

# Projection of Climate-Induced Variations in Global Food Production

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How extreme weather and climate change will affect the stability of major crop production?

We are conducting studies on elucidating the mechanisms and projecting the variations in global food production using the state-of-the-art climate forecast and model that simulate the responses of crop growth and yield to environmental variations and change.

# Increasing Importance of Climate-Induced Variations in Yields, Production and Export Prices



FAO (2013)

## EXTREME WEATHER, EXTREME PRICES

The costs of feeding a warming world



OXFAM Canada (2013)

- Consumers, including the poor, are increasingly dependent on food imports and are thus exposed to variations in yields (export prices) in food-producing regions.
- Given the increased volatility of food markets and the rising incidence of climatic extremes, food price may increase in prevalence in future years.
- Thus, crop failure predictions can provide useful information to food security.

# Crop Failure Forecast

- We conducted a global overview of the reliability of crop failure forecasts for maize, rice, wheat and soybean.
- The key question posed was:

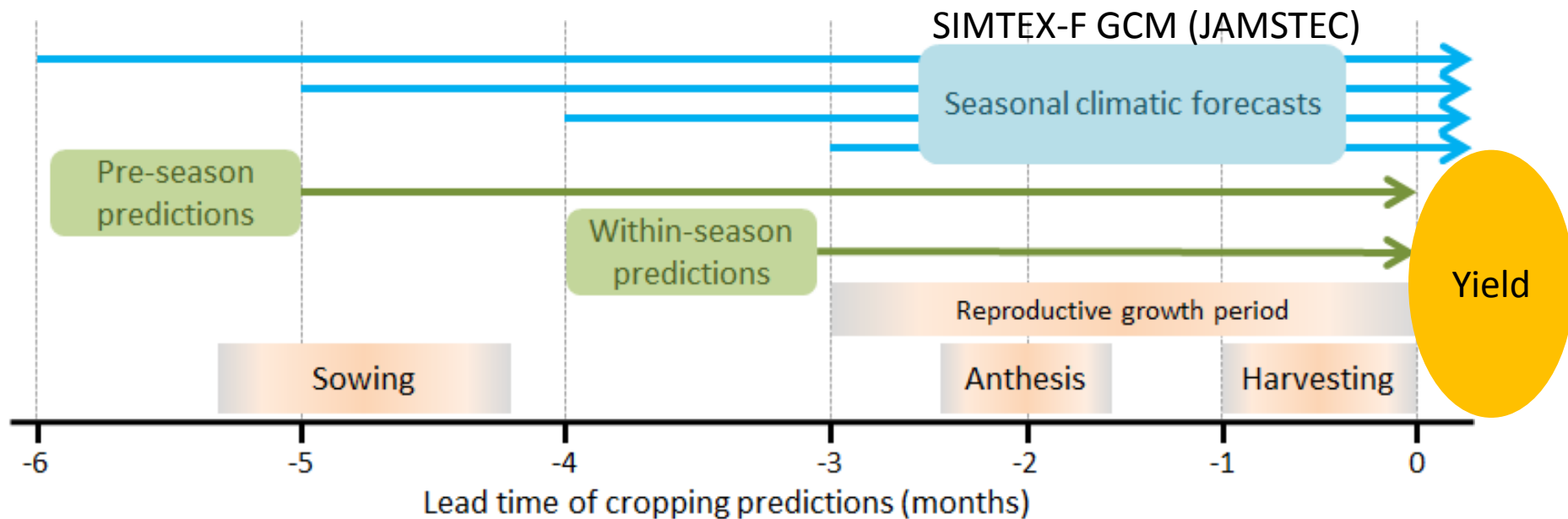
How reliable is the forecasting of crop failure at lead times that allow such information to be of value to governments and commercial concerns?



## Prediction of seasonal climate-induced variations in global food production

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# Yield Predictions Based on Seasonal Climatic Forecasts



- **Pre-season yield predictions** employ climatic forecasts with **lead time of 3—5 months** and provide information on variations in yield for the coming cropping season.
- **Within-season yield predictions** update the pre-season predictions using climatic forecasts with **lead time of 1—3 months**.

# Statistical Crop Model

We developed a **spatially explicit global dataset of historical yields for maize, soybean, rice, and wheat** to explore the year-to-year variation in yields for the period 1982–2006.

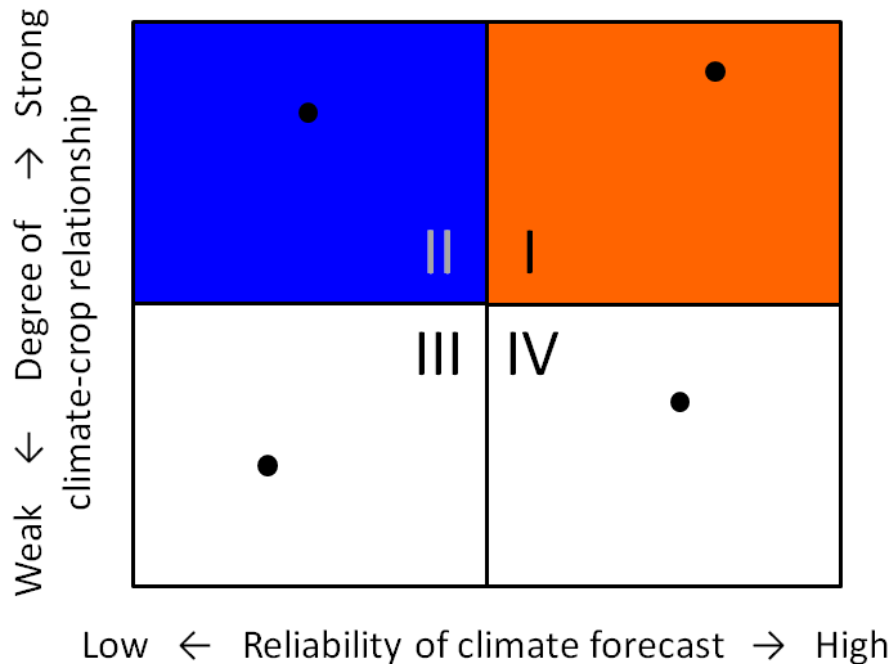
Yearly time series of cropping and climatic data were combined to derive multiple linear regression models:

first-difference time series in **yield ( $\Delta Y$ )**,  
**temperature ( $\Delta T$ )** and **soil water content ( $\Delta SW$ )**

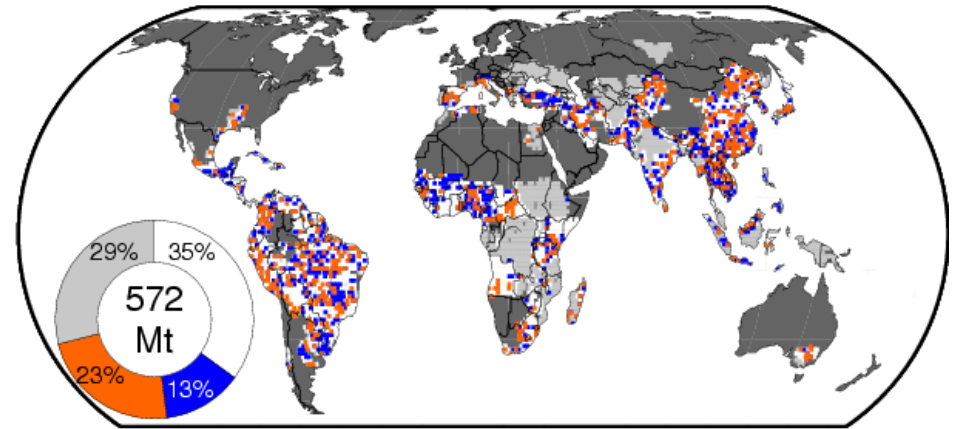
A multiple linear regression model was computed for each cropping system of a crop of interest:

$$\Delta Y = a\Delta T + b\Delta SW + c + \epsilon^2$$

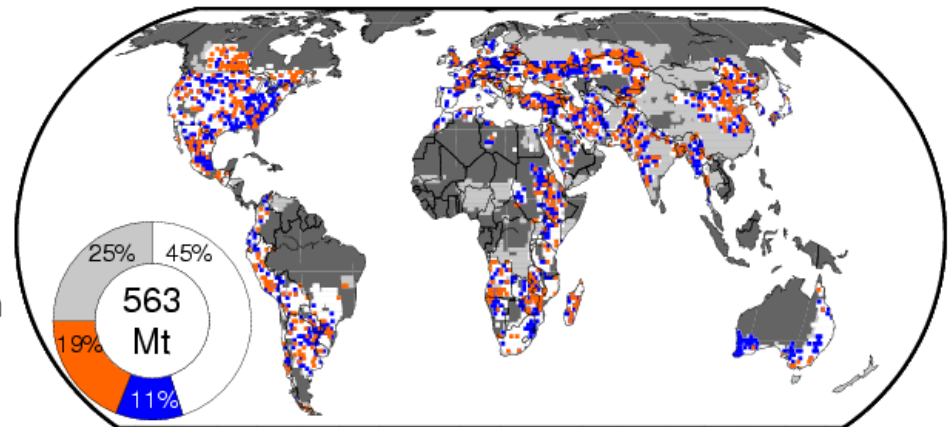
# Evaluation of the Reliability of Within-Season Predictions



## Rice



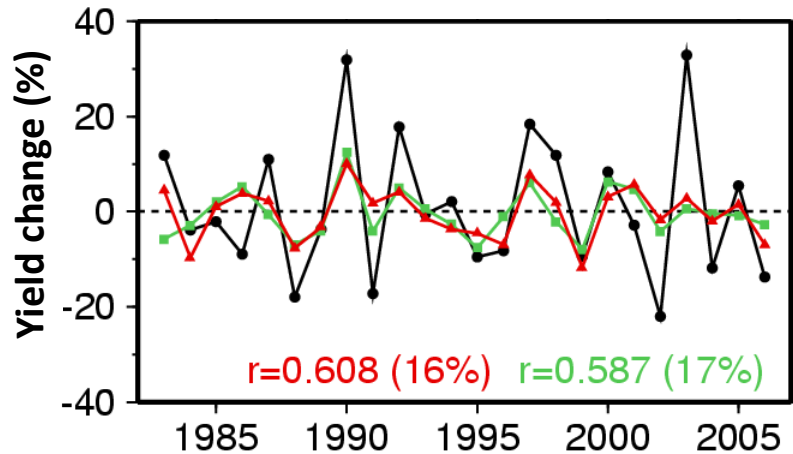
## Wheat



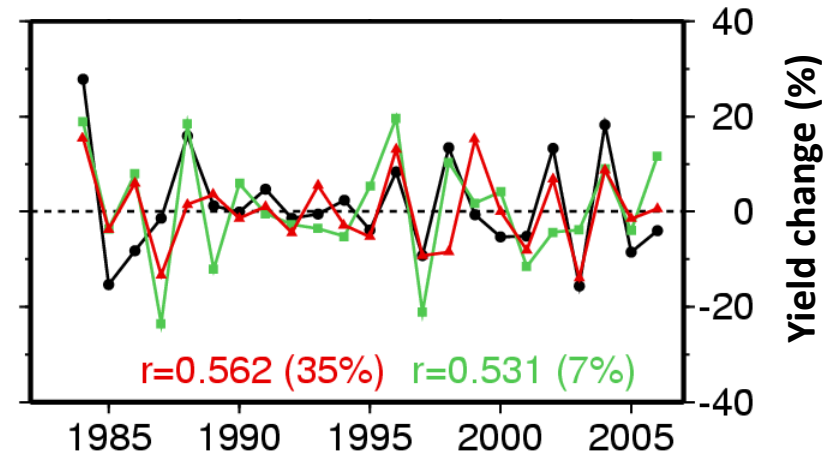
- Moderate-to-marked (5% more) yield losses of rice and wheat over 18—19% of the global harvested area of the crops (correspond to 19—23% of the global production) can be reliably predicted at 3 months before the harvest using within-season prediction.

# Reliability of Wheat Predictions for Exporting Countries

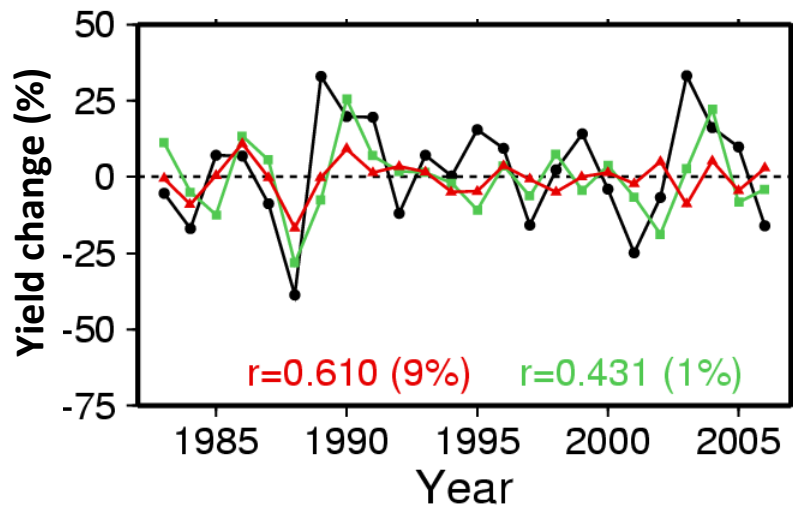
USA (1<sup>st</sup> top exporter)



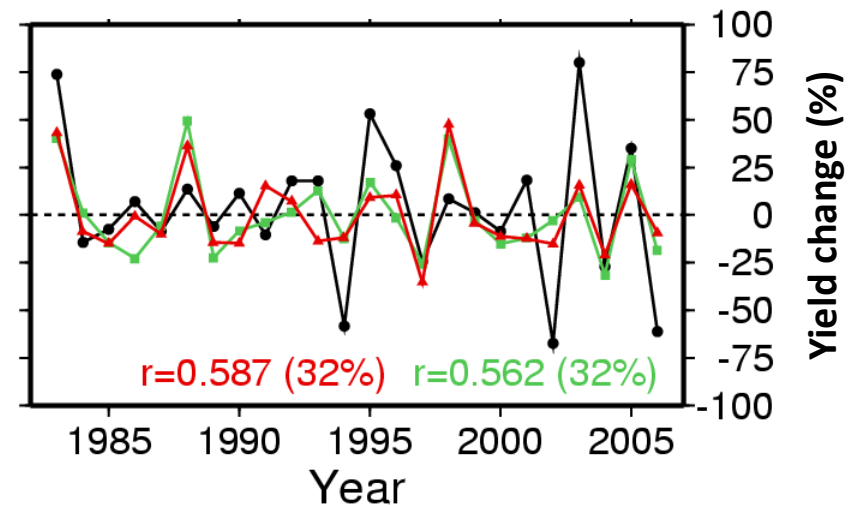
France (2<sup>nd</sup>)



Canada (3<sup>rd</sup>)



Australia (6<sup>th</sup>)



Obs./Within-season/Pre-season

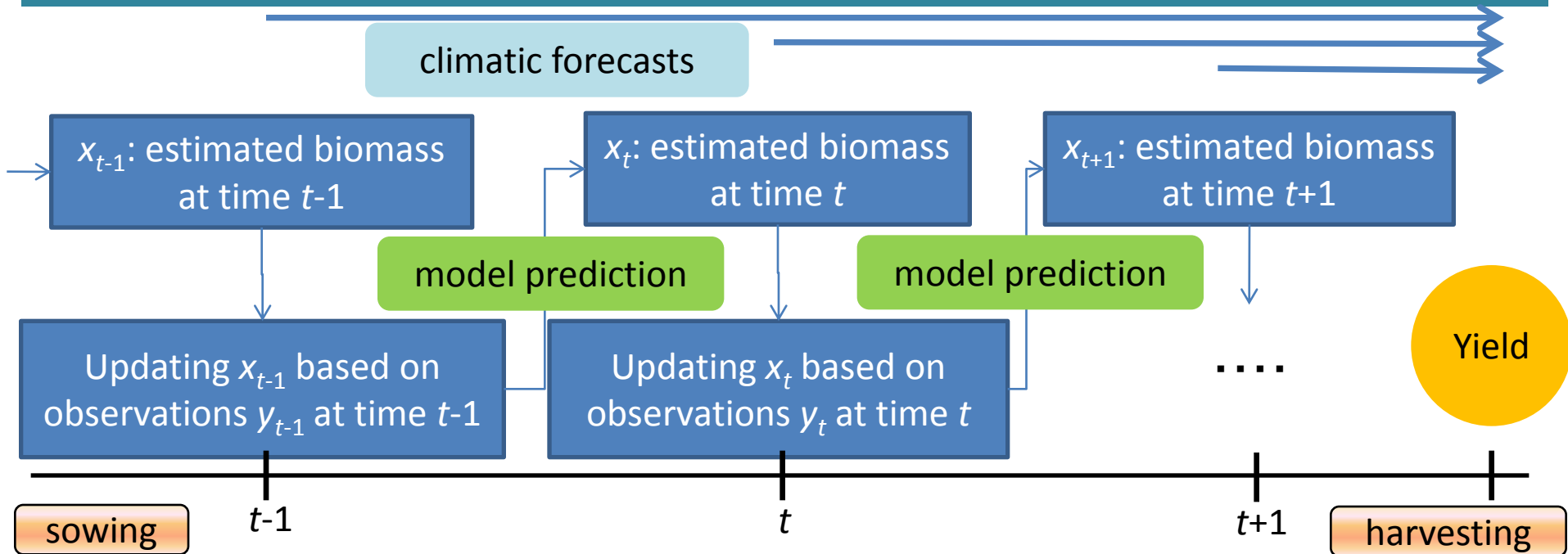
Correlation (Percentage of reliably-predicted area to total harvested area of a crop in a country)



## Remarks

- Crop failures of rice and wheat over a substantial percentage (19–23%) of the global harvested area of these crops can be reliably predicted at 3 months before the harvest.
- The percentages of harvested area (production) of the crops where crop failures of the crops are reliably predictable can increase to 30—33% (31—40%) if climatic forecasts are near perfect.

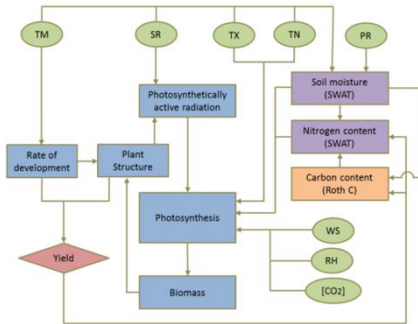
# Further Study: Nowcasting for Food Security



- Nowcasting encompasses a description of the current state of the crops and the prediction of how the crops will grow during the next stage and how much yield harvested.
- The current state of crops is updated with observations.

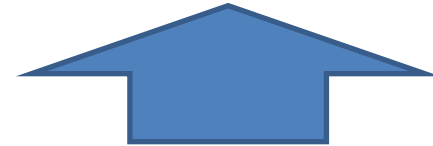
# Biogeochemical Model

## PRYSBI2



wheat  
soybean  
maize  
rice

PRYSBI-2 is a biogeochemical-process-based model that simulate the responses of crop growth and yield to environmental variations.



Under climate change condition, climatic extremes are likely to occur frequently.

Statistical model cannot fully describe the impacts of abrupt changes in environment on crop growth/yield.

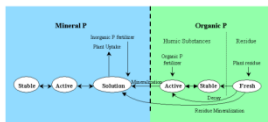


Figure 0-7: Partitioning of Phosphorus in SWAT

**SWAT** | Soil & Water Assessment Tool

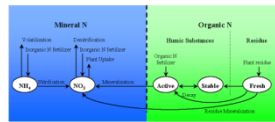


Figure 0-8: Partitioning of Nitrogen in SWAT

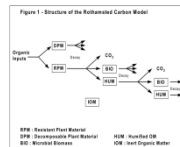


Figure 1: Structure of the RothC Carbon Model

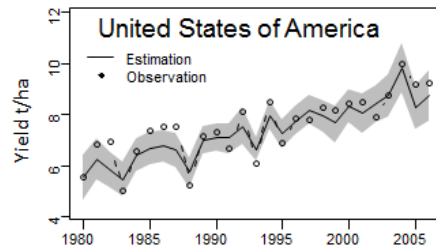
**RothC**

# Biogeochemical Model

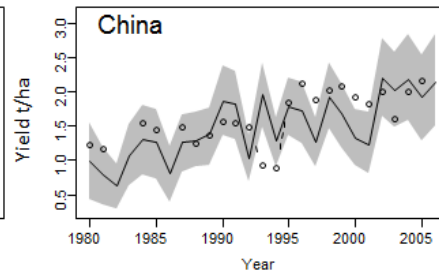
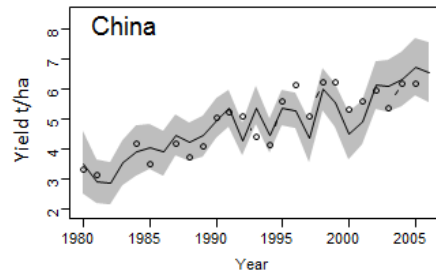
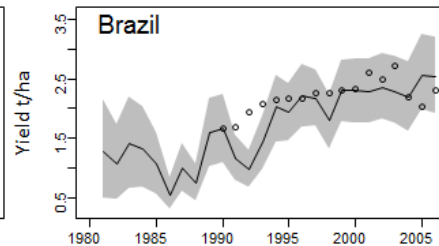
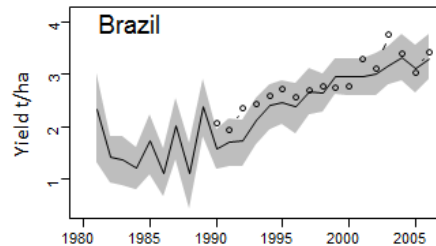
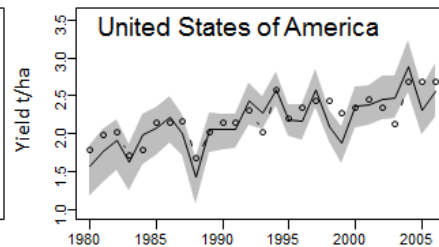
We are developing a biogeochemical process-based model for crop growth/yield to precisely estimate the impacts of climate extremes on agricultural production.

## PRYSBI-2

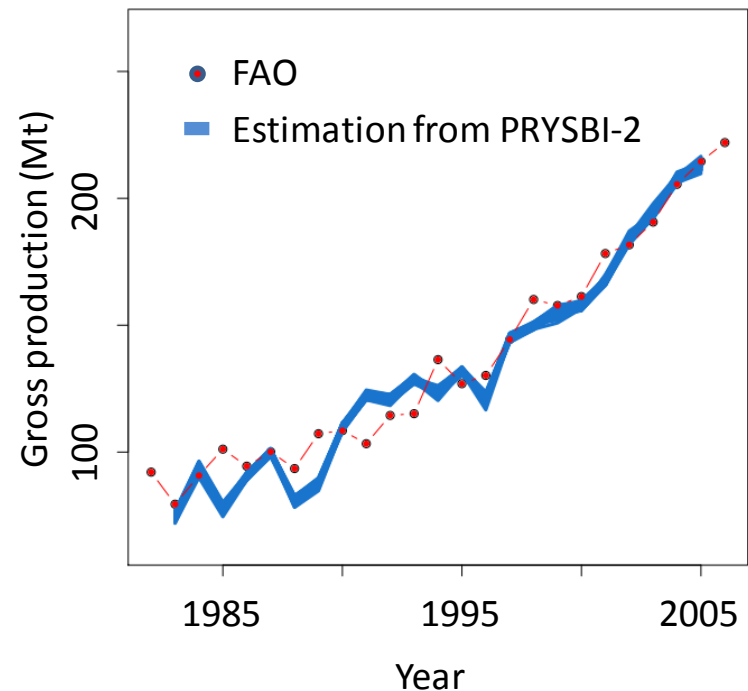
### Maize



### Soybean



## World total of soybean (t)



# Conclusion

The model-data driven yield prediction will be useful for global/regional food security against climatic extremes.

We are developing a nowcasting system for food security together with biogeochemical process-based models, satellite data, observations, seasonal forecasts and so on.

Nowcasting system offers the prospect of more reliable projections, but requires sustained international collaboration and exchange of high-quality data.

Thank you for your kind attention.