Global Assessment on Forests and Water

Professor Xiaohua (Adam) Wei

University of British Columbia, Canada

(Associate Editor of Ecohydrology : IF 2.85;
IUFRO Task Force Coordinator of Forests, Water and Soil Interactions)

Xi'an, China, Oct. 16-18, 2018

Outline

- Importance of forest-water relation
- Global assessment by modelling
- Global assessment by international expert panel
- Final remark

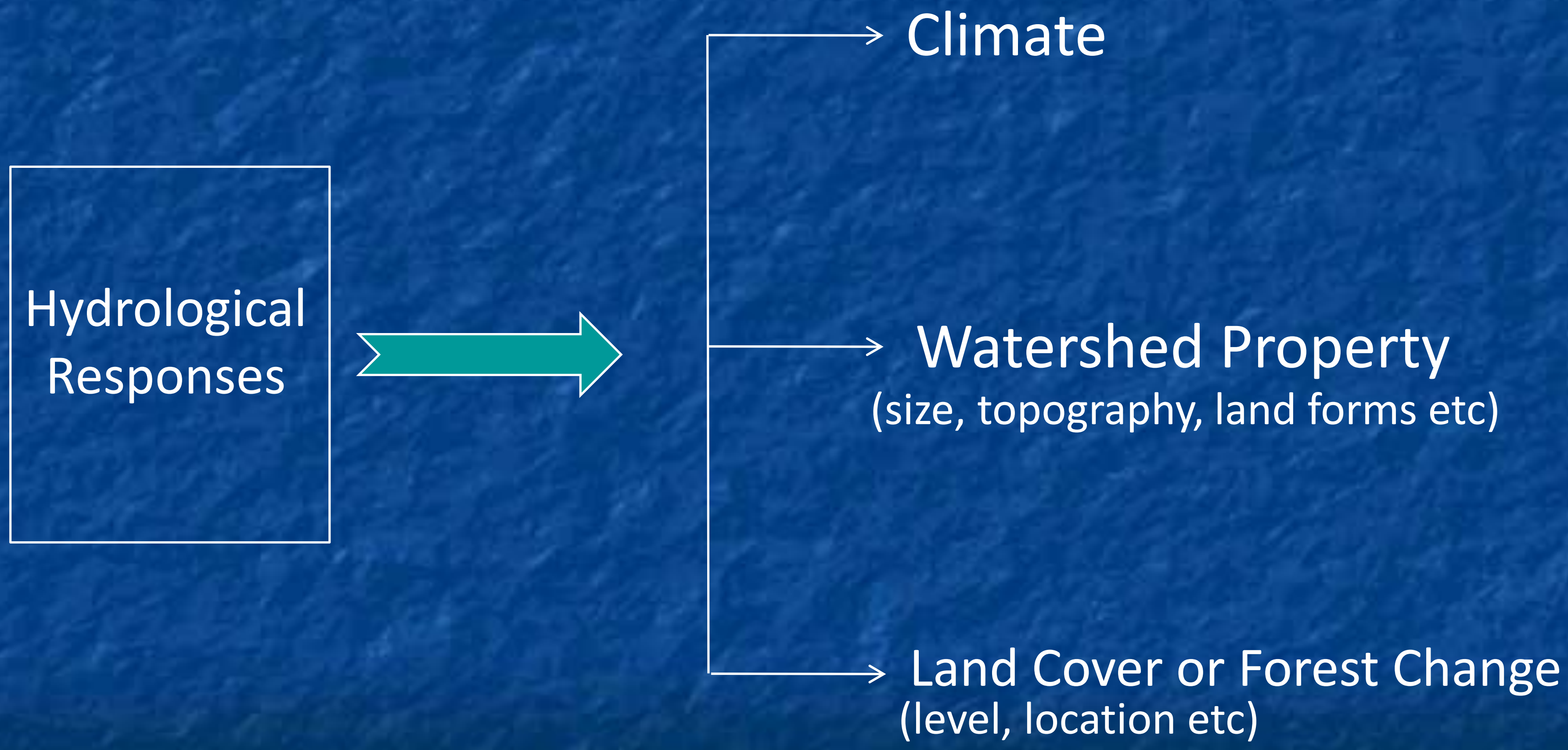
Importance of forest-water relation (1)

- The effects of forest changes on water have long been an important concern

- The relation is closely related to UN 2030 SDGs
  - SDG 6: clear water and sanitation
  - SDG 15: terrestrial ecosystems, sustainably manage forests

- Recent IPCC reports have noted the effects of forest cover or land cover changes on runoff but these effects have not yet been incorporated into future runoff predictions

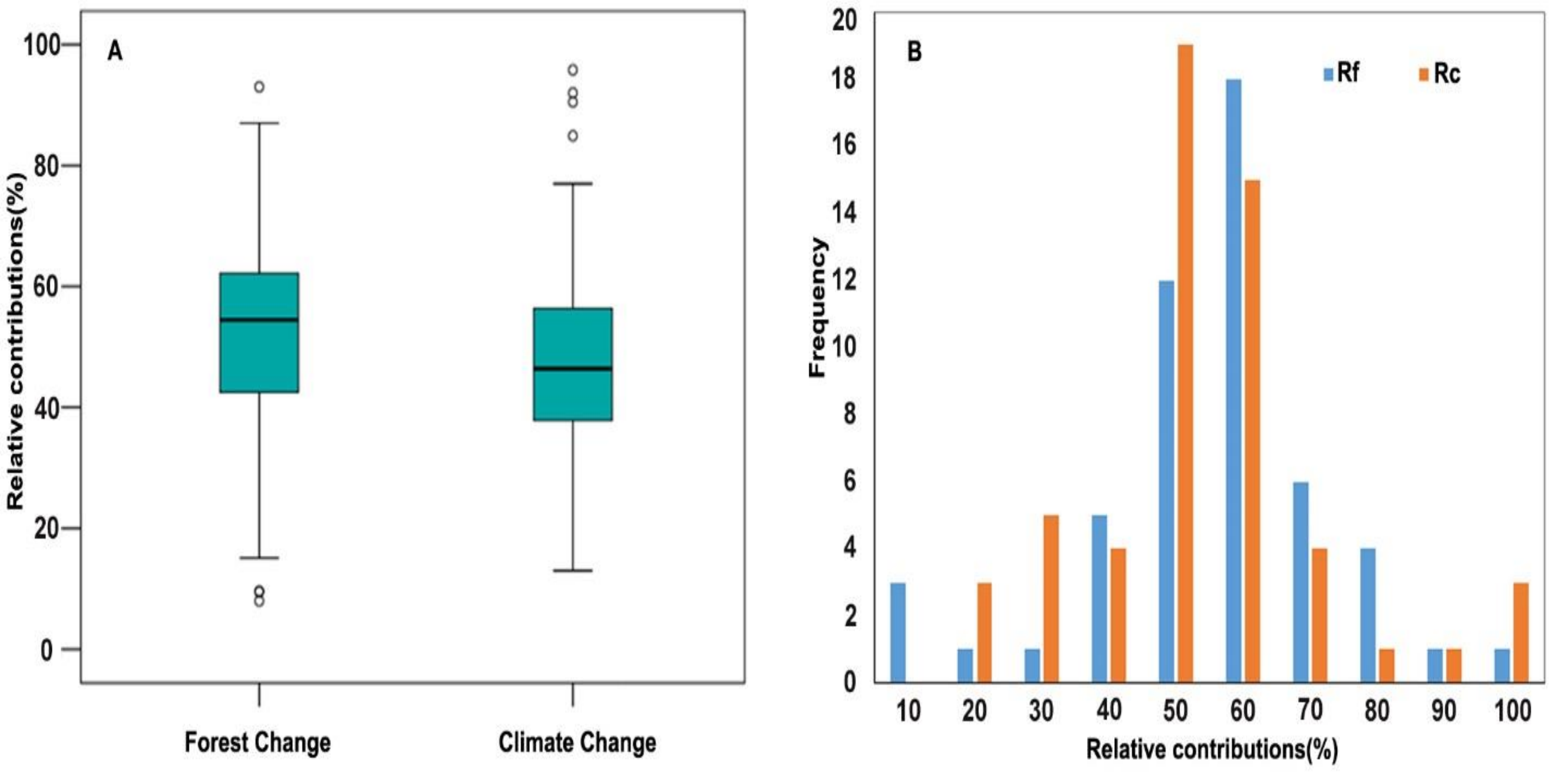
Importance of forest-water relation (2):



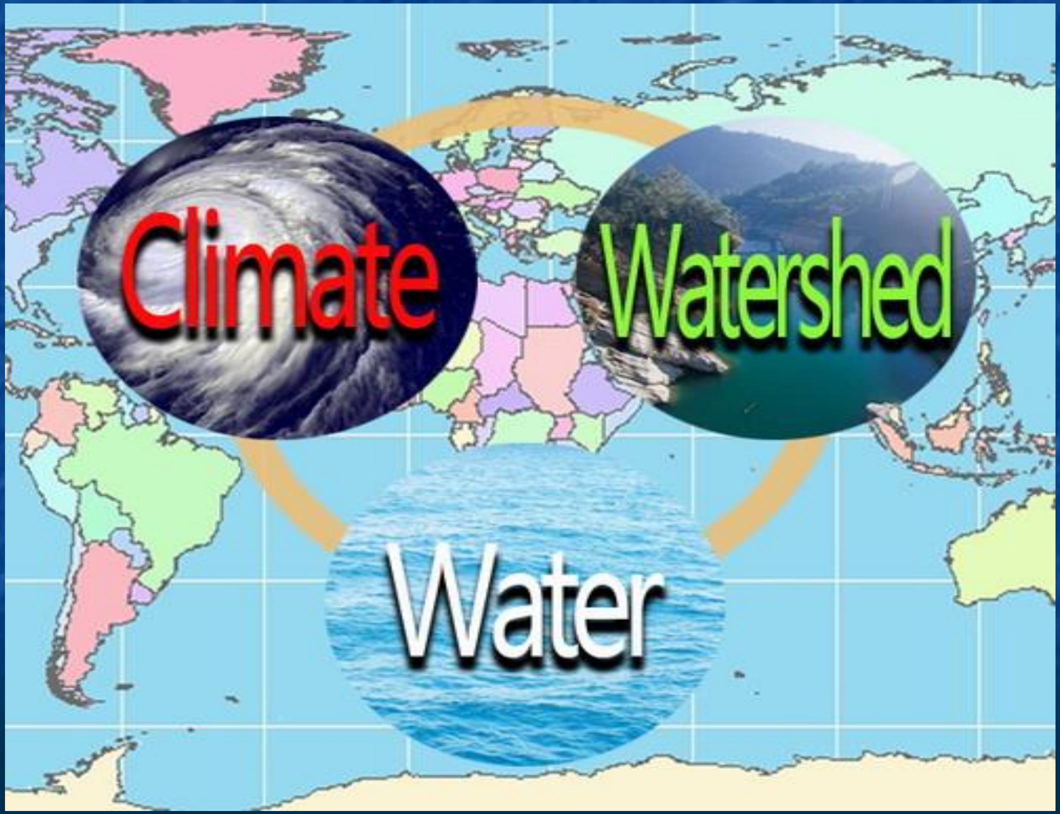
Climate variability and forest change are viewed as two major drivers of runoff variation in forested watersheds

A Global Review on Relative Contributions

(Li et al. 2018)



Global pattern for the effects of climate and land cover on water yield by Zhou et al. 2015 (Nature Communications)



1. Drier regions (P/PET <1) are more sensitive
2. Regions with m<2 are more sensitive

Global Assessment by Modelling

(Global Change Biology, Wei et al. 2017)

Objective

- The objective of this study is to quantitatively assess if vegetation change in forested watersheds is a dominant driver in global water resource change using the Fuh model and the Choudhury-Yang model in forested watersheds of the globe, where forest coverage > 30%

Models

- Fuh model: $$\frac{R}{P} = [1 + (\frac{P}{PET})^{-m}]^{\frac{1}{m}} - (\frac{P}{PET})^{-1}$$

- Choudhury-Yang: $$\frac{R}{P} = 1 - [1 + (\frac{P}{PET})^{n}]^{-\frac{1}{n}}$$

Data

- Four vegetation indices:
  - Forest cover (*30 meters, 2000-2013*)
  - Fraction of Photosynthetically Active Radiation (*FPAR*)
  - Leaf Area Index (*LAI*)
  - Normalized Difference Vegetation Index (*NDVI*)
- Climate data (P and PET, 0.5 x 0.5 degree; 1981-2011)
- 527 hydrometric stations (for validation) and 114 paired watershed experimental studies

Simulations

- Period 1 (1982 to 1999)
  - To use the historical vegetation and runoff data to establish the relationship between the change in watershed property parameters and various vegetation indices
- Period 2 (2000 and 2011)
  - To use the relationships from Period 1 to quantify the relative contributions of vegetation and climate changes to annual runoff change (R_v and R_c, respectively)

Simulations: Period 1

- **Relationships between change in watershed property parameters and changes in four vegetation indices.**

Vegetation indices (X)	$\Delta m = aX + b$		R^2	$\Delta n = aX + b$		R^2
	a	b		a	b	
ΔForest cover (%)	0.009	-0.07	0.33	0.009	-0.066	0.34
ΔFPAR	0.56	0.15	0.19	0.69	0.14	0.21
Δ LAI	6.45	0.15	0.18	7.49	0.13	0.18
ΔNDVI	4.96	0.13	0.19	6.29	0.10	0.23

Note: regression models are all statistically significant with $P<0.01$.

Simulations: Period 2

- Scenario 1: both climate and vegetation changes ($\boldsymbol{R_1}$)
- Scenario 2: climate change only ($\boldsymbol{R_2}$)
- Scenario 3: vegetation change only ($\boldsymbol{R_3}$)

Simulations (Period 2): Relative contributions

- Relative contributions of climate variability

$$R_c = \frac{|R_1 - R_3|}{|R_1 - R_2| + |R_1 - R_3|}$$

- Relative contributions of vegetation changes

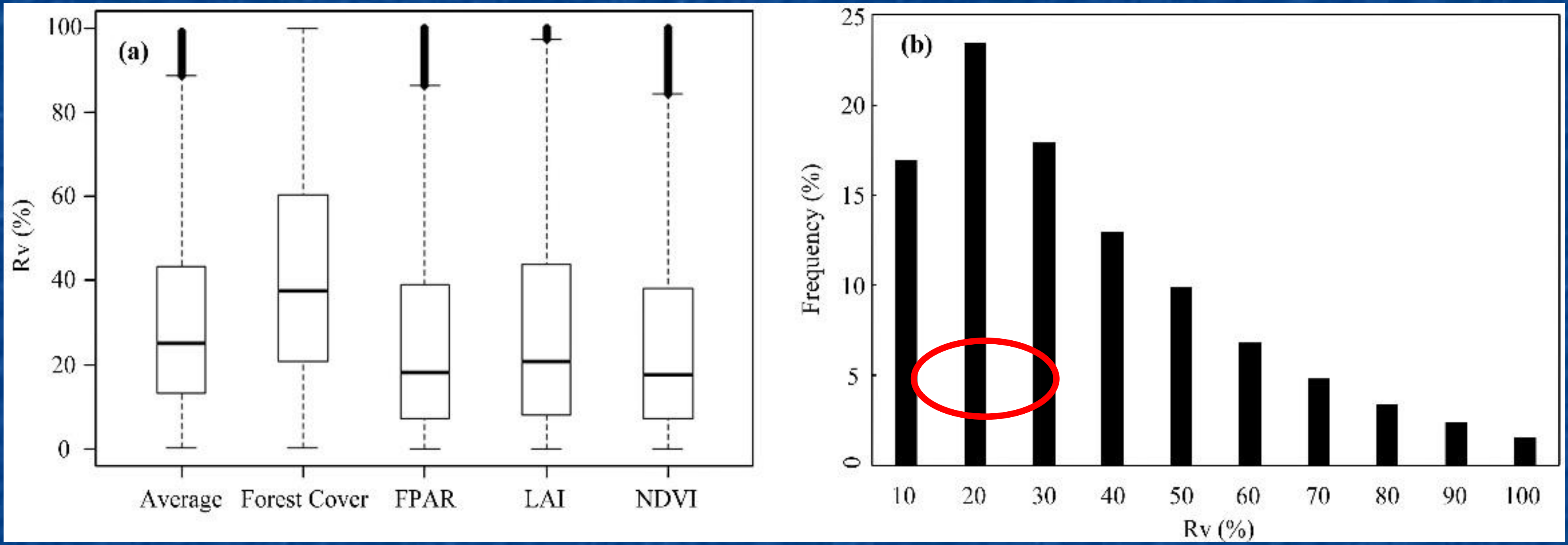
$$R_V = \frac{|R_1 - R_2|}{|R_1 - R_2| + |R_1 - R_3|}$$

Results

- Relative contributions of vegetation changes to annual runoff
- The R_v simulated by the Fuh and Choudhury-Yang models showed similar results for all vegetation parameters

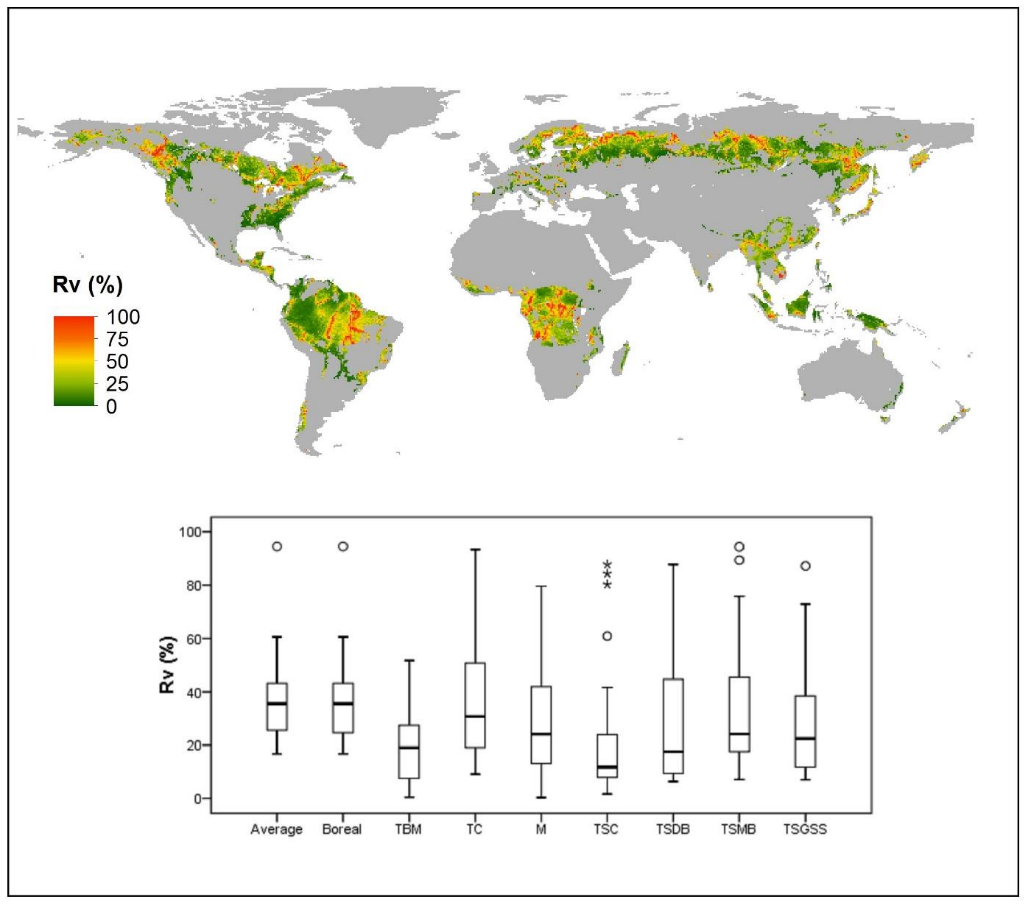
Vegetation parameters	R_v (%) with Fuh model		R_v (%) with Choudhury-Yang model		R_v (%) Average	
	Average	**SD**	**Average**	**SD**	**Average**	**SD**
Forest cover	42.5	25.4	41.1	25.2	41.8	25.3
FPAR	24.6	23.8	27.7	24.5	26.2	24.0
LAI	28.5	25.4	29.3	25.6	28.9	25.5
NDVI	25.1	23.9	26.9	24.8	26.0	24.1
Average	**30.2**	**21.9**	**31.3**	**22.3**	**30.7**	**22.5**

Results



- Global averages of the relative contributions of vegetation changes to annual runoff variations are 30.7 ± 22.5%, with the rest attributed to climate change

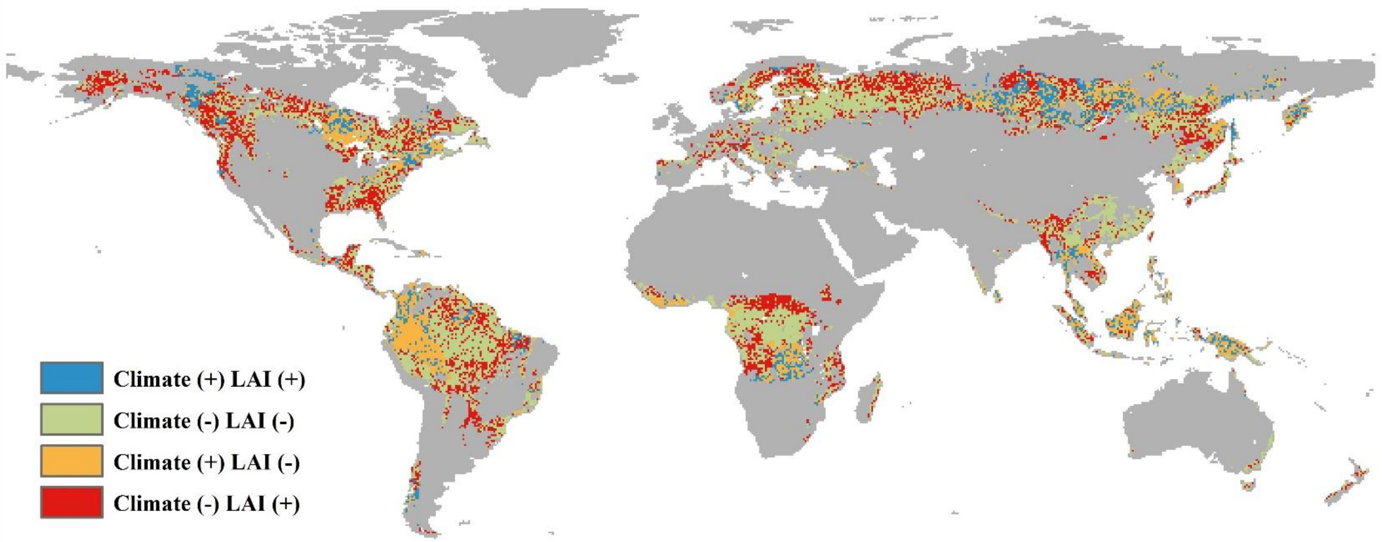
Results



- Tropical and boreal forests experienced the dramatic forest loss between 2000 and 2011, and their R_v values are greater.
  - For examples, the R_v values in British Columbia, Canada are about 39.0 $\pm$ 27.4 % due to the large-scale mountain pine beetle infestation.
  - In the tropics, Brazil has the second highest forest loss (-4.7 $\pm$ 6.5%) in the world with the R_v of 37.4 $\pm$ 21.3%.

- Thus, the effects of vegetation change on runoff are larger with greater vegetation changes.

Results



Spatial Coverage (%)	Forest cover	FPAR	LAI	NDVI
Climate (+) Vegetation (+)	22.5	10.0	10.8	8.5
Climate (-) Vegetation (-)	11.5	46.6	43.8	48.7
Climate (+) Vegetation (-)	4.3	16.8	16.1	18.4
Climate (-) Vegetation (+)	61.6	26.5	29.4	24.4

- Spatial coverage of **additive and offsetting** effects of **vegetation change** on annual runoff are evenly split, accounting for 50.6% and 49.4% of the study area, respectively.
-

Key Conclusions from Modelling

- Changes in vegetation cover is an important driver to annual runoff in forested regions. To our surprise, it’s role is similar to what climate does in flow variations.
- The interactions (offsetting and additive effects) between vegetation cover and climate change have important implications for understanding and predicting changes in water resources
- Both vegetation cover and climate change must be considered in predicting and managing future global water resources
- A research gap on the feedbacks between forests and climate is identified

Global Assessment by Expert Panel

(2018 IUFRO Global Forest Expert Panel of 20 scientists)

GLOBAL FOREST EXPERT PANELS

IUFRO-led initiative of the Collaborative Partnership on Forests (CPF) since 2006

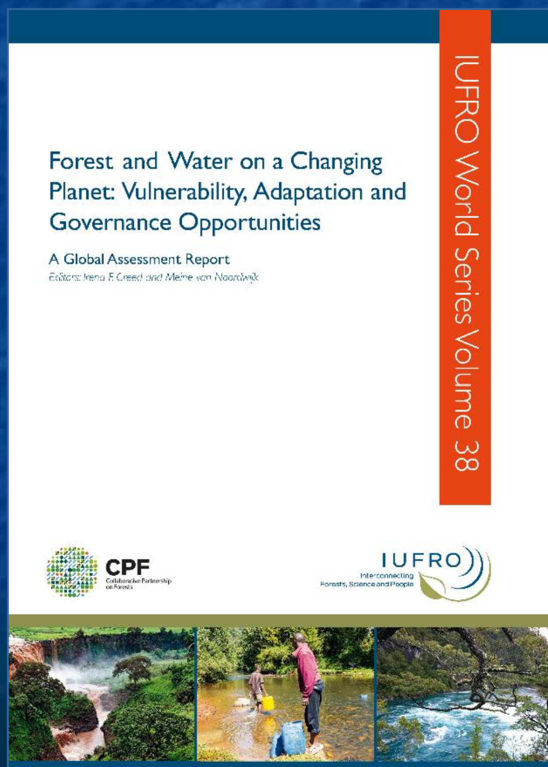
Supports forest-related intergovernmental processes by producing assessment reports on emerging global issues of high concern

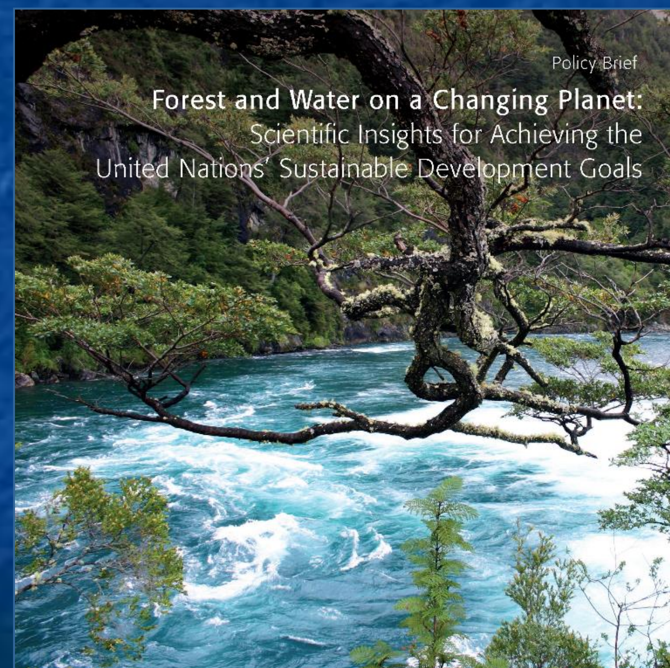
CPF members:


University of Cambridge

Forest and Water on a Changing Planet: Vulnerability, Adaption and Governance Opportunities

A Global Assessment Report





GLOBAL RELEASE – 10 July 2018

Interconnecting Forests, Science and People

LAUNCH: Side-event during United Nations High-Level Political Forum on Sustainable Development (HLPF 2018)

Photo by IISD/ENB | Natalia Mroz

GFEP on Forests and Water

CONCLUSIONS:

1. Water is central to all 17 SDGs and ambitions.

2. A systems approach to climate-forest-water-people relations that integrates hydrological processes and their interactions at all scales is needed.

3. Forests, especially natural forests, contribute to the resilience of water supply for humans in the face of global change.

4. Forests can be managed for resilience of water supplies to enable adaptation to change if locally relevant data and resources are available.

5. Multiple water-related objectives across the portfolio of SDGs present new challenges for policymakers and managers of forests and landscapes with partial tree cover.

GFEP on Forests and Water

IUFRO
Interconnecting Forests, Science and People

CONCLUSIONS:

6. International and regional institutional and governance frameworks can play a key role in optimizing climate-forest-water management.

7. A clear policy gap in climate-forest-water relations exists, waiting to be filled.

8. Regulations and rights-based approaches to climate-forest-water relations provide an essential foundation for innovation in forest-water governance.

9. To successfully achieve SDGs, social and environmental justice, along with equity targets, must be integrated into climate-forest-water policies and management strategies.

10. The global nature of the current assessment limited the scope to be quantitative and geographically explicit.

A question regarding how forest changes (through ET) may affect local and/or downwind precipitation (forest-climate feedbacks) was intensively debated

ET as Sources of Precipitation (1)

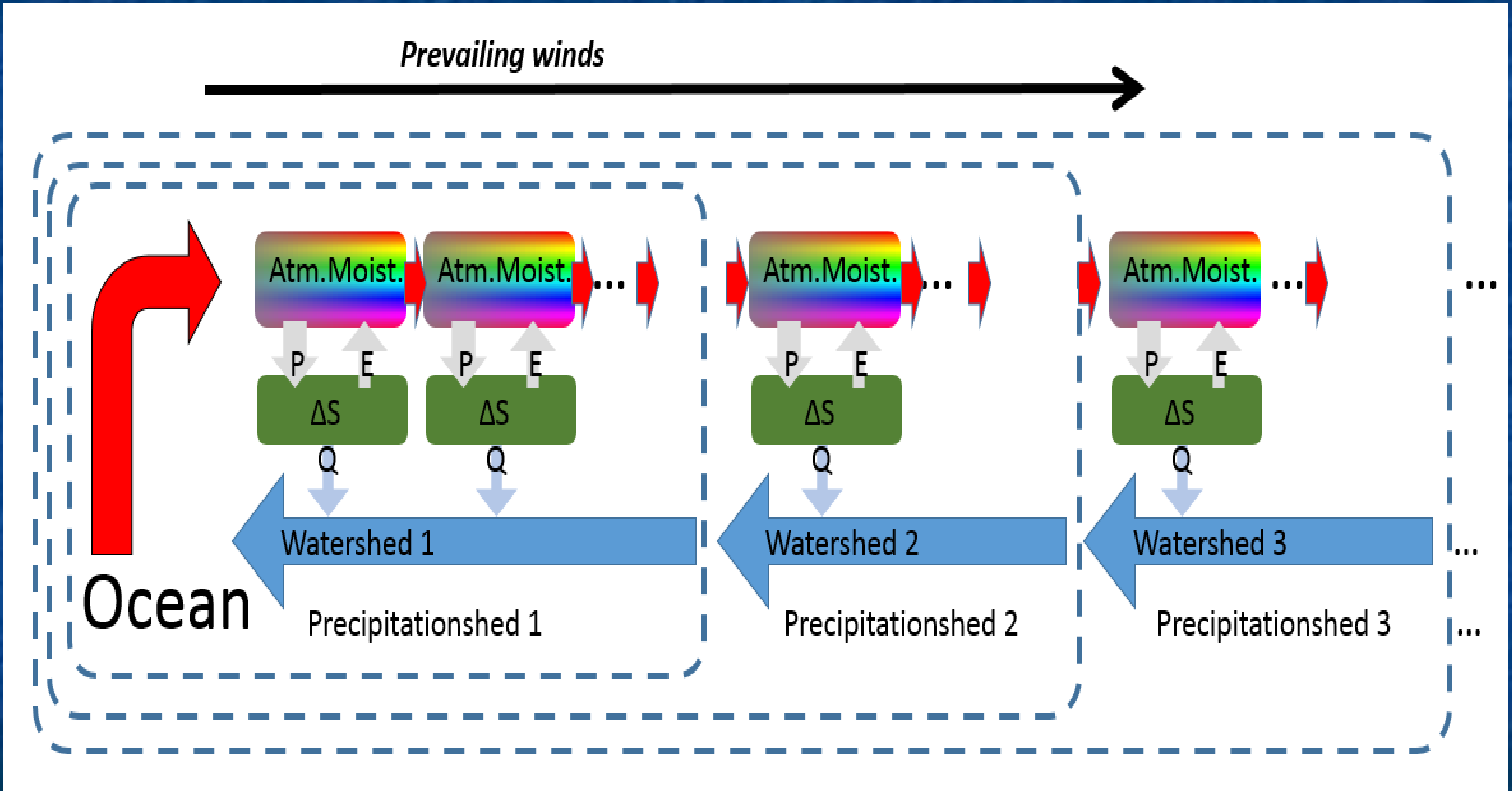
- Forests can affect climate (P and T) and thus streamflow
  - Forests and P: P recycling, hydrological intensification and moisture transport downwind
  - Marengo (2006) summary (26 studies): deforestsation caused P declining in Amazon
  - Forests and T: cooling effect

ET as Sources of Precipitation (2)

- Ellison et al (2012)
  - Trees can reduce runoff at the small catchment scale – at larger scales, trees are more clearly linked to increased precipitation and water availability
  - Perspective shift: from demand- to supply-side thinking

- Li, Piao et al (2018) found divergent hydrological response to large-scale afforestation and vegetation greening in China because of vegetation-climate feedback

Precipitationsheds and Watersheds



Final Remark

- Forests play a critical role in hydrology locally, and downstream and perhaps downwind directions
- Take a systems approach to study ecohydrological processes and their interactions (e.g., land cover, climate and water)
- Both global assessments suggest a critical gap on the feedbacks between forests and climate (challenge)
- With big data, computing capacity and advanced statistical and modelling tools, analysis on interactions and feedbacks in large watersheds or regions is becoming realistic (opportunity)

Thank you

adam.wei@ubc.ca

Simulations– Phase 1

- Group 1-- Global forest cover
  - The high-resolution (i.e., 30 meters) is only available since 2000
  - A total of 114 PWE studies were compiled
  - Forest cover change in the treated watershed *(% of the watershed*), *P*, *PET*, and R of controlled and treated watersheds (Q_C and Q_T) were collected
  - The *m* and *n* for controlled (M_c and N_c) and treated (M_T and N_T) were calculated
  - Then, the changes in two parameters (Δm and Δn) caused by forest cover change were calculated using $\Delta m = M_T - M_c$ and $\Delta n = N_T - N_c$.
  - Finally, the linear regression models between changes in two parameters (Δm and Δn) and forest cover changes were respectively established

Simulations– Phase 1

- Group 2-- *FPAR*, *LAI*, and *NDVI*
  - A three-year average were determined to minimize the inter-annual variations in climate, runoff, and vegetation parameters.
  - For each selected pixel, three-year averages of *P*, *PET*, *R*, *FPAR*, *LAI*, and *NDVI* were calculated and then the watershed property parameters (i.e., *m* and *n*) were generated
  - Stations were further filtered
    - No significant changes ($P>0.05$) in *P*, *PET*, and *P/PET*
    - Significant trends ($P<0.05$) in each vegetation indices
    - a total number of **102 stations** were finally selected (460 were initially selected)
  - Simple linear regression models between changes in watershed property parameters (i.e., Δm and Δn) and change in vegetation parameters (i.e., $\Delta FPAR$, ΔLAI, and $\Delta NDVI$), respectively were established.