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Water and Food Relationship Evaluation on WEF Nexus in Greenhouse with Water Stress and Soil Condition

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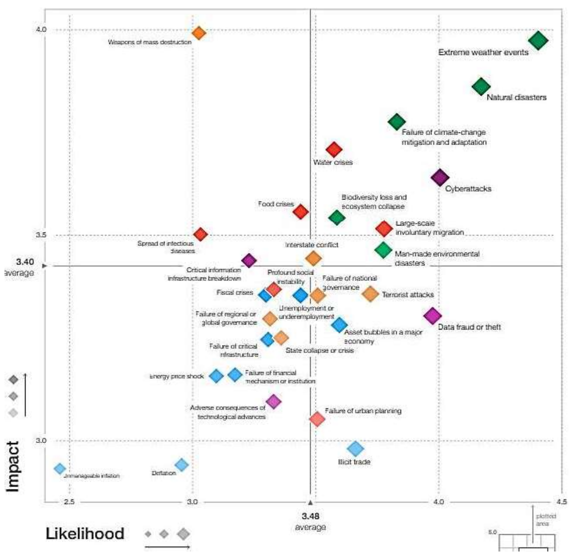
I Introduction

Water-Energy-Food Nexus

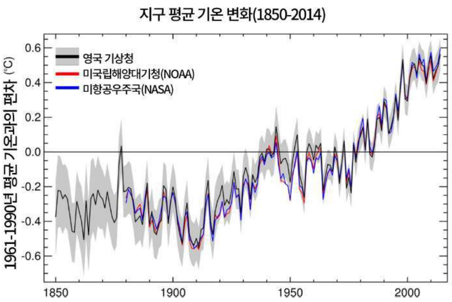
- ❖ Population growth ⋯ **food production demand** increased, **water and energy use** also increased.
- ❖ **Climate change** ⋯ crop yields decreases, **food production instability** increased → **Food security**
  ⋯ temperature and precipitation change, extreme events, difficulty in securing water resources
  → **Water security**
- ❖ Water and food, energy security → 10 most likely and influential **global risk factors & SDGs**



I Introduction

Water-Energy-Food Nexus

- ❖ As sustainability issues of important resources are presented, it is necessary to analyze the relationship between limited resources (water-food-energy).
- ❖ **2011 World Economic Forum** ··· the concept of "Water-Food-Energy Nexus" to interpret the linkage of water, energy, and food resources and to suggest an integrated management plan
- ❖ **Various scenarios application, trade-off analysis** ··· evaluation of the sustainability of water, energy, and food resources



자료출처 : 세계기상기구(WMO), 2014

I Introduction

NEXUS in Greenhouse (Protected cultivation)

- ❖ One of the best examples of water-energy-food nexus application
- ❖ Protected cultivation ··· **Resource intensive farming**
  → high productivity, few time and space constraints, enable production throughout the year
- ❖ Demand for good quality, stable supply throughout the year increases → greenhouse industry increases
- ❖ **Nexus in Greenhouse (Protected cultivation)**
  - Cut off outdoor environmental conditions (temperature, precipitation, wind speed etc.)
  - Put resources (water, energy) in order to provide an appropriate growth environment for crops
  - **Testbed for analyzing the trade-off between resources/ Various scenarios application**


I Introduction

Importance & Purpose

To evaluate the relationship between water and food resource

among the Water-Energy-Food Nexus

in greenhouse with water stress and soil condition

- ❖ To estimate the **crop yields** and **irrigation water requirement** by the environmental **temperature condition** of the greenhouse
- ❖ To simulate the response of the crops to **water stress and soil fertility stress** influencing the crop growth and water productivity

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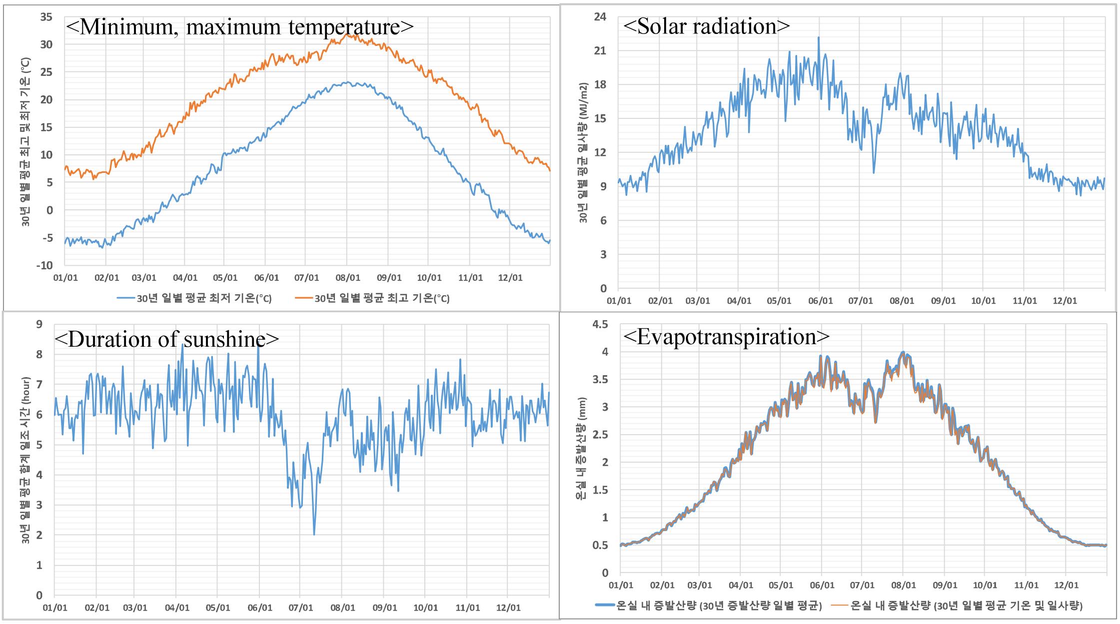
II Materials & Method

Study Area

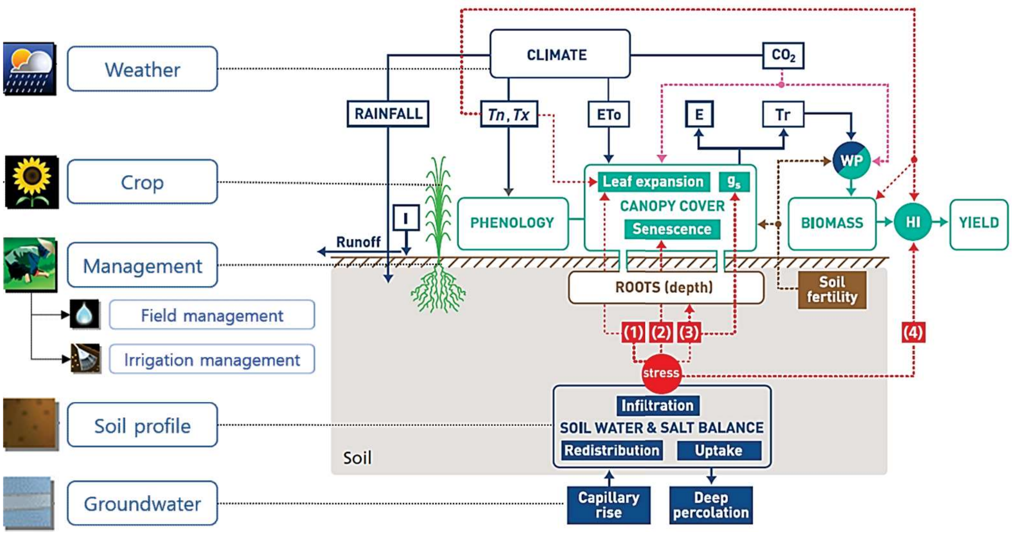
- ❖ Study area: Greenhouse cultivation area, Danmok-ri, Jinju, South Korea
- ❖ Crop: **Tomato**, Hot pepper, Squash/ Greenhouse cultivation implemented a year round
- ❖ Weather data: 30-years daily climate data applied → **1-year standard temperature model**
- ❖ **Scenarios by the inner temperature, irrigation method (water stress), soil fertility condition**



II Materials & Method

Crop Growth Simulation Model: AquaCrop (FAO)

- ❖ Analyzing the effect of **weather condition, water stress, fertilizer, irrigation method** on **crop yield, evapotranspiration and irrigation water requirement**
- ❖ Simulating the **response of crops to water → crop productivity, water efficiency** research
- ❖ Accounting for the dynamic effects of water, temperature stress and CO_2 concentration on crop growth



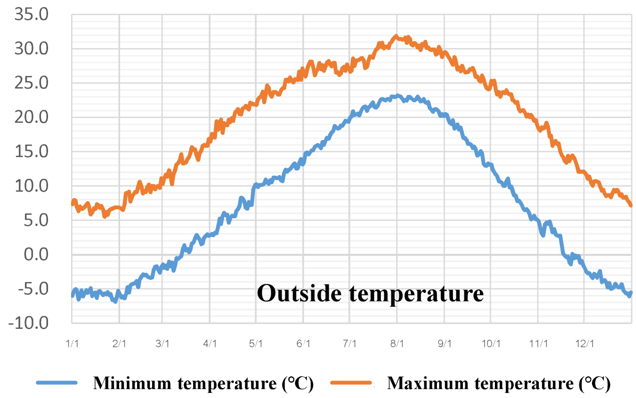
AquaCrop training handbooks, Understanding AquaCrop (FAO, 2017)

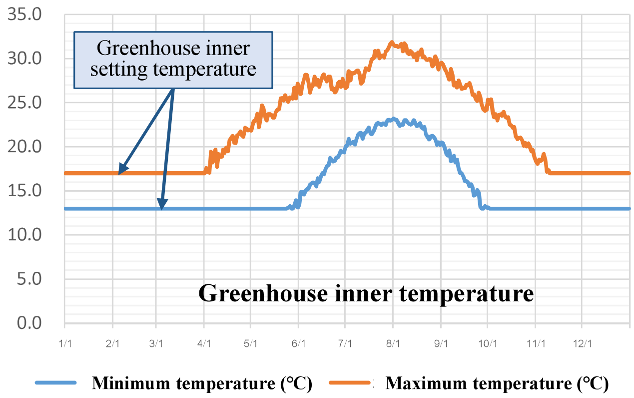
II Materials & Method

Scenarios

❖ **Temperature scenario (Greenhouse inner temperature)**

- Jinju (1981-2017) 30-years weather data → **1-year standard temperature model building**
- Temperature scenarios based on the greenhouse inner setting temperature (Min 14℃ to Max 30 ℃)





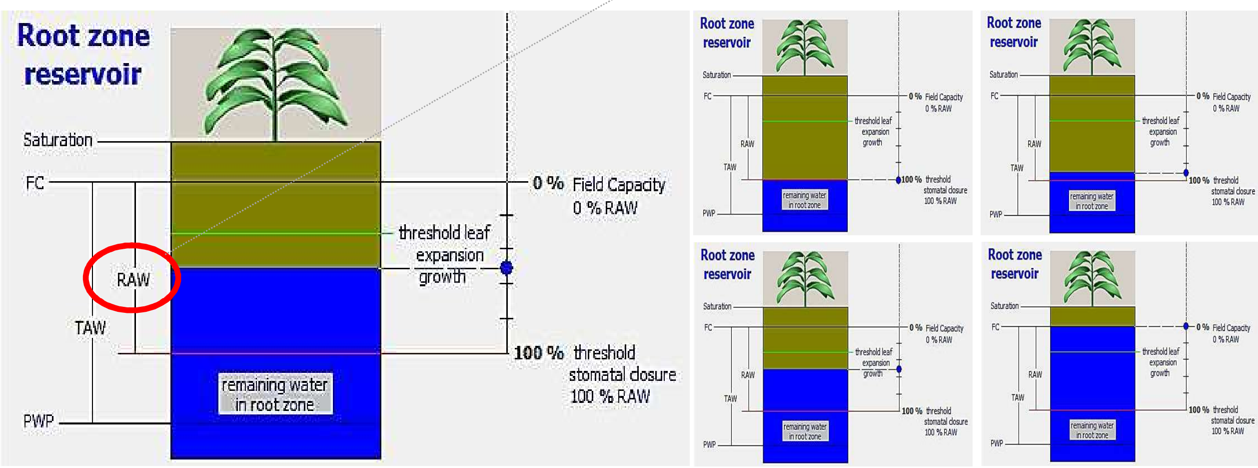
Heating energy
(Greenhouse setting temperature cases)

II Materials & Method

Scenarios

❖ **Water stress scenario** ··· according to the soil water content (**RAW**: Readily Available soil Water)

→ Not irrigated, irrigated at the point of 10%, 50% RAW remained, Potentially irrigated



❖ **Soil fertility stress scenario** → soil fertility stress 0 – 70% (Potential, Optimal, Moderate, Half, Poor, Very poor)

	Potential	Optimal	Moderate	Half	Poor	Very poor
Soil fertility stress	0%	23%	42%	51%	59%	69%

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III Result & Discussion

Crop yield, Irrigation water requirement simulation results

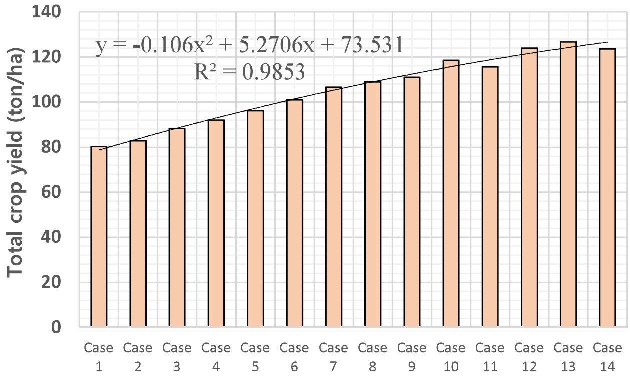
❖ **Annual crop yield, irrigation water requirement, water productivity results by AquaCrop**

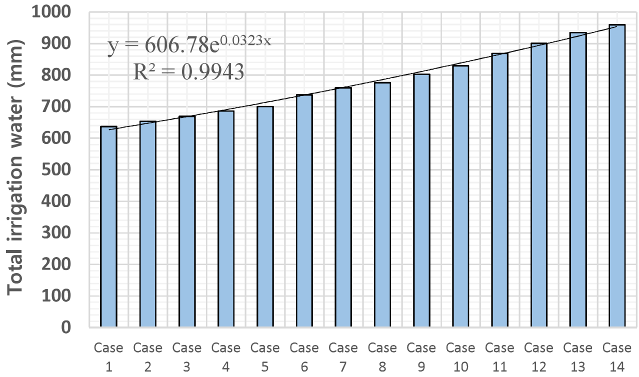
Case	T min (℃)	T max (℃)	Total crop yield (ton/ha/year)	Total irrigation water requirement (mm)	Water productivity (ton/ha/mm)
Case 1	13	17	80.2	636.9	0.126
Case 2	14	18	82.9	654.1	0.127
Case 3	15	19	88.3	669.4	0.132
Case 4	16	20	92.0	686.3	0.134
Case 5	17	21	96.2	700.5	0.137
Case 6	18	22	100.9	737.1	0.137
Case 7	19	23	106.5	759.7	0.140
Case 8	20	24	109.0	775.8	0.140
Case 9	21	25	111.0	803.1	0.138
Case 10	22	26	118.4	829.6	0.143
Case 11	23	27	115.6	868.4	0.133
Case 12	24	28	123.9	900.8	0.138
Case 13	25	29	126.7	934.5	0.136
Case 14	26	30	123.6	959.3	0.129

III Result & Discussion

Crop yield, Irrigation water requirement simulation results

❖ **Annual crop yield, irrigation water requirement, water productivity results by AquaCrop**



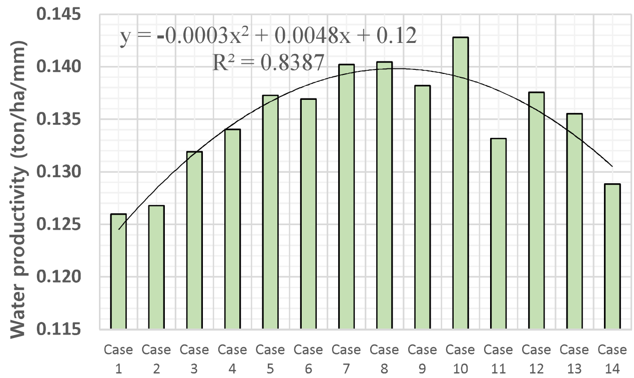


Water productivity

$$= \frac{Crop\ yield\ (ton/ha)}{Irrigation\ water\ (mm)}$$

❖ Concept that links crop yield and agricultural water use

❖ **Indicator of agricultural water use efficiency**

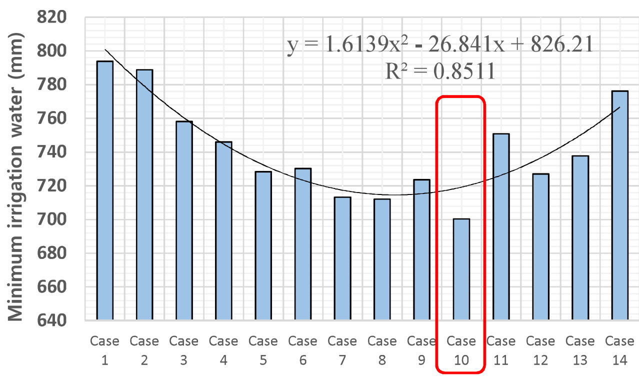


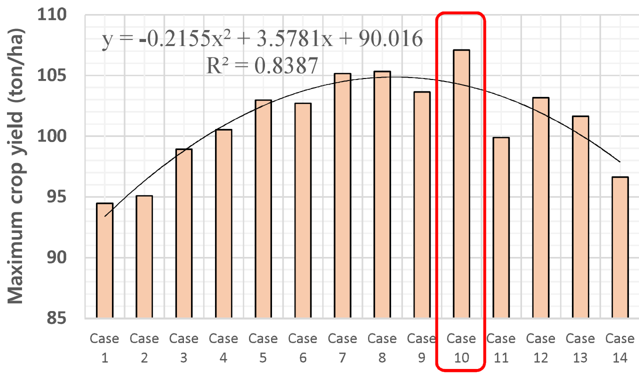
III Result & Discussion

Scenario applications (Example)

❖ **Scenario application of crop yield and irrigation water simulation results**

Scenario	**Scenario 1** **Crop yield >100 ton/ha**	**Scenario 2** **Irrigation water <750 mm**
Case	**Minimum irrigation water**	**Maximum crop yield**
Case 1	793.9	94.5
Case 2	788.8	95.1
Case 3	758.1	98.9
Case 4	746.1	100.5
Case 5	728.4	103.0
Case 6	730.3	102.7
Case 7	713.3	105.1
Case 8	712.0	105.3
Case 9	723.6	103.6
Case 10	700.4	107.1
Case 11	750.9	99.9
Case 12	727.0	103.2
Case 13	737.8	101.6
Case 14	776.2	96.6





III Result & Discussion

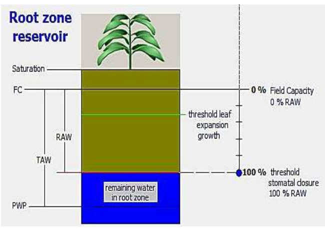
Crop growth and water stress simulation results

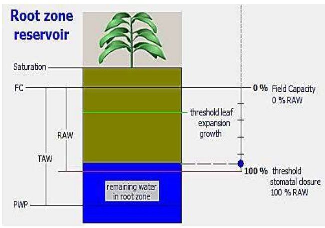
❖ **Case 10 > Water stress scenario**

➢ Irrigation according to the soil water content (RAW: Readily Available soil Water)

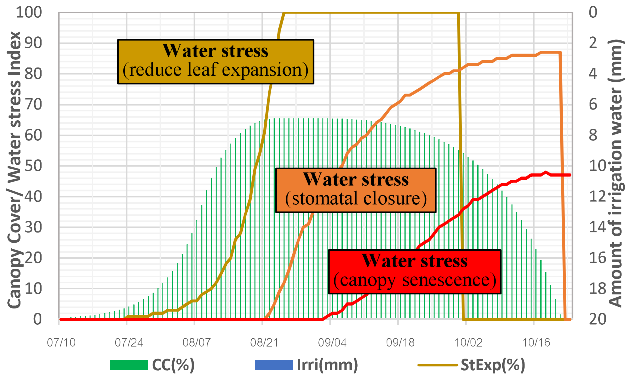
➢ **Crop yield, Irrigation water simulation**

	Biomass (ton/ha)	Crop yield (ton/ha)	Irrigation water (mm)
Not irrigated	6.04	3.41	0
Irrigated at 10% RAW remained	12.97	8.17	135.8
Irrigated at 50% RAW remained	13.42	8.47	191.4
Irrigated at 100% RAW remained (potential)	13.48	8.50	307.7

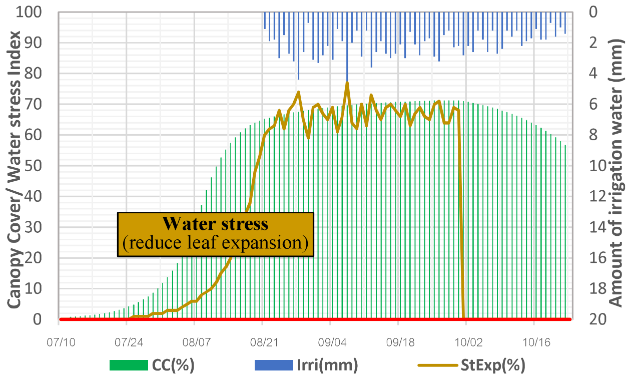




※ StExp >> Percent water stress reducing leaf expansion
※ StSto >> Percent water stress inducing stomatal closure
※ StSen >> Percent water stress triggering early canopy senescence



<Not irrigated (Threshold stomatal closure)>



<Irrigated at 10% RAW remained>

III Result & Discussion

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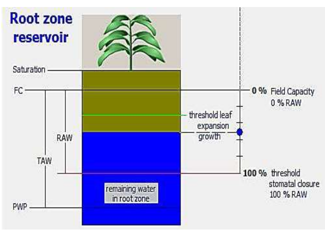

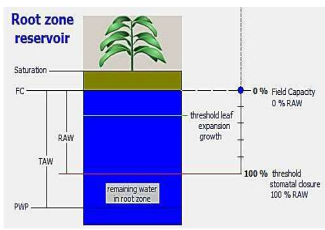

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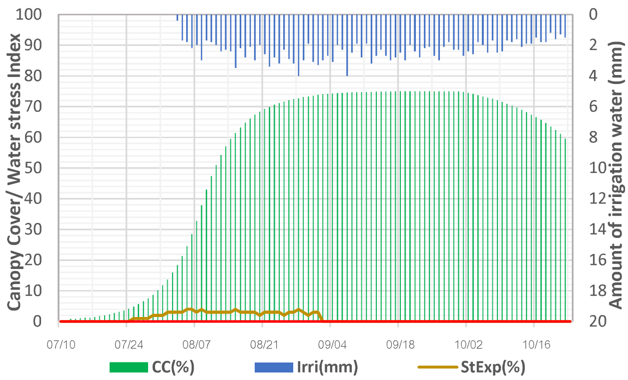
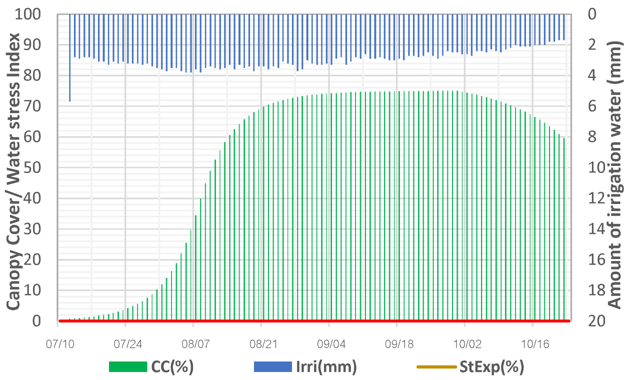


<Irrigated at 50% RAW remained>



<Irrigated at 100% RAW remained (potential)>

III Result & Discussion

Crop growth and soil fertility stress simulation results

❖ **Case 10 > Soil fertility stress scenario**

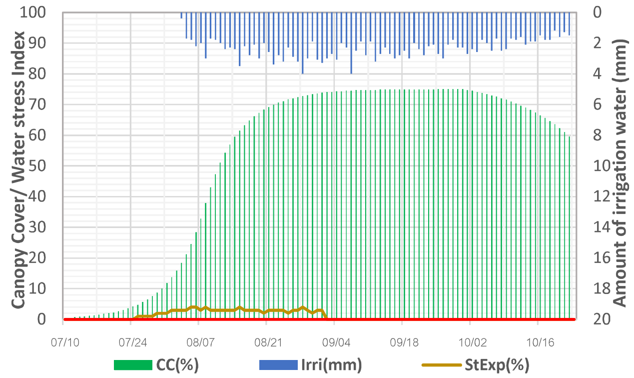
➢ **Crop yield, Irrigation water simulation**

	Soil fertility stress	Biomass (ton/ha)	Yield (ton/ha)	Irrigation water (mm)	Water productivity
Potential	**0%**	13.42	8.45	191.4	4.42
Optimal	**23%**	10.77	6.79	174.1	3.90
Moderate	**42%**	8.09	5.10	150.8	3.38
Half	**51%**	6.70	4.22	136.9	3.08
Poor	**59%**	5.43	3.42	122.3	2.80
Very poor	**69%**	3.90	2.45	101.5	2.42

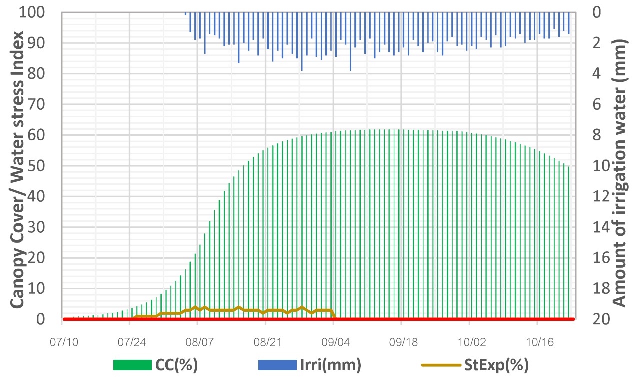
➢ Soil fertility stress has a **negative effect** on **crop yield** and **water productivity**

➢ Soil fertility ··· **the amount of fertilizer**

→ Concepts linked to **energy resources, cost**



<Potential (Soil fertility stress 0%)>



<Optimal (Soil fertility stress 23%)>

III Result & Discussion

Crop growth and soil fertility stress simulation results

❖ **Case 10 > Soil fertility stress scenario**

➢ **Crop yield, Irrigation water simulation**

	Soil fertility stress	Biomass (ton/ha)	Yield (ton/ha)	Irrigation water (mm)	Water productivity
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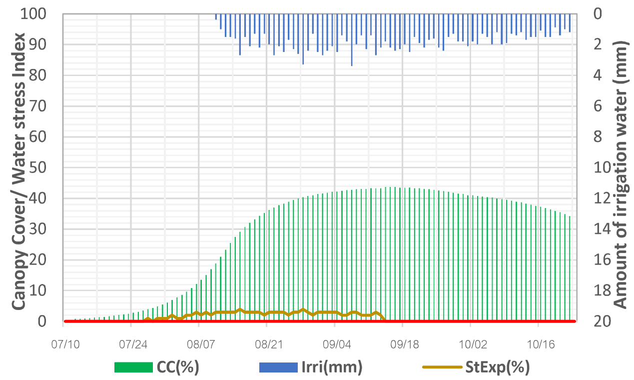
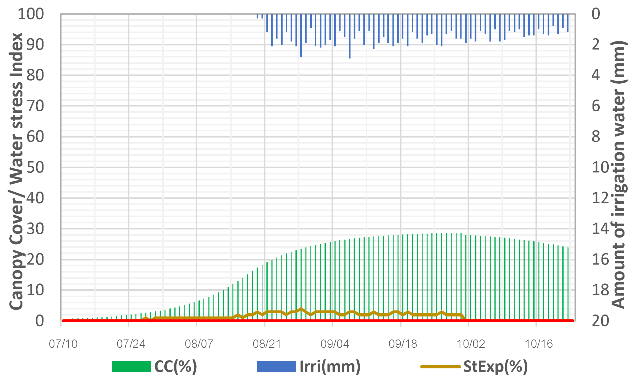


<Half (Soil fertility stress 51%)>



<Very poor (Soil fertility stress 69%)>

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IV Conclusion

Summary of results & Future study

❖ **Summary of results**

1) **Protected cultivation** ··· environmental condition adjustment, production throughout the year
2) **Temperature increases** → both **crop yield and irrigation water tend to increase**
   The increasing slope ··· **crop yield**: **decreased**, **irrigation water**: **increased** (exponential function)
3) **Water productivity** ··· indicator of **water use efficiency** → policy, decision making with various scenarios
4) **Water stress** ··· no significant difference in the crop yield (50% RAW, Potential) → **water use efficiency**
5) **Soil fertility stress** ··· the amount of fertilizer → **energy resource and cost**

IV Conclusion

Summary of results & Future study

❖ **Limitation**

➢ 1-year total crop yield, irrigation water … by multiplying the **unit yield and irrigation water per day for the growing period** → Calibration by field survey and statistical data

❖ **Future study and implication**

1) Application to **various testbeds** such as paddy field and upland field
2) **Inventory building** with various testbeds, field data and simulation results
3) **Selecting the efficient scenarios** based on **constraints or goals** by analyzing the relationship between food and water resources
4) Building W-E-F Nexus through linkage analysis with **energy resources (cost)** … **policy evaluation, decision-making tool**

Thank you for your attention !