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Assessment of Ecosystem Productivity and Efficiency based on Flux Measurement: A case study of Haenam Farmland in Korea

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Contents:

Study background

What is Climate-Smart Agriculture (CSA) ?

Global vision initiated by **FAO** to ensure food security, to mitigate climate change, and to preserve the natural resources, **through three objectives**

1. **Sustainability increasing productivity and income**
2. **Adapting and building resilience to climate change**
3. **Mitigating GHG emissions**

e.g. Lipper et al., 2014

Study background

On going concern of CSA (e.g. Lipper et al., 2014; Rosenstock et al., 2016)**:**

✓ building scientific evidences and appropriate assessment tools
  - The need of robust studies in different ecological-societal system;

✓ Assessing the synergies and/or trade-off on the three objectives
  - The need of scientifically credible and relevant integrated indicators of ecological-societal systems as the assessment tools.

Study background

The use of **indicators** as quantitative assessment.

Direction of indicator (Nielsen and Jørgensen, 2013):

- biotic indicator (i.e. related to already well-known and well-established classical indices);
- network indicator (i.e. come from information theory and entropy measure) and
- thermodynamic indicator (i.e. derived from physics either first or second law of thermodynamics)

Study background

The availability of long term data is important for CSA assessment to capture the important change in the system.

Flux tower measurement provide:

- ✓ quantitative assessment of energy, matter and information flows in ecosystem
- ✓ time series data for a considerable long period with diverse variables from wide range of environments
- ✓ the availability of global network with open access data

The **purpose of this study:**

- ✓ to assess the ecosystem productivity and efficiency of an agricultural system toward achieving the first objective of CSA.

Materials and Methods

CSA indicators used in this study

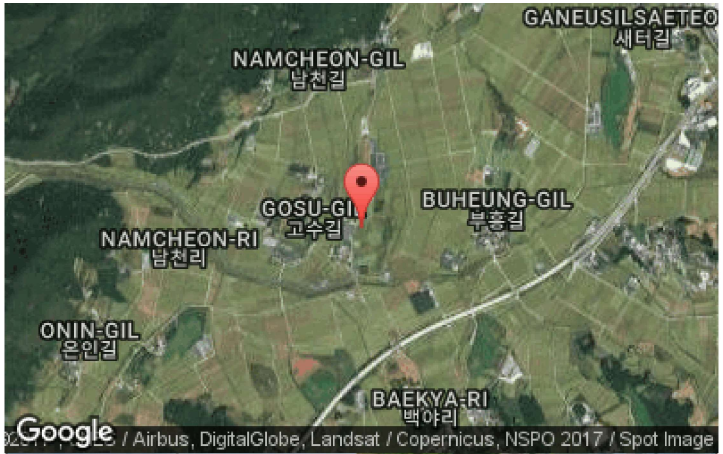
CSA Objective	Direction	Category	Indicator
Sustainability increasing productivity	Biotic	Productivity	gross primary productivity (GPP) (g C m^{-2}) (Kwon et al., 2009)
		Efficiency	Carbon efficiency (CUE) (unitless) = GPP/RE (Odum, 1969)
			Water use efficiency (WUE) (g C kg H_2O^{-1}) = GPP/ET (e.g. Ponton et al., 2006)
			Light use efficiency (LUE) (g C MJ^{-1}) = GPP/APAR (e.g. Gitelson and Gamon, 2015)

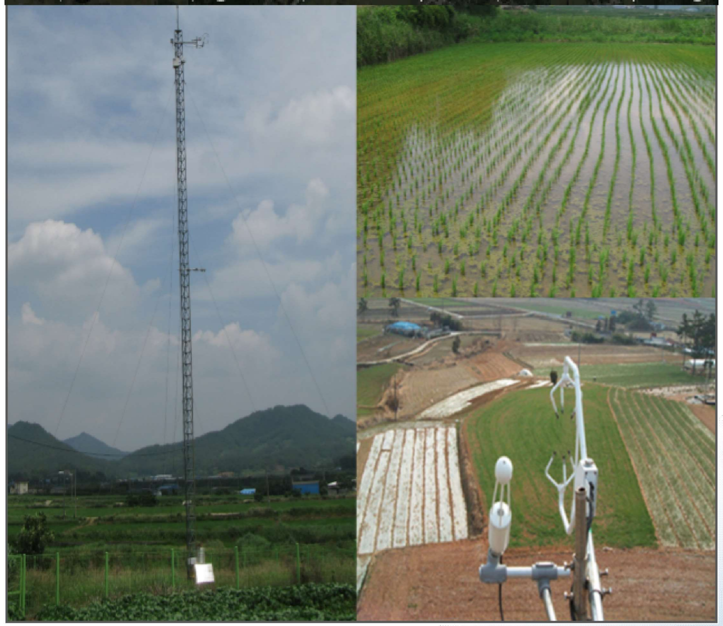
Materials and Methods

Flux and micrometeorological measurement

Site information

Location	Haenam-gun, Jeollanamdo, Korea
Position	34.55° N, 126.57° E
Elevation	13.74 m a.s.l.
Slope	2°
Fetch	~ 2000 m
Vegetation type	Rice , barley, seasonal vegetable, bean
Rice growing season	June to October





Results and Discussions

Meteorological condition

Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	avg	std
Rsdn (M J m^{-2})	2251	2432	2382	2365	2357	2333	2404	2336	2338	2423	2506	2366	2454	2381	62
Rsup (M J m^{-2})	410	436	450	436	435	430	435	420	425	425	464	609	464	449	48
Rldn (M J m^{-2})	5027	5106	5142	5228	5275	5276	5189	5312	5240	5237	5320	5272	5223	5219	81
Rlup (M J m^{-2})	5651	5733	5750	5737	5785	5782	5710	5764	5727	5729	5795	5676	5695	5733	41
Rnet (M J m^{-2})	1217	1368	1323	1421	1413	1397	1447	1464	1427	1506	1566	1354	1518	1417	87
Ta (°C)	20.9	21.8	22.3	21.4	21.8	22.1	21.8	22.6	21.9	22.1	22.8	20.8	21.5	21.8	0.6
P (mm)	1050	1208	770	872	1050	661	858	629	701	710	534	385	566	769	224
ET (mm)	348	391	330	349	339	375	344	386	369	423	378	341	343	363	26
LAI max (m^2 m^{-2})	4.6	5.5	5.1	5.2	6.8	5.7	5.2	7.0	5.4	6.0	6.6	5.1	5.9	5.7	0.7

Results and Discussions

CSA objective : Productivity and Efficiency during rice growing season from 2003 to 2015

Indicator	'03	'04	'05	'06	'07	'08	'09	'10	'11	'12	'13	'14	'15	AVG	Std
GPP ($g\ C\ m^{-2}$)	812	860	937	892	778	912	818	869	822	831	878	875	919	**862**	**45**
WUE ($g\ C\ kg\ H_2O^{-1}$)	2.42	2.20	2.84	2.63	2.44	2.44	2.48	2.23	2.32	1.93	2.47	2.73	2.83	**2.46**	**0.25**
CUE (-)	1.15	1.28	1.17	1.15	1.00	1.31	1.27	1.21	1.16	1.06	1.14	1.21	1.20	**1.18**	**0.08**
LUE ($g\ C\ MJ^{-1}$)	1.41	1.47	1.59	1.54	1.29	1.43	1.11	1.38	1.39	1.21	1.19	1.42	1.16	**1.35**	**0.14**

Results and Discussions

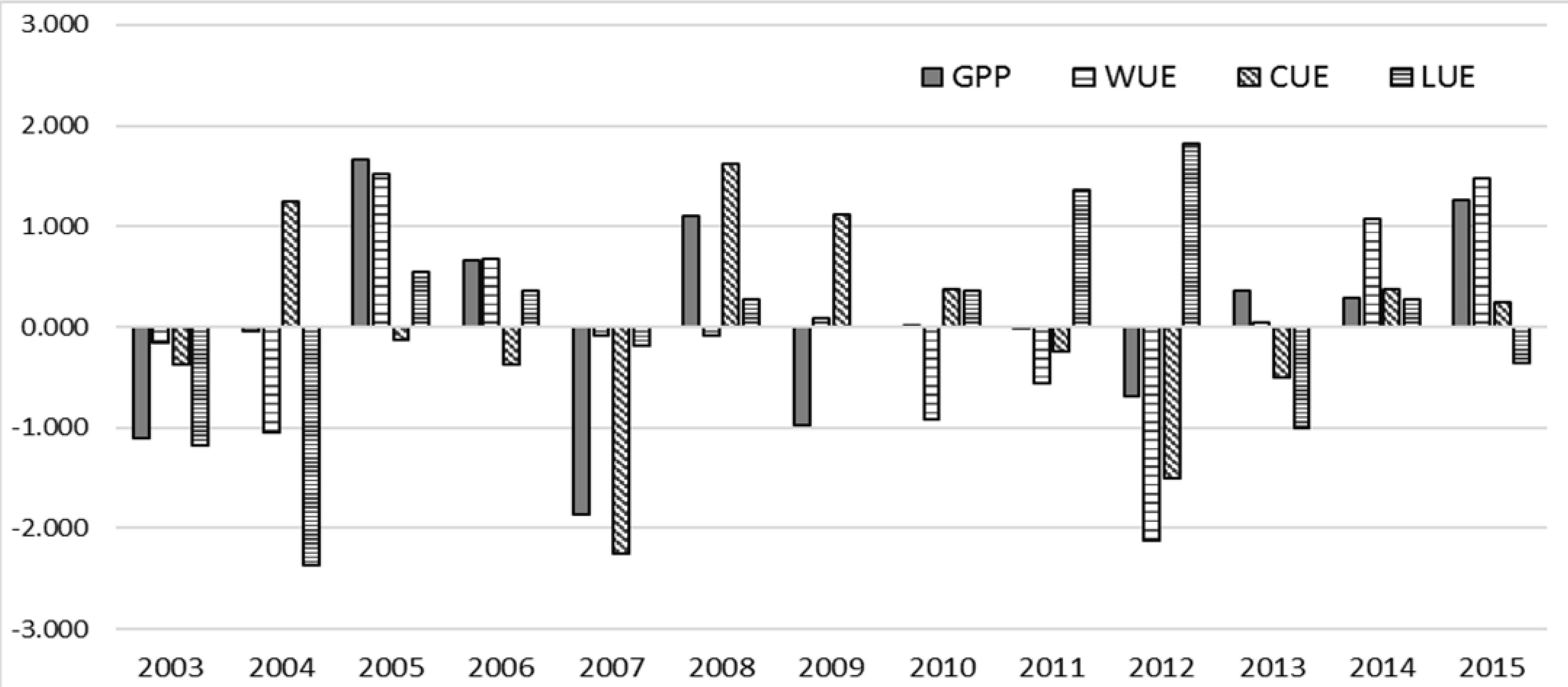
Sites comparison

Site name	Country	Lat/lon	Growing	Year	P	GPP	RE	ET	WUE	CUE
MSE	Japan	36.05°N, 140.03°E	Early May-Mid Sept	2003	545	809	470	366	2.23	1.72
				2004	547	996	526	518	1.95	1.89
				2005	652	901	554	442	1.99	1.63
				2006	614	872	483	373	2.35	1.81
				avg	**590**	**895**	**508**	**425**	**2.13**	**1.76**
IRRI	Philippines	14.14°N, 121.26°E	Jul-Oct	2008	741	932	393	401	2.32	2.37
			Jun-Nov	2009	1045	879	412	531	1.65	2.13
				avg	**893**	**905**	**403**	**466**	**1.99**	**2.25**
GRK	Korea	35.73°N, 126.85°E	Mid Jun – Mid Oct	2011		997	670	528	2.10	1.72
				2012		957	802	435	2.40	1.89
				2013		916	784	668	1.97	1.63
				2014		1028	760	552	2.05	1.81
				avg		**974**	**754**	**546**	**2.13**	**1.76**
CRK	Korea	38.2°N, 127.25° E	late May – early Sept	2016		921	570	426	2.16	1.62

Results and Discussions

Synthesis of Efficiency Indicators

Trade-off observed to gain high GPP by lowering the efficiency (WUE, CUE and LUE)



Agricultural intervention is needed to improve the productivity in HFK, which can be applied in the form of new technology (e.g. direct seeding).

Summaries

- The state of productivity in HFK assessed through GPP was slightly lower in national standard but still within the average of productivity in Asia.
- Overall performance of efficiency showed high water use efficiency (*WUE*), average light use efficiency (*LUE*) and low carbon use efficiency (*CUE*) among agricultural site in Korea and Asia.
- There was a tendency to sacrificed one of efficiency to gain higher *GPP*.
- Agricultural intervention (e.g. direct seeding) may become an alternative solution to sustainably increasing productivity.

Further study

- Examining GHG mitigation and resilience for complete assessment of CSA.

System	Outcome	Direction	Indicator
Agricultural ecosystem	GHG Mitigation	Biotic	CO_2/CH_4/ N_2O flux, Carbon footprint
	Resilience / adaptability	thermodynamic	energy capture, energy dissipation, entropy balance
		Network	Network/ information growth

Thank You

Discussion time