Impact of Afforestation on the discharge of the Chao Phraya River under a warmer climate

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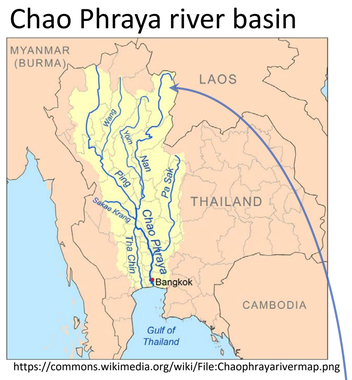
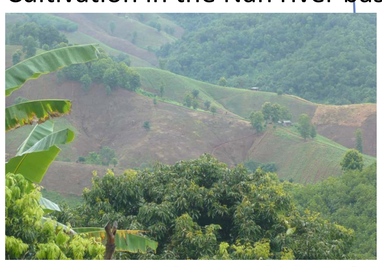
Background

- Chao Phraya river basin



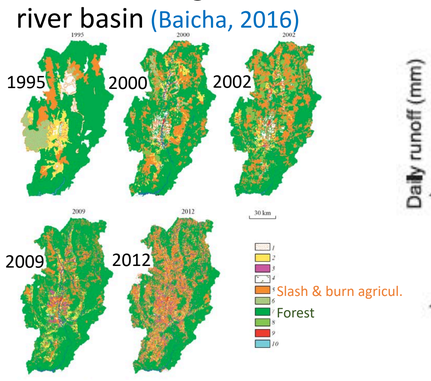
https://commons.wikimedia.org/wiki/File:Chaophrayarivermap.png

- Cultivation in the Nan river basin

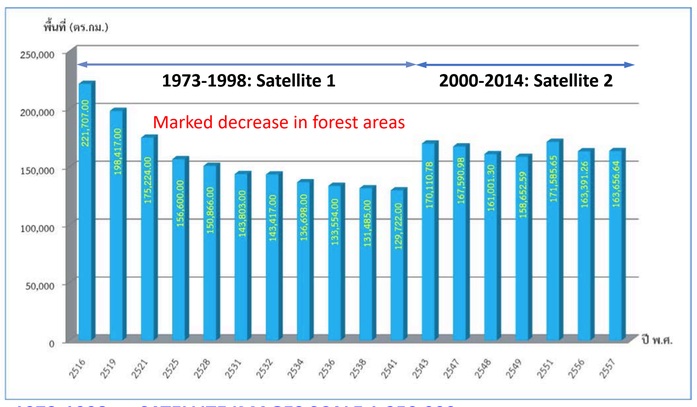


(Courtesy of Adisorn C.)

- Land use change in the Nan river basin (Baicha, 2016)



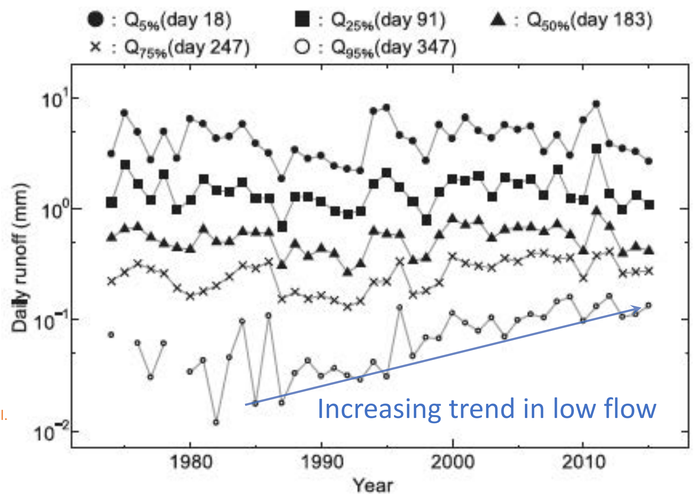
- Forest area in 1973-2014 (Royal Forest Department, 2015)



1973-1998 => SATELLITE IMAGES SCALE 1:250,000
2000-2014 => SATELLITE IMAGES SCALE 1:50,000

(Courtesy of Adisorn C.)

- Changes in river flow in Nan river watershed in 1974-2015 are associated with decrease in forested areas. (Tebakari et al., 2018)

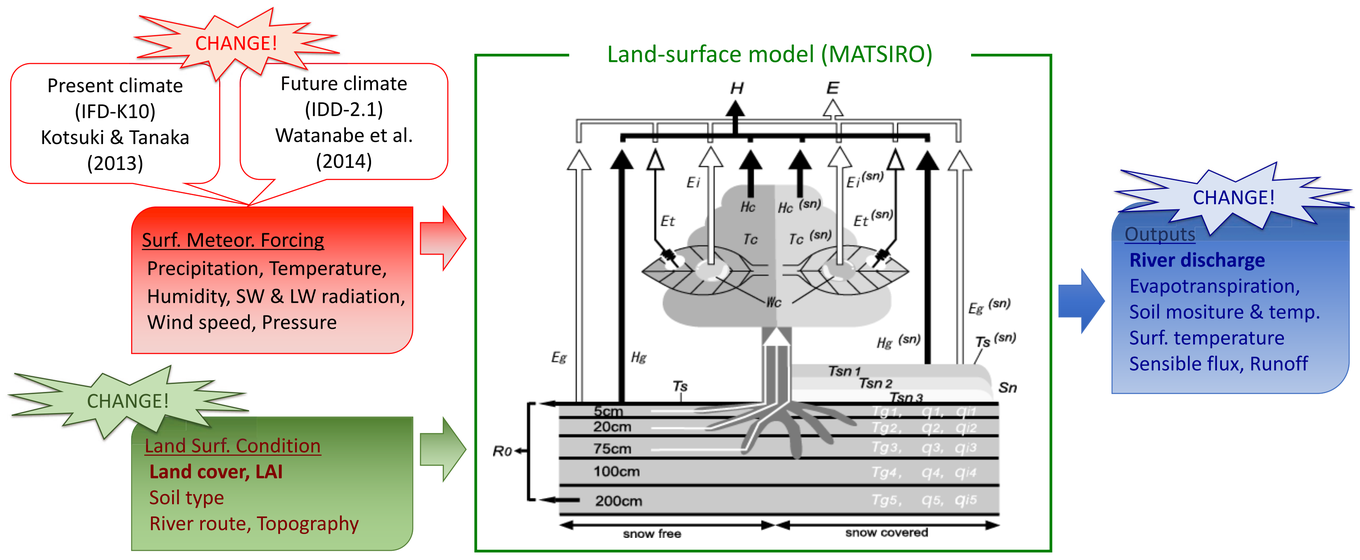


➢ Object of this study:

➢ Quantify of LUC impact in comparison to CC impact in the upper Chao Phraya river (from Nakhon Sawan) using a land surface model (MATSIRO).

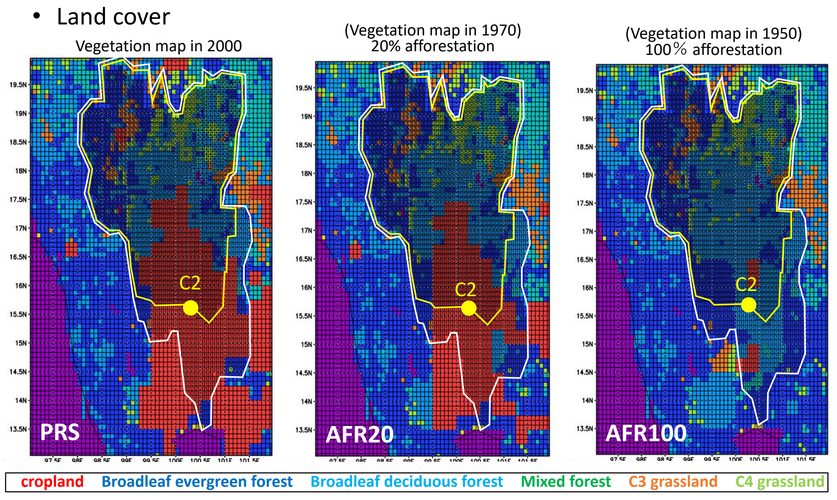
Model

- A land surface model: MATSIRO
  - Ref.: Nitta et al. (2014, J. Clim.), Takata et al. (2003, Glob. Planet. Change)
  - Consider **effects of vegetation canopy** (radiation, interception, transpiration, & root uptake) in energy-water balance on the surface.
  - Multi-layer soil for temperature and moisture calculation.
  - Runoff: **simplified TOPMODEL** + River-route, **TRIP** (Oki and Sud, 1998).



Experiment

- Horizontal resolution: 5 arc-min. (~10 km)
- Period: 20C (1981-2004), mid-21C (2040-2059), end of 21C (2080-2099)
- Vegetation distribution: Present (PRS) = 2000, 20% afforest. (AFR20) = 1970, 100% afforest. (AFR100) = 1950
  - ✓Pseudo-afforestation = Change LU from cropland to natural vegetation, that is expanded from 1970 (or 1950) to 2000
- Experiment: Spin-up (20-30 yrs) for each climate (2RCP, 3GCM), switch 3 vegetation map (sensitivity experiments)
- Analysis: Monthly mean, in upper Nakhon Sawan (C2)
  - Land cover



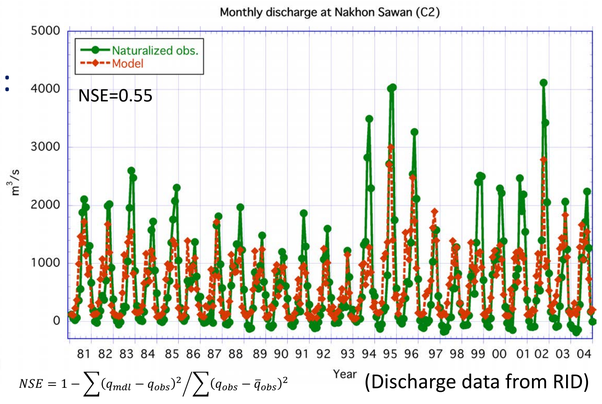
  - List of experiments

Period	Clim. scenario	Met. Forcing	Land cover	Exp. [# of cases]
1981-2004	20C	-	PRS	20C [1]
2040-2059	RCP4.5	M1 (cs36) M2 (ge2m) M3 (mir5)	PRS AFR20 AFR100	RCP4-2050 [9]
	RCP8.5	M1 (cs36) M2 (ge2m) M3 (mir5)	PRS AFR20 AFR100	RCP8-2050 [9]
2080-2099	RCP4.5	M1 (cs36) M2 (ge2m) M3 (mir5	PRS AFR20 AFR100	RCP4-2050 [9]
	RCP8.5	M1 (cs36) M2 (ge2m) M3 (mir5)	PRS AFR20 AFR100	RCP8-2050 [9]

Validation (River discharge)

- Monthly discharge at C2
  - Mean annual discharge (1981-2004): obs.=681 m^3/s, model=633m^3/s
  - Seasonal cycle & inter-annual variations of river discharge at C2 are roughly agree with naturalized* obs.

(*Naturalized obs.: Correction for water fluxes by reservoir operation is applied.)



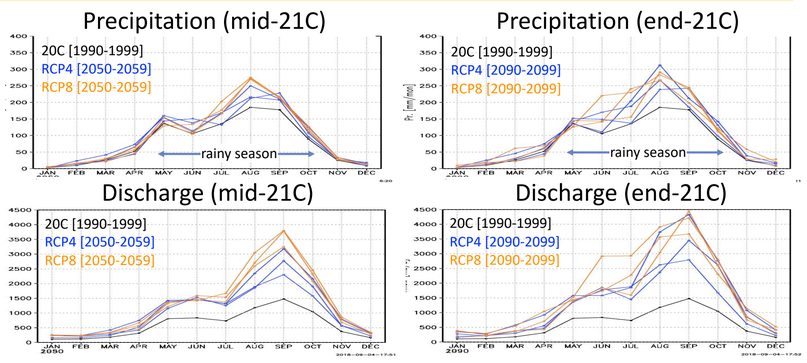
(Discharge data from RID)

Mean seasonal cycle of precipitation and discharge (present & warming)

- Precipitation (Kotsuki & Tanaka, 2013)
- Seasonal pattern of increase in discharge under the warming is similar to Kotsuki et al. (2014).

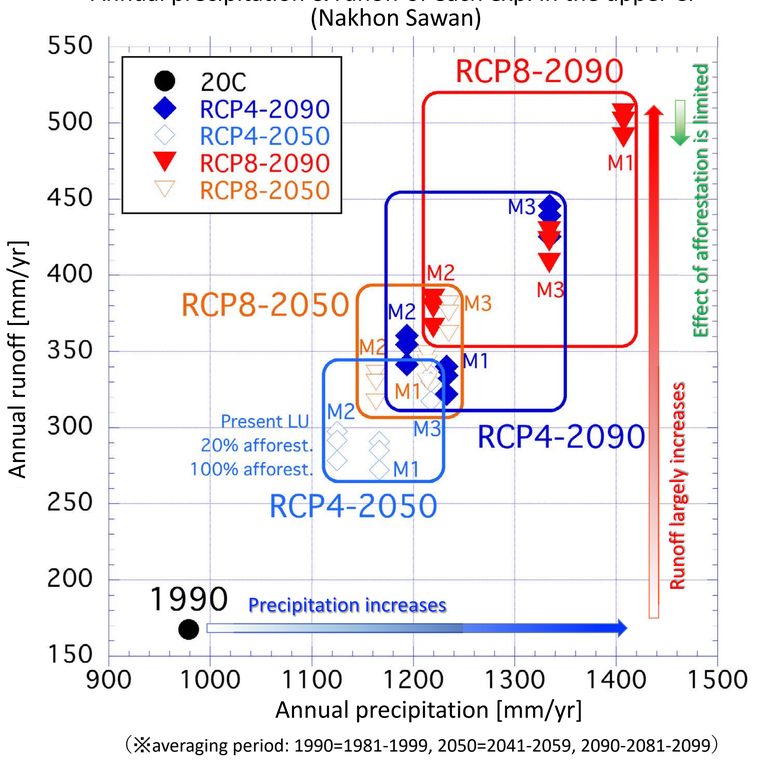
↓

- **Runoff increases are reduced by afforestation?**



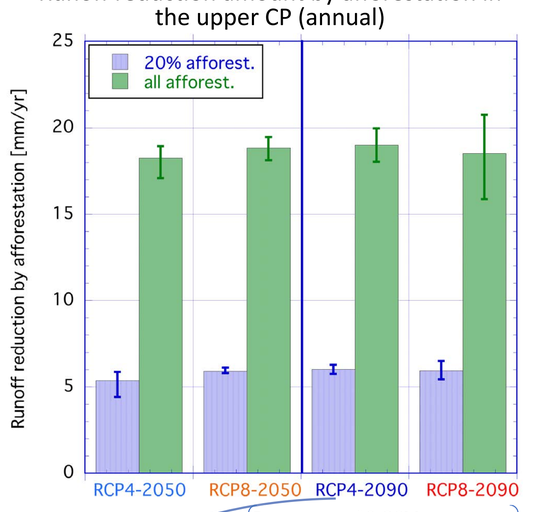
Effect of warming and afforestation in annual water balance

- Annual precipitation & runoff of each exp. in the upper CP (Nakhon Sawan)



(※averaging period: 1990=1981-1999, 2050=2041-2059, 2090-2081-2099)

- Runoff reduction amount by afforestation in the upper CP (annual)



- 90% of runoff reduction amount occurs in rainy season (May-Oct) and 10 in dry season (Nov-Apr).
- Runoff changes in RCP4-2090 converted to volumes, those per unit area of afforestation, & ratio to capacity of the major dams

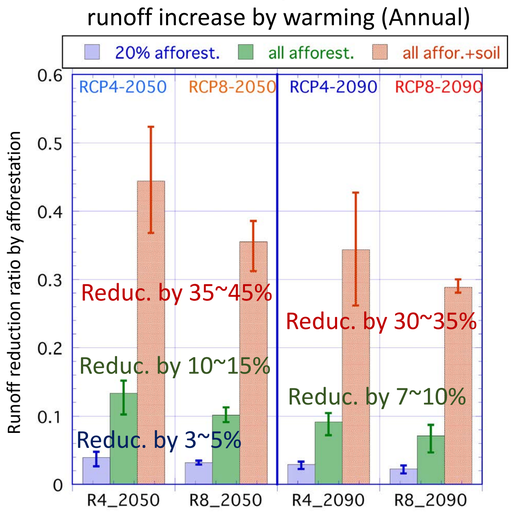
	Incre. by warming	Reduc. by 20% affor.	Reduc. by 100% affor.
mm/yr	214.5	6.0	13.0
m^3/yr	24531x10^6	686x10^6	1486x10^6
m^3/yr per 1km^2 affor.	-	120x10^3	55x10^3
m^3/yr per 1km^2 affor.	-	192	88
% of BB dam	182%	5.1%	11.0%
% of SK dam	258%	7.2%	15.6%

Sensitivity to changes in soil properties (Discussion)

- Physical properties of forest soil is different from compacted mineral soils = High permeability & large water holing capacity.
  - Saturation hydraulic conductivity = 6 times
  - Porosity = 1.5 times
  - In the upper 1m depth

  (Kosugi, 2017; Ohta et al., 1989)
- 100% afforestation exp. w/ forest soil.

Reduction ratio by afforestation to runoff increase by warming (Annual)



- Runoff reduction ratios by afforestation are decreased in accordance with enhancement of the warming. (P. Chacuttrikul et al., 2018)

Conclusion (1)

➢ **Runoff reduction effect by affor. is limited in comparison to runoff increase by warming.**

➢ Runoff reduction ratio by 20% afforestation is only **3~5%**。

➢ Runoff reduction ratio even by 100% afforestation is limited to **10~15%** (in mid-21C) at most.

Future issues

➢ Consideration for different responses in accordance with the location of afforestation area.

➢ Elaboration of sensitivity to soil properties.

Conclusion (2)

➢ Runoff reduction ratio by afforestation is increased by 3~4 times = **Soil property is important**

➢ Problems: Evaluation of soil properties at large scales; Quantify runoff primary processes, etc.

Acknowledgments: This study is supported by the Environment Research and Technology Development Fund (S-14-5), the SATREPS program (ADAP-T) of JST and JICA, and Low-carbon Research Program of NIES.