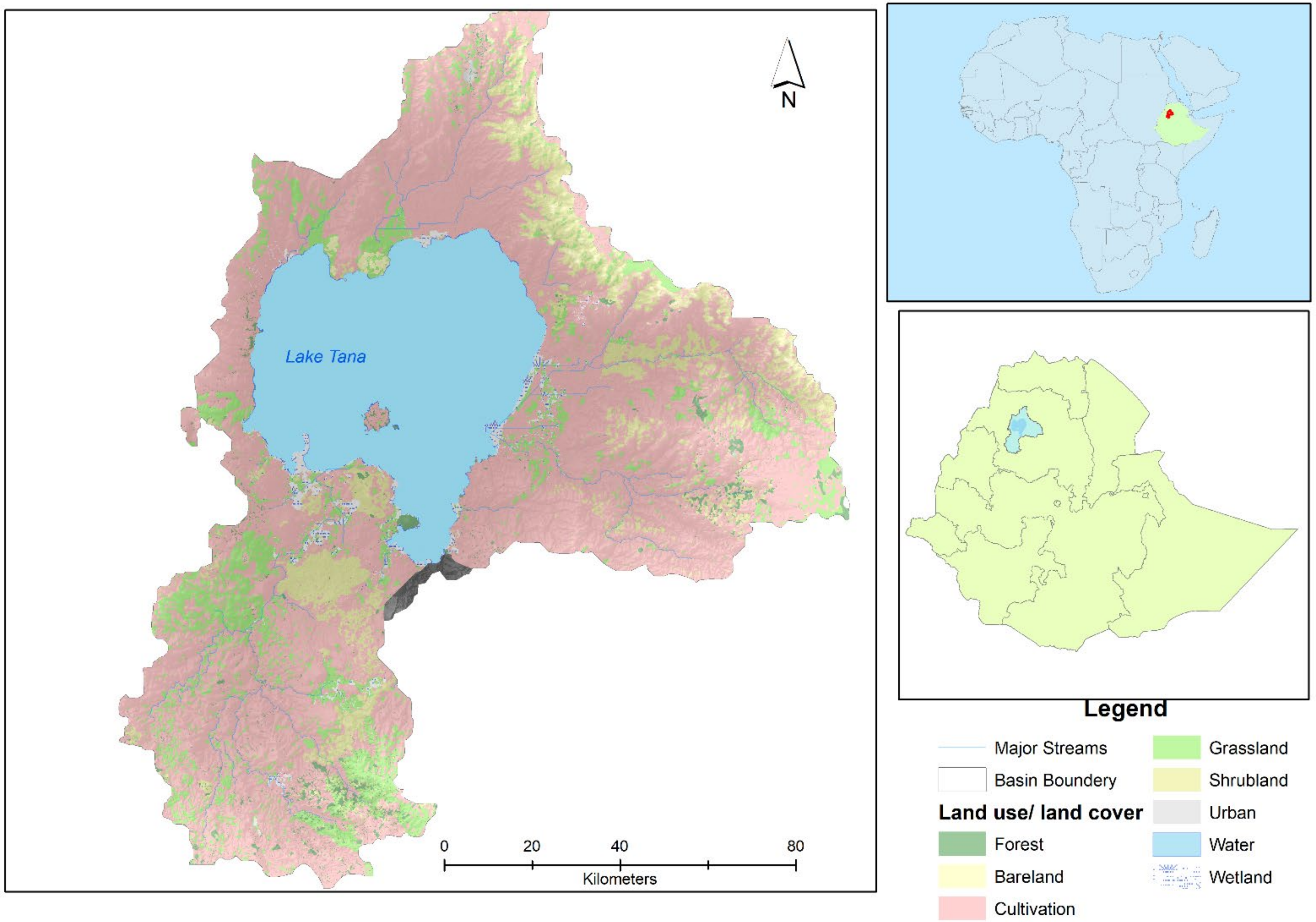
Source, White 1997

Multi-sensor remote sensing to improve crop growth monitoring and production estimation in smallholders

Overall workflow



The Study Area



- ✓ Upper Blue Nile basin, parts of Ethiopia
- ✓ total area of 15,100 km^2.
- ✓ Cultivated land accounts for 56% of the area
  - ✓ *tef*, maize, rice and wheat (70%)
- ✓ Annual rainfall 970 mm to 1900 mm
  - ✓ occurring during June to September (‘*kiremt*’) season
- ✓ Altitude range 1300 – 4100masl

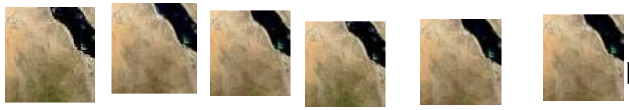
Ch1: Modeling the dynamics of Land Surface Phenology in Lake Tana basin

- Existing coarse resolution data are less effective
  - Topographic complexity and fragmented land cover
  - Lack of ground calibration
  - Robustness of phenology models are environment specific
- Multi-sensor spatiotemporal fusion to better determine phenology in heterogeneous environment

CH1: Research Questions

- Does high-resolution image acquired through spatiotemporal fusion capture vegetation phenology better in the heterogeneous environment in Lake Tana basin?
- What is the reliable model to determine the timing of vegetation phenology across different landscapes and vegetation class?

CH1: Methodology



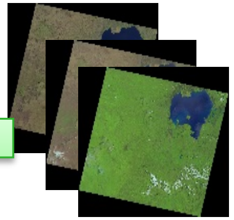
MODIS

Jun Sep May

OLS

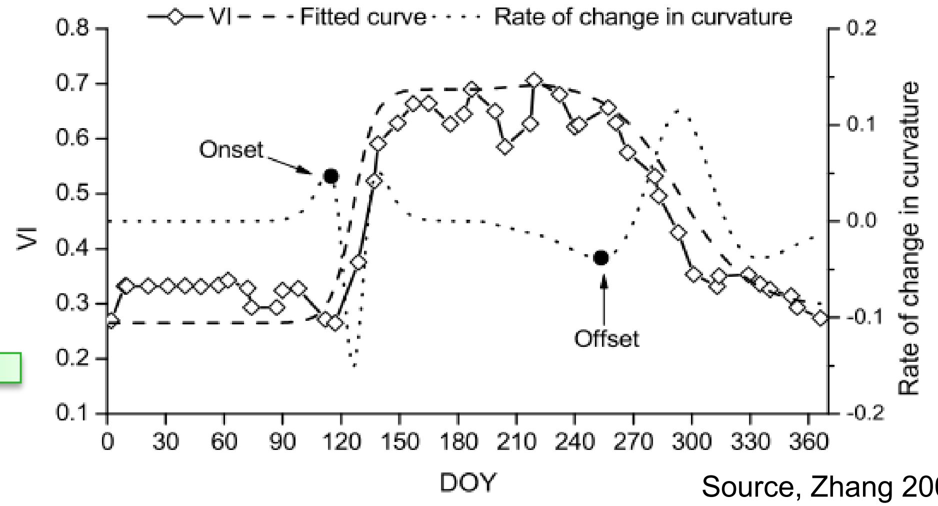
Fusion : ESTARFM , [Zhu et al. (2010)]

$$(L\,(\tfrac{x_w}{2},\tfrac{yw}{2},tp_{,b}) = \sum_{i=1}^{N} L(\tfrac{xw}{2},\tfrac{yw}{2},to_{,b}) + wi * vi * (M\,(xi,yi,tp_{,b}) - (xi,yi,to_{,b}))$$



NDVI $=\frac{NIR-R}{NIR+R}$

Phenology model



Source, Zhang 2003

Land use/ land cover

Stratification

Field data

Key growth Stages

Model evaluation and validation

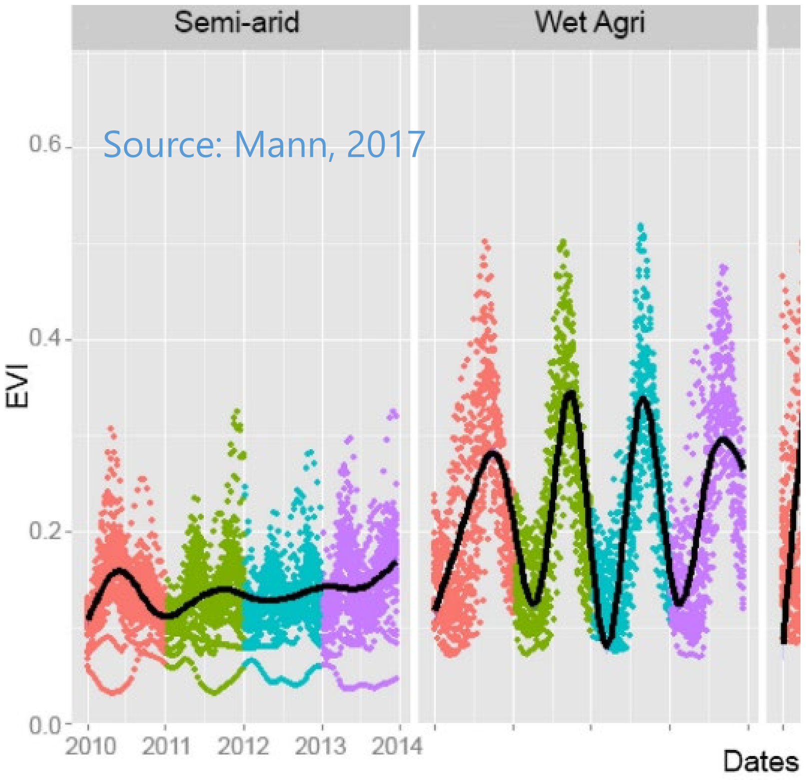
Fusion: Predicted and original Landsat image

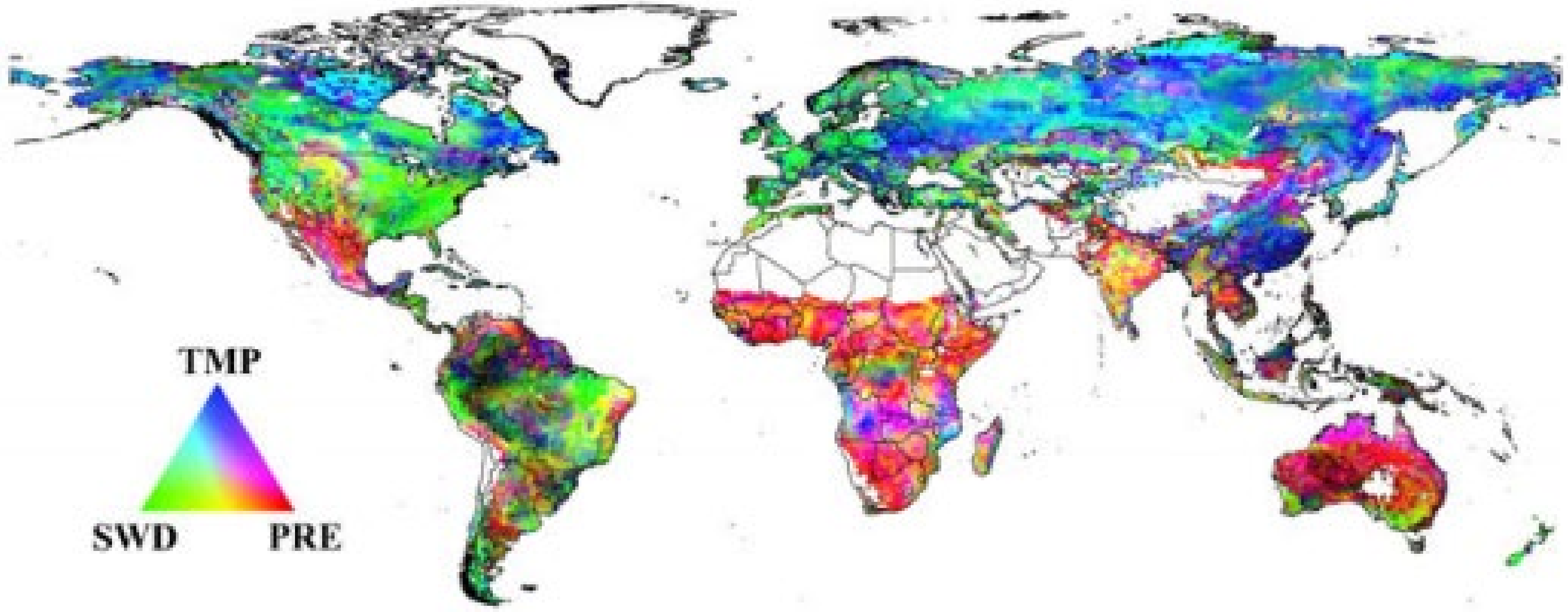
Phenology: Inter-comparison of phenology detection models field data

Expected Output: Phenological parameters at 30m and 8 day across vegetation class

Ch2. Trends of vegetation phenology and the influence of climate variability/change

- Lengthening of the growing season at global scale
- The trend and response depends on climate region and vegetation types
- Crop failure, disease, and invasive species occurring frequently in Ethiopia





The responses temperature (TMP), precipitation (PRE), and solar radiation (SWD); source: Wu,2015

Ch2. Research Questions

- ❖ What is the medium-term seasonal and inter-annual trajectory of vegetation phenology and climate variability during the growing season?
- ❖ What is the interrelationship between vegetation phenology and climate variability during the critical phenological stages of vegetation in Lake Tana basin?

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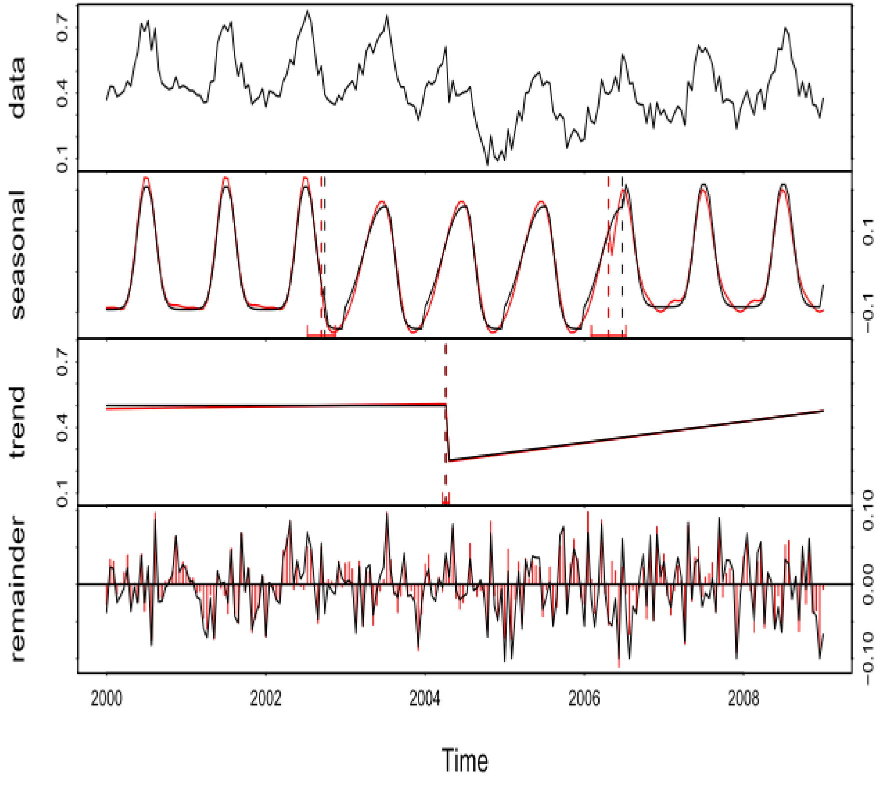
Ch2. Methodology

Fusion (ESTARFM) → Time series phenology (2001-2020) → Phenology-climate trend → Phenology-climate relation



[Source: Verbesselt et al., 2010]

Breaks for Additive Seasonal and Trend (BFAST)

Partial Least Square (PLS) regression

Expected output

Trends in vegetation growth dynamics and climate factors across land cover type

Drivers of phenology and critical period affecting vegetation growth and development

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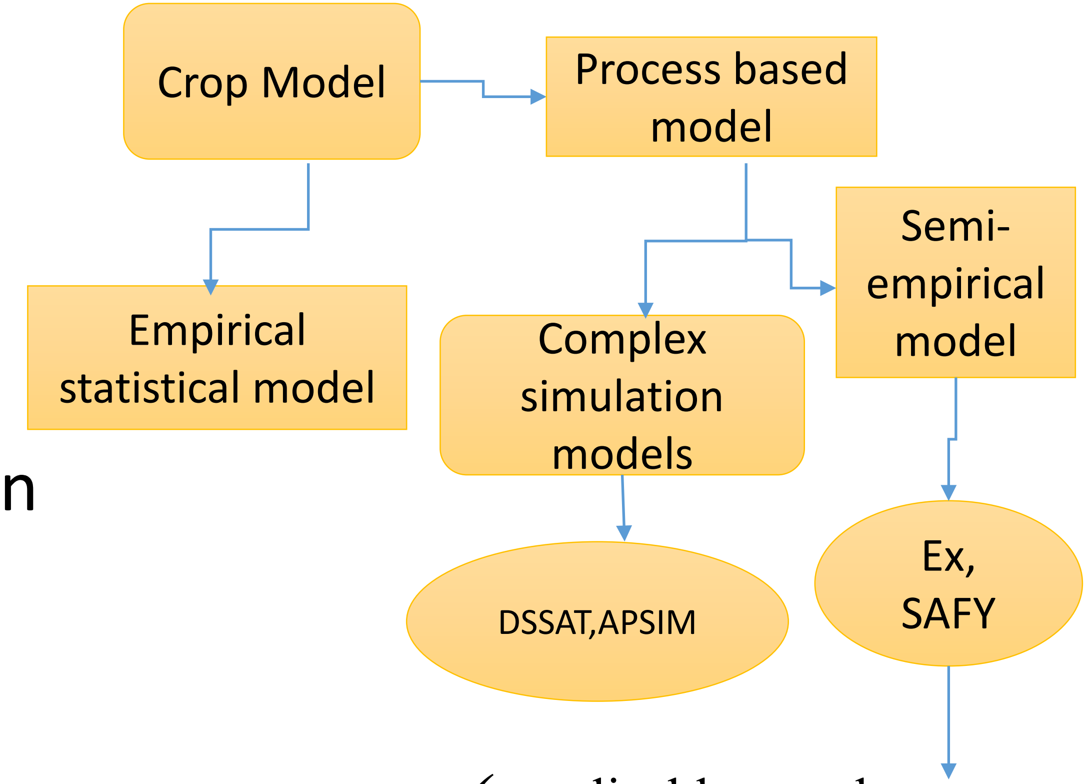
Ch3. Biomass and crop yield estimation for major cereal crops

- Production uncertainty a common problem
- Growing food demand
- Timely and accurate crop yield information is important
- Remote sensing data has a potential for crop biomass and yield estimation
  - But limited efforts

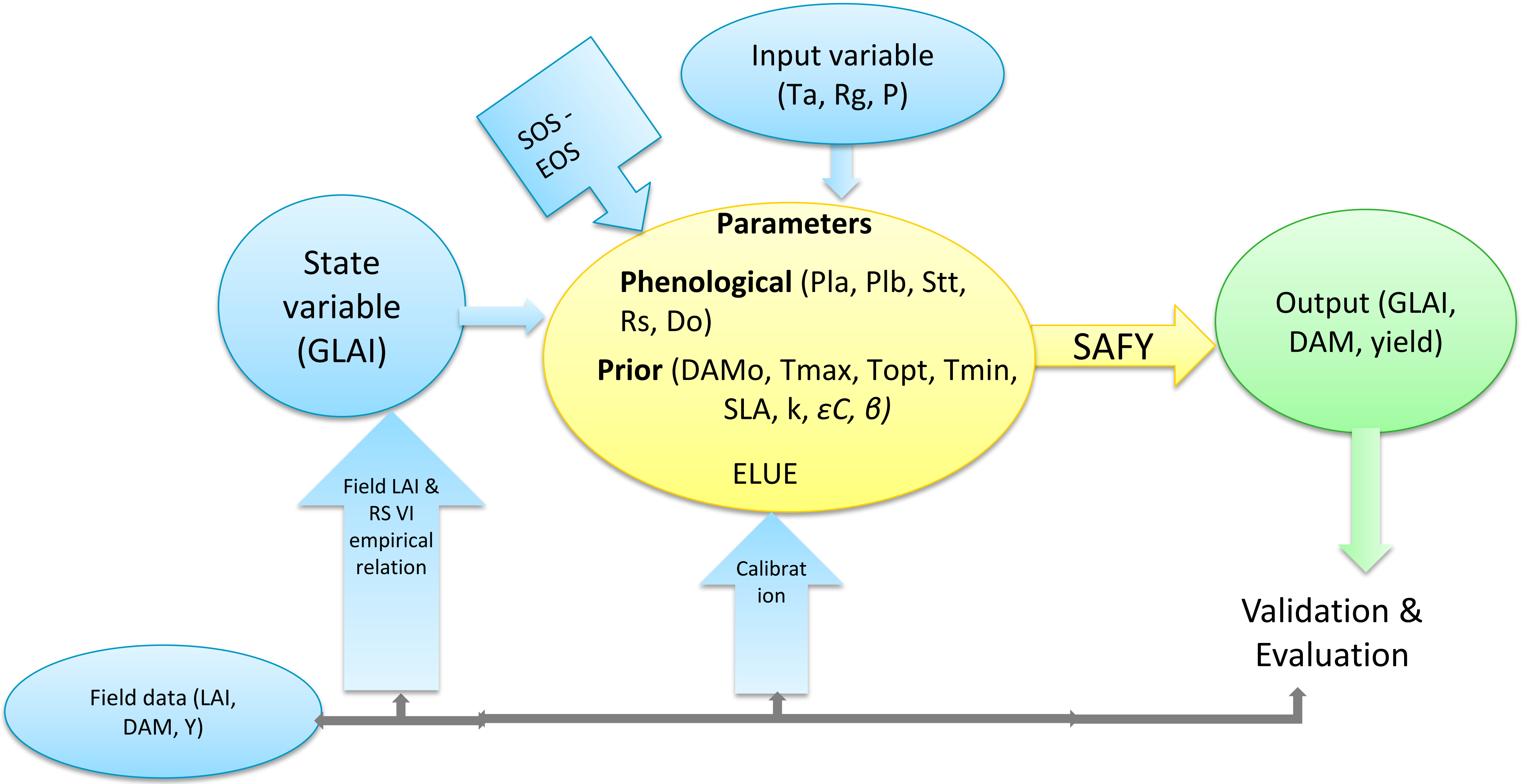


✓ applicable over large area
✓ use satellite data, smaller input parameter

Ch3. Research Question

- Do fused spatial-temporal data improve crop yield estimates in a topographically complex and fragmented landscape?

Ch4. Methodology



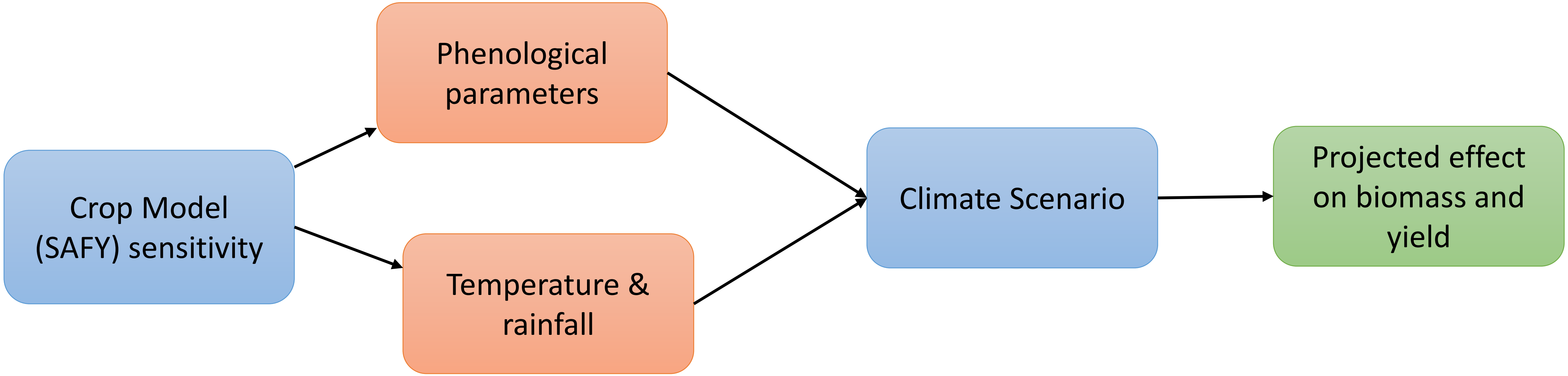
Ch4. Spatiotemporal variability of biomass and yield based on trends of phenological metrics and climate stress factors

- Crop models can be used to assess the response of crops to climate variability
- SAFY uses with few parameters
  - The simplicity of the model and integration of remote sensing data may requires sensitivity analysis
- Parameter SA to rank the relative importance
  - Temperature and rainfall factors
  - Phenology variation (SOS, EOS, LOS),
- Associating trends of phenological parameters over time with production for projecting production impact

Ch4. Research Questions

- What are the dominant parameters and input factors for the spatial and temporal variability of biomass and yield?

Ch4. Methodology



- SA to identify the relative importance for yield variation and predict future impacts on production
- Scenarios for early and late sowing based on representative concentration pathway

Time plan of the research

No	Activities	2019			2020				2021				2022	
		2	3	4	1	2	3	4	1	2	3	4	1	2
1	Preparation for data collection													
2	First round field data collection													
3	Research objective 1 & article 1													
	Data analysis													
	Research writing													
	Review													
	National workshop presentation													
4	Research objective 2 & article 2													
	Data analysis													
	Research writing													
	Review													
	International Workshop participation													
5	Second round field data collection													
	Research objective 3 & article 3													
	Data analysis													
	Research writing													
	Review													
	Research objective 4 & article 4													
	Data analysis													
	Research writing													
	Review													
6	Thesis compilation													

Thank You!

Q & A