미래 기후변화 대응 및 불확실성: 앙상블 접근법의 효용

(기후변화 시나리오 전망 및 예측 기후 정보 활용에서)

정유란

응용사업본부, 응용사업팀, 에이펙 기후센터

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Climate Change

- Climate Variation
  - Uncertainty

- Long-term Climate
  - Adaptation
  - Mitigation

- Impact Assessment
  - Sensitivity
  - Vulnerability

Sustainable Development

Climate Change

- Climate Models

  - various climate models (global climate models, regional climate models)

- Ensemble

  - coupled

  - multi-disciplinary

Future Climate Change Scenarios

- Many Scenarios
  - about 27 GCMs

- low resolution
  - over 100~200 km

mdlnms	Historical						RCP4.5						RCP8.5					
	PR	TX	TN	WD	SR	RH	PR	TX	TN	WD	SR	RH	PR	TX	TN	WD	SR	RH
ACCESS1-0	1	1	1				1	1	1				1	1	1			
bcc-csm1-1-m	1	1	1				1	1	1				1	1	1			
bcc-csm1-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
CanESM2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
CCSM4	1	1	1				1	1	1				1	1	1			
CESM1-BGC	1	1	1				1	1	1				1	1	1			
CESM1-CAM5	1	1	1				1	1	1				1	1	1			
CMCC-CM	1	1	1				1	1	1				1	1	1			
CMCC-CMS	1	1	1				1	1	1				1	1	1			
CNRM-CM5	1	1	1				1	1	1				1	1	1			
CSIRO-Mk3-6-0	1	1	1				1	1	1				1	1	1			
FGOALS-g2	1	1	1				1	1	1				1	1	1			
FGOALS-s2	1	1	1				1	1	1				1	1	1			
GFDL-CM3	1	1	1				1	1	1				1	1	1			
GFDL-ESM2G	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
GFDL-ESM2M	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
HadGEM2-AO	1	1	1				1	1	1				1	1	1			
HadGEM2-CC	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
HadGEM2-ES	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
inmcm4	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
IPSL-CM5A-LR	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
IPSL-CM5A-MR	1	1	1				1	1	1				1	1	1			
IPSL-CM5B-LR	1	1	1				1	1	1				1	1	1			
MIROC-ESM-CHEM	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
MIROC-ESM	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
MIROC5	1	1	1				1	1	1				1	1	1			
MPI-ESM-LR	1	1	1				1	1	1				1	1	1			
MPI-ESM-MR	1	1	1				1	1	1				1	1	1			
MRI-CGCM3	1	1	1				1	1	1				1	1	1			
NorESM1-M	1	1	1				1	1	1				1	1	1			

Issues / Concerns

- When applied Climate Information of climate modes to Other Models

  - Hydrological Models

  - Agricultural Models … (crop models or pest/disease models)
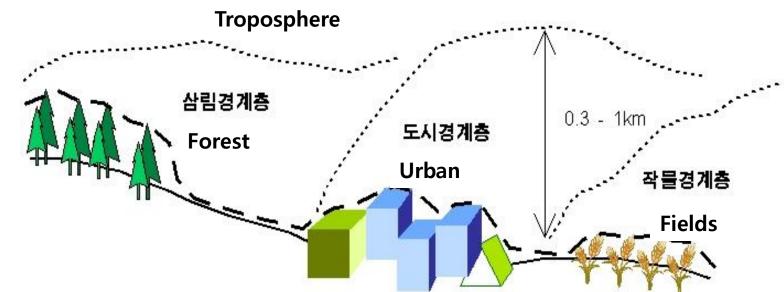
Local/Site-Specific Environment

- Site-specific climate: topography, vegetation, land cover
  - distance, elevation,
  - slope effect,
  - heat island effect, cold air drainage effect etc.

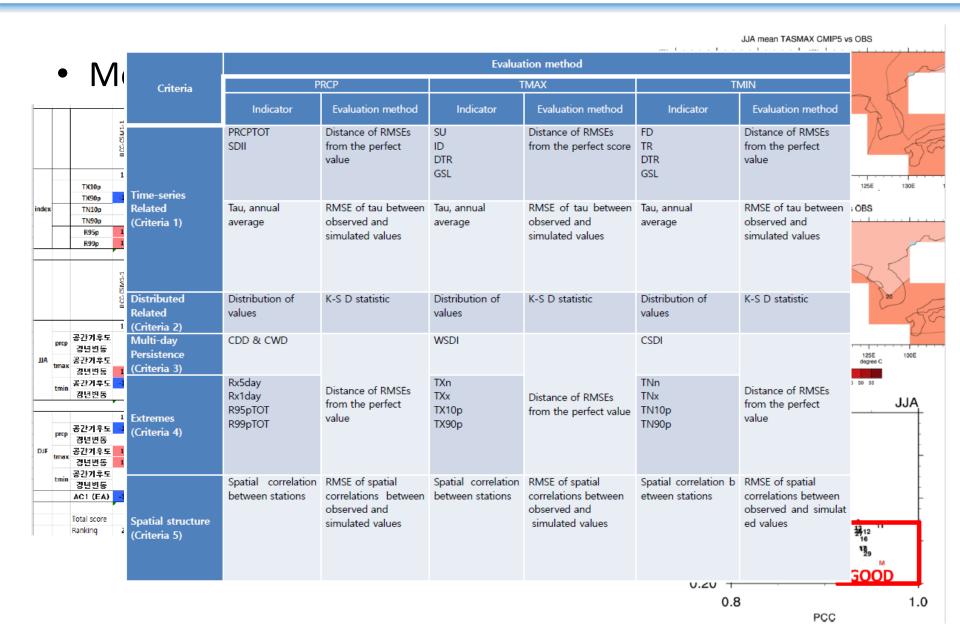- **Downscaling methods**
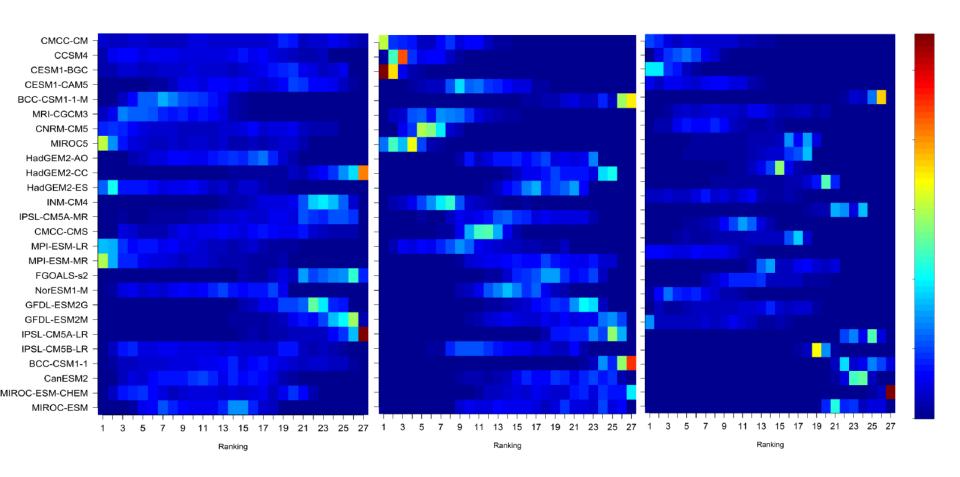 - temporal
  - spatial

Uncertainty of Downscaling

• M

JJA mean TASMAX CMIP5 vs OBS

Criteria	Evaluation method					
	PRCP		TMAX		TMIN	
	Indicator	Evaluation method	Indicator	Evaluation method	Indicator	Evaluation method
Time-series Related (Criteria 1)	PRCPTOT SDII	Distance of RMSEs from the perfect value	SU ID DTR GSL	Distance of RMSEs from the perfect score	FD TR DTR GSL	Distance of RMSEs from the perfect value
	Tau, annual average	RMSE of tau between observed and simulated values	Tau, annual average	RMSE of tau between observed and simulated values	Tau, annual average	RMSE of tau between observed and simulated values
Distributed Related (Criteria 2)	Distribution of values	K-S D statistic	Distribution of values	K-S D statistic	Distribution of values	K-S D statistic
Multi-day Persistence (Criteria 3)	CDD & CWD		WSDI		CSDI	
Extremes (Criteria 4)	Rx5day Rx1day R95pTOT R99pTOT	Distance of RMSEs from the perfect value	TXn TXx TX10p TX90p	Distance of RMSEs from the perfect value	TNn TNx TN10p TN90p	Distance of RMSEs from the perfect value
Spatial structure (Criteria 5)	Spatial correlation between stations	RMSE of spatial correlations between observed and simulated values	Spatial correlation between stations	RMSE of spatial correlations between observed and simulated values	Spatial correlation between stations	RMSE of spatial correlations between observed and simulated values

Uncertainty of Downscaling

- PRCP
- TMAX
- TMIN

Models vs. Models:

Growth Stage of Soybean

- Growing season: timing of planting, flowering, pod development, and seed filling

Growing Period or Growing Season

Criteria abnormal temperature

- Critical growth stages

Crop	Vegetation period		Reproduction period	
	Base Temp.	Range of Opt. Temp.	Range of Opt. Temp.	Failure Temp.
Soybean	10	25-30 (DT), 19-24 (NT)	26-32 (DT), 22-27 (NT)	37

(*Holmberg, 1973; Gibson and Mullen, 1996*)

Crop model simulation:

Crop models

- Crop
  - Cereal: Rice, Maize,
  - Legume: Soybean, Peanut …
  - Root: Potato, Taro …

- Potential Yield

Production situation

		defining factors: CO_2 radiation temperature crop characteristics - physiology, phenology, - canopy architecture … etc
1	*potential*	
2	*attainable*	limiting factors: water nutrients
	Yield-increasing measures	
3	*actual*	reducing factors: weeds pests diseases pollutants
	Yield-protecting measures	

Production level (t/ha)

Climate information:
Observation, …
Long-term climate change scenarios

Simulation

- Observation climate:

  - Normal year:

  - Normal 8110: no high temperature during growing seasons

  - High temp. : high(extreme) temperature occurred during critical periods

- Climate change scenarios:

Results: Observation Climate

- Pod number

Jeonju

Results: Climate change scenarios

- Normal vs. High temperature
  - gray & black line: no high temperature
  - red dot line: high temperature occurred

Miryang

Shift growth stages

- ## Planting Season
  - mid- May to mid-June (to end-June)

  May   June

- ## Changing flowering and grain filling time
  - mid-July and late- August

  July   August

  high temperature frequently occur

Shift growth stages

- **Change planting time**: easy way to avoid extreme cases, such as high temperature or no rainy days (i.e., conditions in which crops can not grow/cultivate well)

- In the case of Korean soybean, usually plant June 10 in the southern region

    - shift (+/-) 5 days (shorten / delay)

    - for example,

        ➢ shorten – May 25, June 5 with based on June 10

        ➢ delay – June 15 etc…

Results

- Relative change on yield planted at June 10

Results

- Relative change on yield planted at June 10

Reproducibility:

Future Climate Change Scenarios

- 9 Climate Change Scenarios (among many scenarios)

  - 8 GCMs

  - 1 RCM

- Simple Quantile Mapping

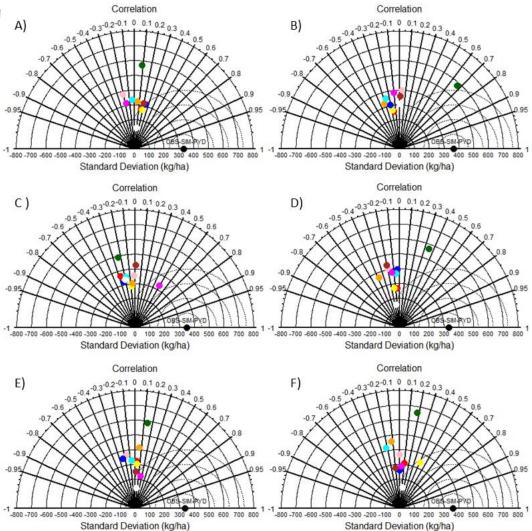| Model	Origin	Country	Resolution
KMA-12km	Korea Meteorological Administation	Korea	12.5km x 12.5km
CanESM2	Canadian Centre for Climate Modeling and Analysis	Canada	2.8° x 2.8°
GFDL-ESM2G	NOAA/GFDL (Geophysical Fluid Dynamic Laboratory)	USA	2.5° x 2.0°
GFDL-ESM2M			
HadGEM2-CC	Meteorological Office Hadley Center	UK	1.88° x 1.25°
inmcm4	Institute for Numerical Mathematics	Russia	2° x 1.5°
IPSL-CM5A-LR	Institute Pierre Simon Laplace	France	3.75° x 1.8°
MIROC-ESM	Atmosphere and Ocean Research Institute, National Institute for Environmental Studies, and Japan Agency for Marine-Earth Science and Technology	Japan	2.8° x 2.8°
MIROC-ESM-CHEM			

Reproducibility of predicted yield

- Reproducibility
    - past climate(weather) at the growth stages

    - necessary to analyze in more detail whether the downscaled climate data from GCMs during the major crop growth periods reproduced the observed climate accurately enough, and to evaluate the plant responses in the crop model.
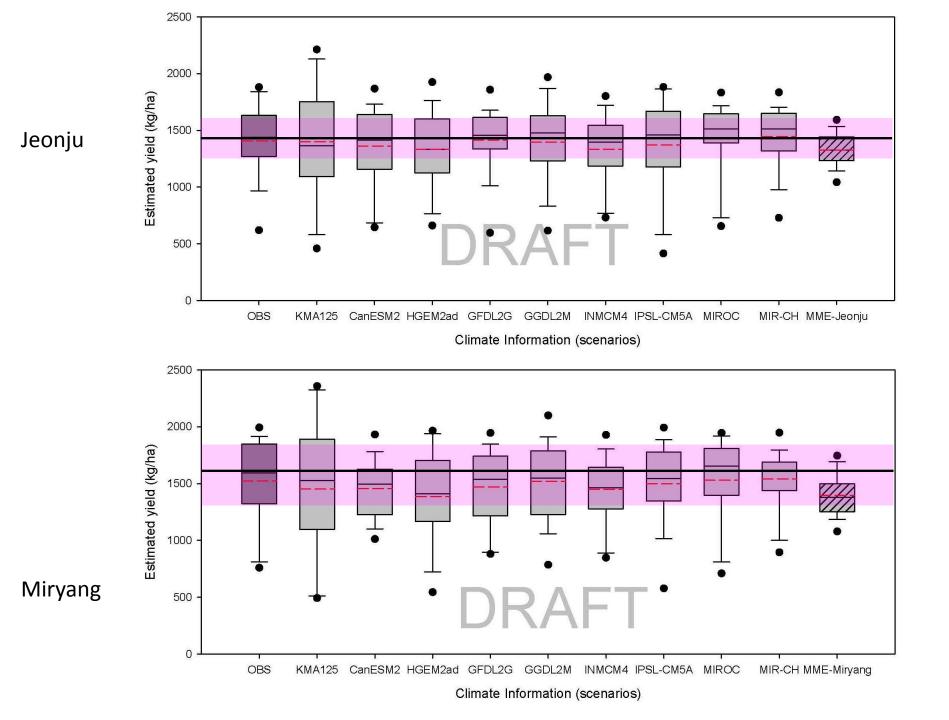
Chung U, Kim YU, Seo BS, Seo MC (2017) Evaluation of Variation and Uncertainty in the Potential Yield of Soybeans in South Korea Using Multi-model Ensemble Climate Change Scenarios. Agrotechnology 6: 158. doi: 10.4172/2168-9881.1000158)

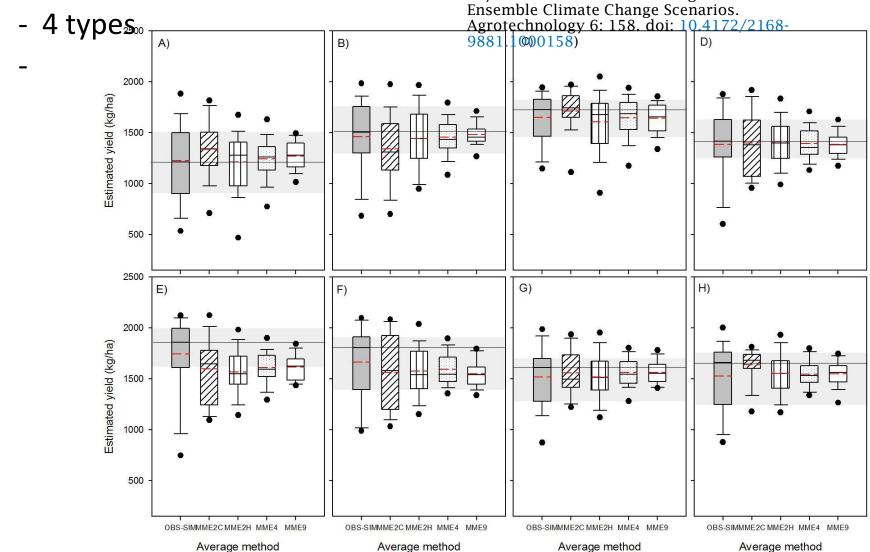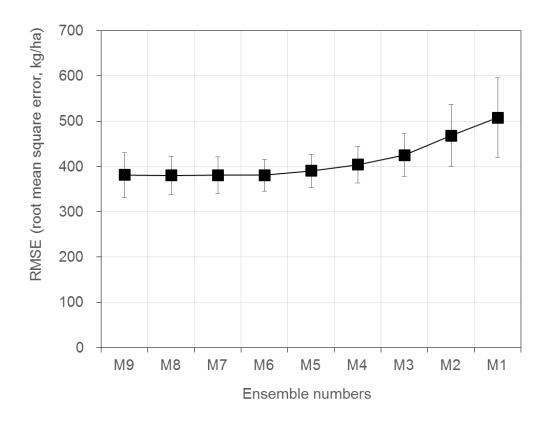# Multi-Model Ensemble (MME):
Ensemble averaging

Jeonju

Miryang

Multi Model Ensemble Methods

- Ensemble averaging types
  - 4 types
  -

Chung U, Kim YU, Seo BS, Seo MC (2017) Evaluation of Variation and Uncertainty in the Potential Yield of Soybeans in South Korea Using Multi-model Ensemble Climate Change Scenarios. Agrotechnology 6: 158. doi: 10.4172/2168-9881.1000158)

Number of participating

- Number of participating in MME simulation
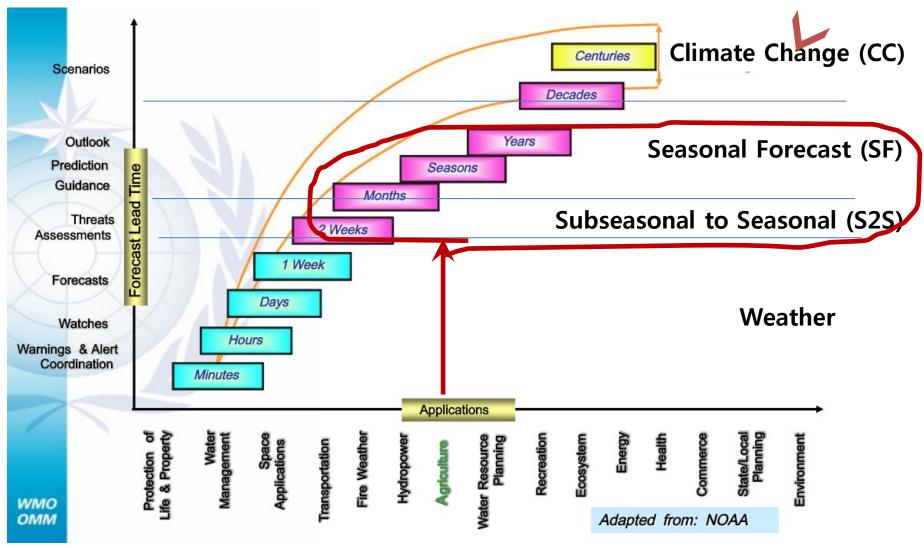 - the estimation error decreased as the number of GMCs in ensemble averaging

Forecast information:

Seasonal (1~6 ms) and Sub-Seasonal (7~30 days) forecast information

Additional

➢ Multi-range climate information

Source: http://slideplayer.com/slide/1447561/

Case study: **Project Overview**

Forecast mixing in daily time-step (S2S and Seasonal)

Hydrology (watershed modeling)	**Agriculture (Crop modeling)**

drought forecast information & weights for models

week~months

Drought forecast using machine learning and R/S (SPI, …)	**Drought forecast using Seasonal forecast(EDI)**

Down-scaling	**Down-scaling**	**Down-scaling**

Remote Sensing	**S2S Forecast**	**Seasonal Forecast**	**Climate Change**

Risk components for Risk Assessment Framework

Risk Assessment & management Framework
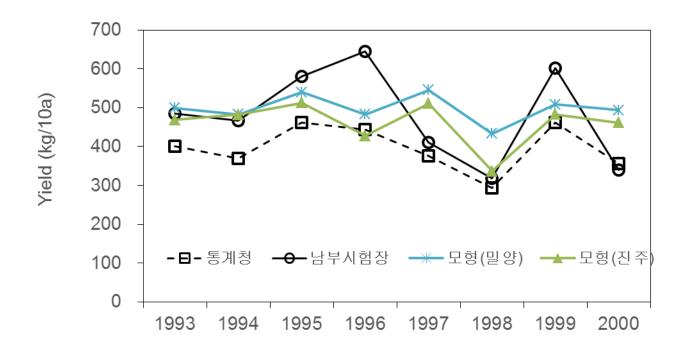
Crop Responses (Seasonal)

- Crop Model Simulation based on multi-scale climate information

    1) Assessment change of cropping calendar from Seasonal Forecast information

        - example, change planting(sowing) day, or suggest rotated crop

2) Assessment critical growth stages of crop responses (or yield components) from S2S information

- in cropping season: 1~2 weeks (within 7 ~ 15 days)

- 3 critical periods (e.g., 1~2 weeks after planting, flowering period, or grain filling period during reproductive period, those periods are within 7~15 days)
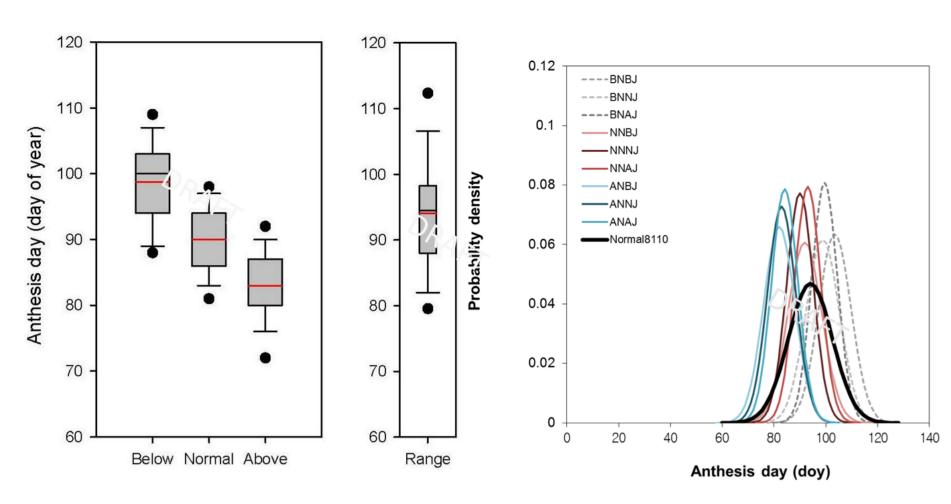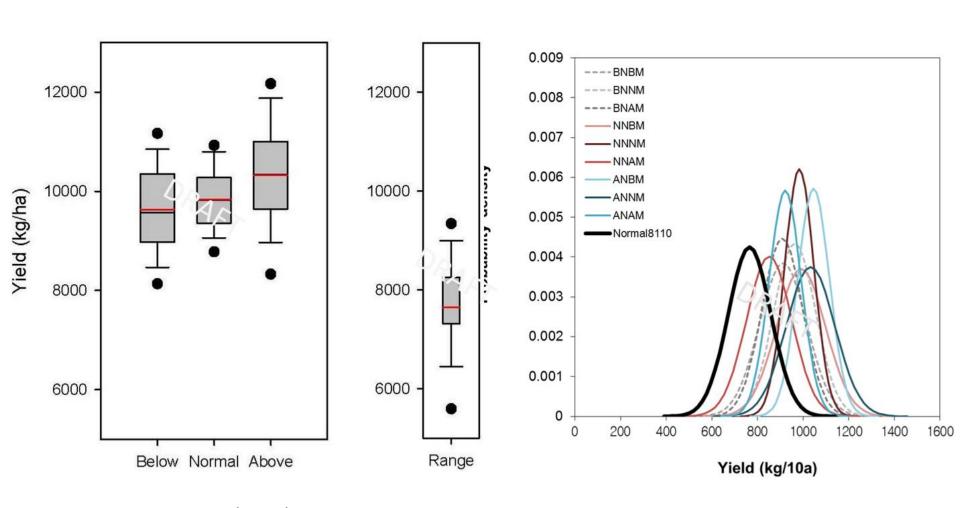
쌀보리 유전모수 추정 후, 모형 결과 비교

Winter Seasonal Forecast

Jinju (winter barley: 쌀보리)

Winter Seasonal Forecast
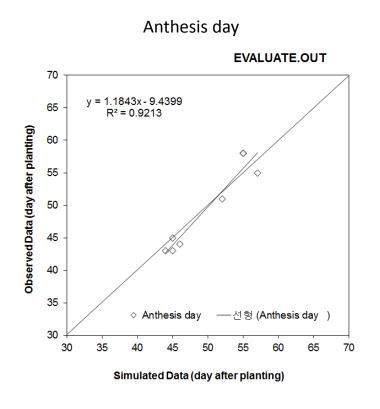

Jinju (winter barley: 쌀보리)

Conclusions:

Breeding & Plant Physiology: Genetic information < <u>Big Data</u>
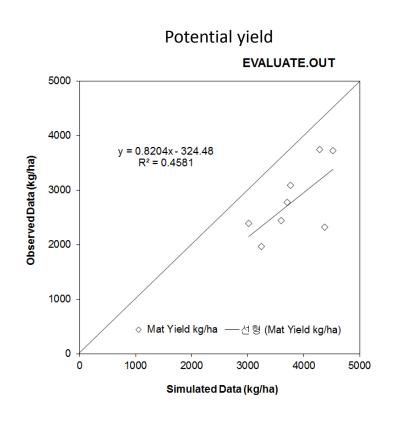
Multi-Disciplinary Researches < <u>Ensemble</u>

Conclusions – I: Genetic Information

- example: TaeGwang (medium and late maturity)

	CSDL	PPSEN	EM-FL	FL-SH	FL-SD	SD-PM	FL-LF	LFMAX	SLAVR	SIZLF	XFRT	WTPSD	SFDUR	SDPDV	PODUR	THRSH	SDPRO	SDLIP
Taegwang	12.70	0.32	18.71	4.92	9.52	35.84	9.56	1.03	350.00	300.00	1.00	0.19	10.10	1.35	29.28	78.00	0.40	0.20

Anthesis day

Potential yield

Anthesis day chart: EVALUATE.OUT, y = 1.1843x - 9.4399, R² = 0.9213

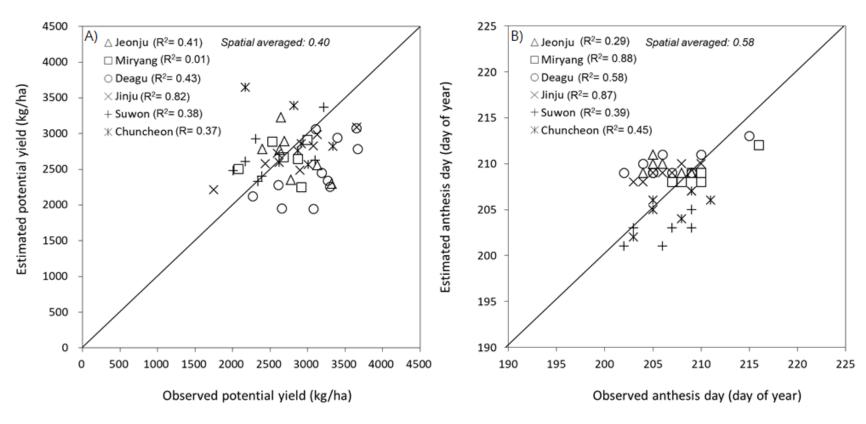Potential yield chart: EVALUATE.OUT, y = 0.8204x - 324.48, R² = 0.4581

Genetic Information

- Evaluation genetic properties of TaeGwang
  - 16 sites

정유란, 신평, 서명철 (2017): 작물모형의 생물계절 및 잠재수량 예측력 개선 방법 탐색: I. 유전 모수 정보 향상으로 콩의 개화시기 및 잠재수량 예측력 향상이 가능한가? 한국농림기상학회 (in printed).

Conclusions - II: multi-disciplinary study

- multi-sectors combined approach

  - breeding

  - plant physiology
    (phenology)

  - agro-climatology

  - crop modeling

  - socioeconomics

Bio-economic approach

Bio-physical

Socio-economic

Combined under the extreme weather events

Chung et al., 2014: Modeling the effect of a heat wave on maize production in the USA and its implications on food security in the developing world. *Weather and Climate Extreme*, v5-6, 67-77.
(doi: 10.1016/j.wace.2014.07.002)

'4차 산업혁명과 GIS' 온라인 세미나

4차 산업혁명 시대의 성패를 좌우할 '데이터'
특별한 지식 없이도 누구나 데이터 분석 전문가가 될 수 있는 방법을 소개합니다

더 알아보기

'4차 산업혁명' 어떻게 준비하고 계신가요?

모든 것이 데이터화되는 4차 산업혁명 시대의 핵심은 '데이터 활용' 입니다. 막대한 양의 데이터를 어떻게 수집, 분석, 활용하는지가 성패를 좌우하기 때문입니다. 그러므로 경쟁력을 확보하기 위해서는 데이터 기반 조직으로 변화해야 하며, 데이터 분석가뿐 아니라 조직 내 구성원 모두가 데이터를 이해하고 활용할 수 있어야 합니다.

경청해 주셔서 감사합니다.
Q & A

정유란
(uran.chung@gmail.com/uchung@apcc21.org)
응용사업팀, 에이펙 기후센터

APCC APEC CLIMATE CENTER