Modeling the impact of land use change on basin-scale transfer of fecal indicator bacteria: SWAT model performance

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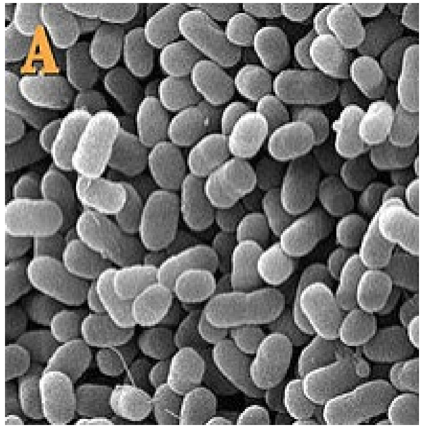
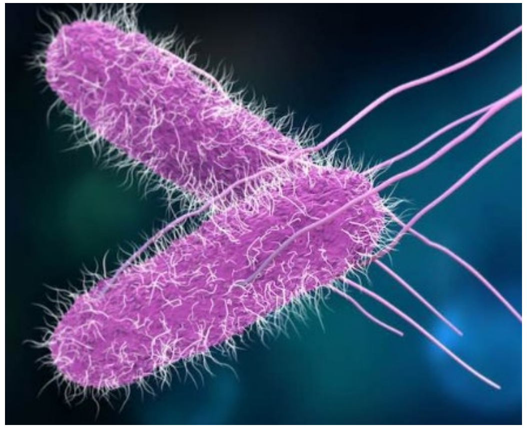
1. Introduction

Bacterial pathogens

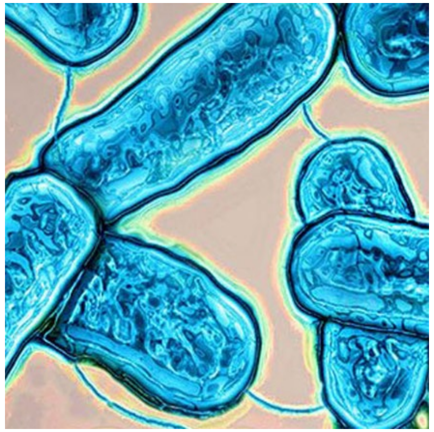


Escherichia coli O157:H7



Salmonella

Campylobacter



Legionella

Bacterial pathogens can cause
: Fever, diarrhea, cramps, headache, nausea and abdominal pain.

About 1.5 million people, mainly children, die annually from water-borne diseases, mainly as a consequence of the consumption of water contaminated by bacterial pathogens (WHO, 2015).

1. Introduction

Monitoring → Modeling

To quantify the level of microbial contamination.

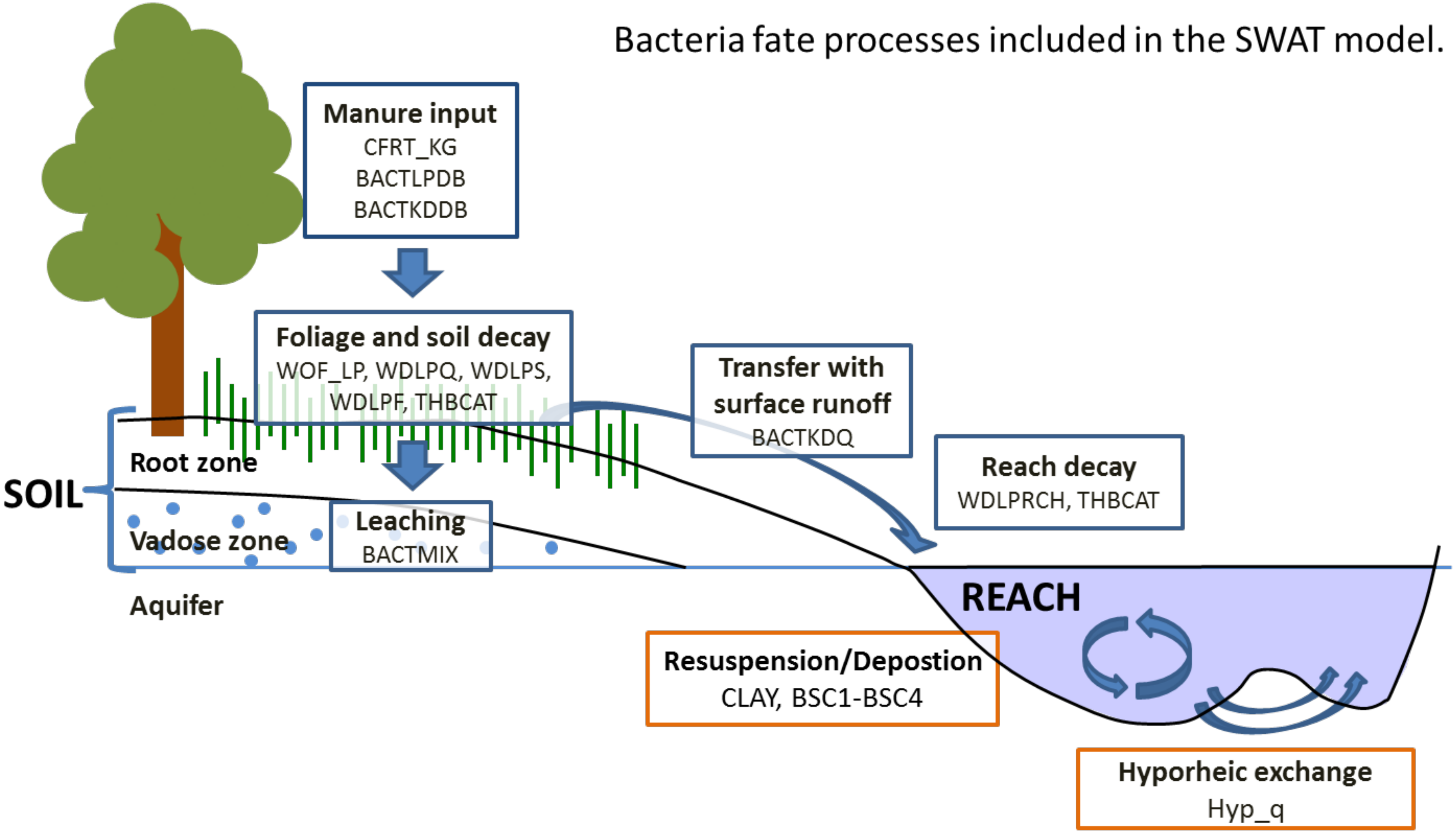
To assess the impact of environmental variables on the fate and transport of bacteria.

Fecal Indicator Bacteria (FIB):

- FIB are proxies to detect the *potential presence of pathogens* in water samples.
- It can be obtained by a relatively **cheap**, **easy** and **low risk** way.
- Widely used FIB: Escherichia coli (*E. coli*) and Enterococcus.

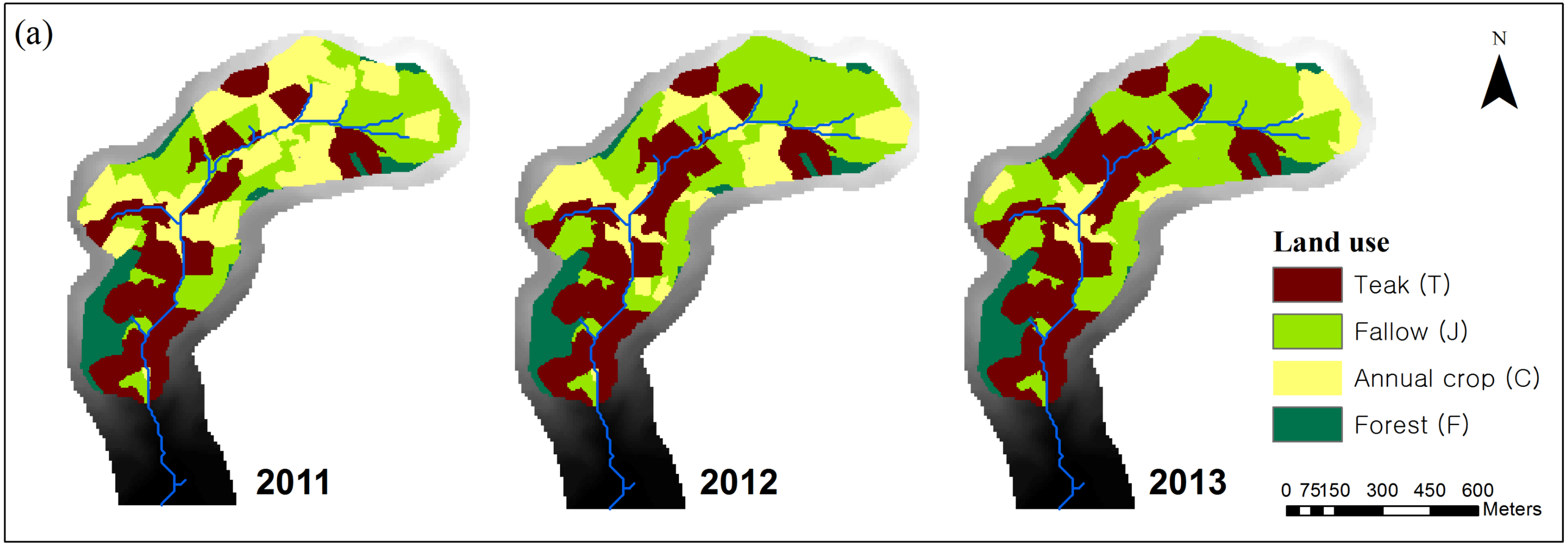
2. Method

Bacteria fate processes included in the SWAT model.



2. Method Houay Pano watershed in Laos

Expansion of commercial teak tree plantation



ha (%)	Annual crop	Fallow	Forest	Teak
2011	20 (33%)	17 (29%)	6 (10%)	17 (28%)
2012	12 (21%)	24 (39%)	6 (10%)	18 (30%)
2013	6 (11%)	28 (46%)	5 (9%)	21 (34%)

Leaf Area Index

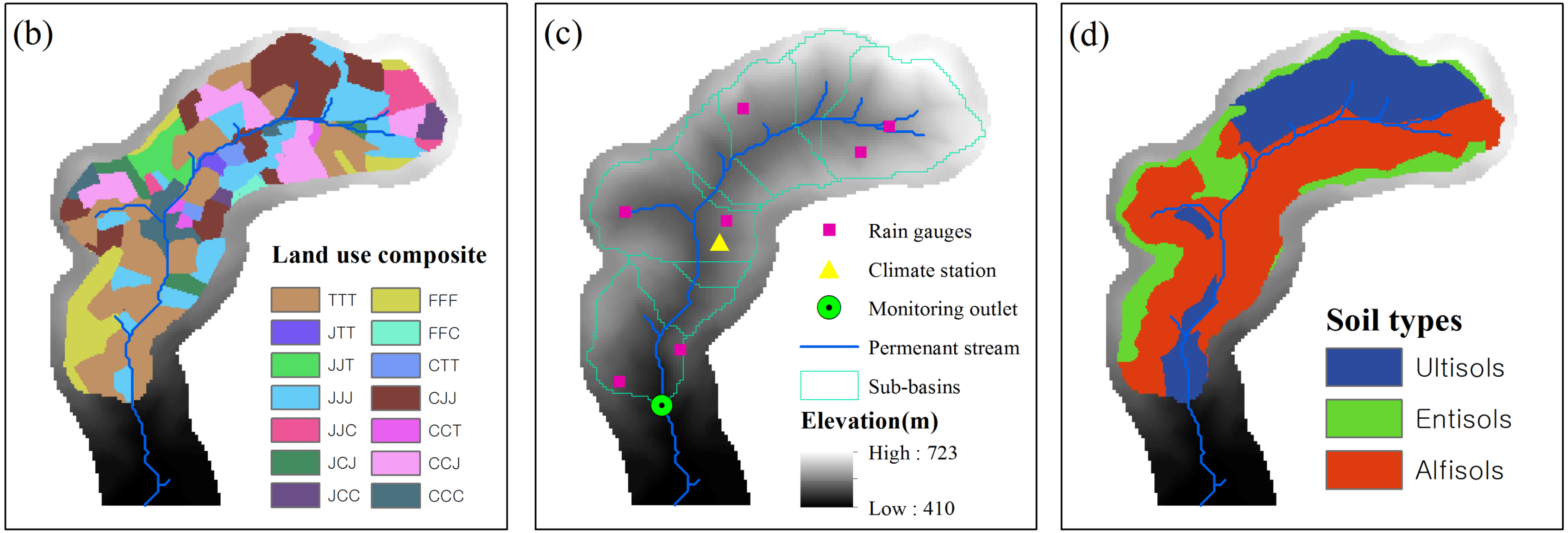
Rainfall energy from canopy

Curve number

2. Method

Application of land use change:

Multiyear LU composite map was used because lup.dat covers only existing HRUs.



e.g., CCT indicates
C in 2011; C in 2012; T in 2013.

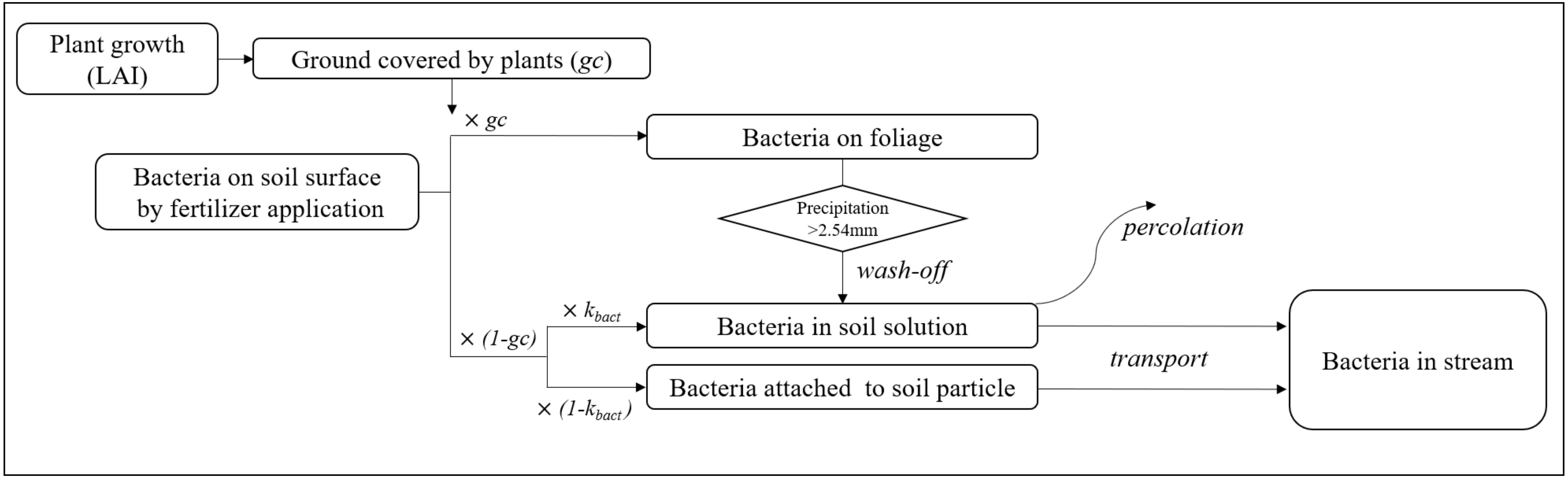
Land use category	Management schedule (planting – harvesting)	BLAI†	PHU‡	CUSLE§	CN2B¶	CN2D¶
Annual crop (C)	May 15 - October 15	2.5	2,026	0.003	77	87
Fallow (J)	January 1 – December 31	3	5,000	0.003	69	84
Forest (F)	January 1 – December 31	5	5,000	0.001	55	77
Teak (T)	January 1 – December 31	5	5,000	0.2	80	90

Update in management input file

Rainfall energy from canopy

2. Method

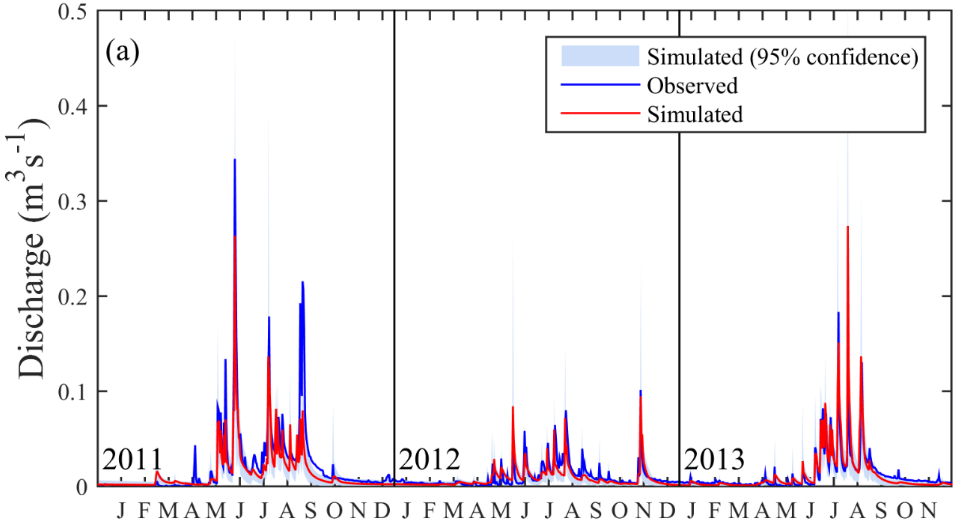
LAI → fraction of ground covered by plants (*gc*) → Three-pool partitioning

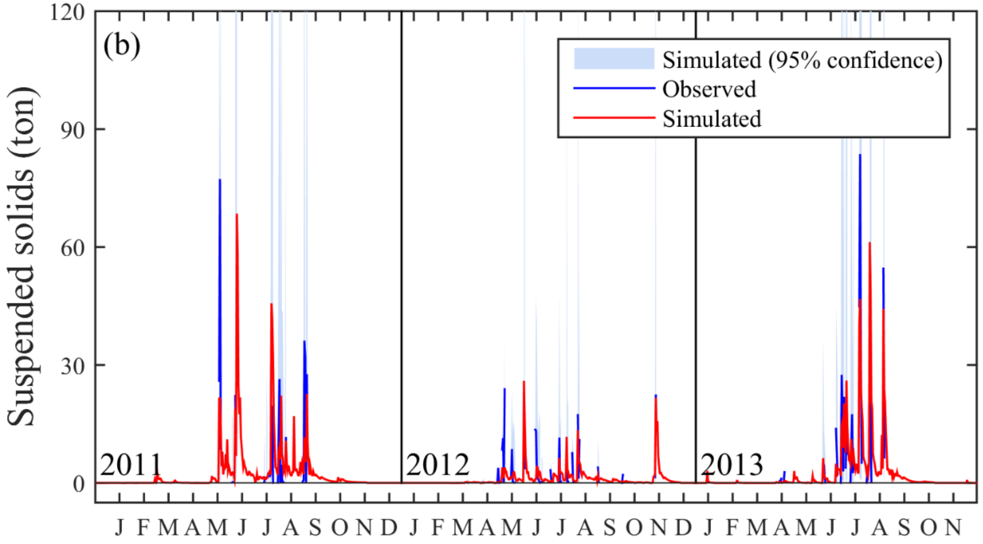


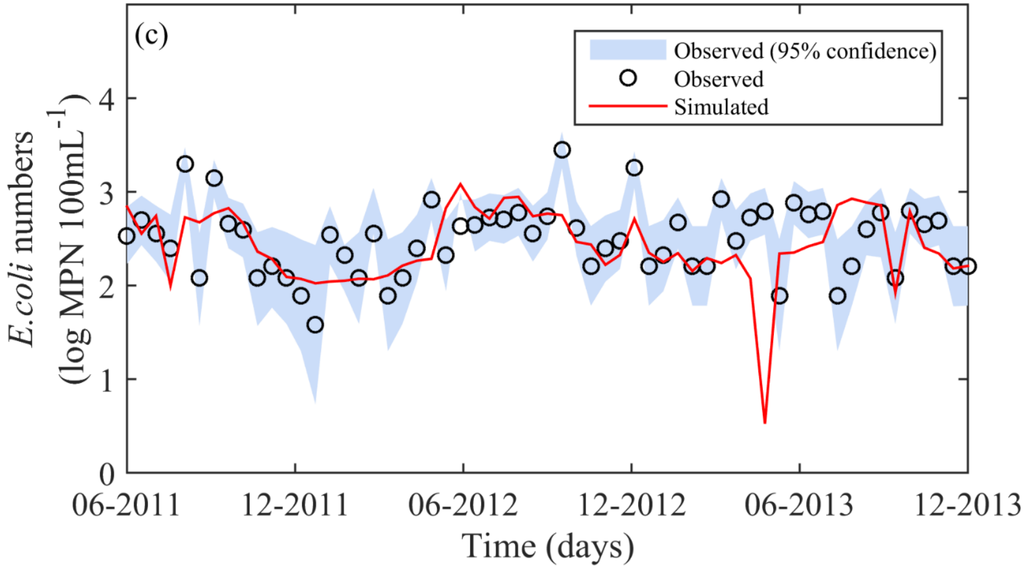
Bacteria in soil solution – surface runoff

Bacteria attached to soil particle – suspended solids in surface runoff

3. Result



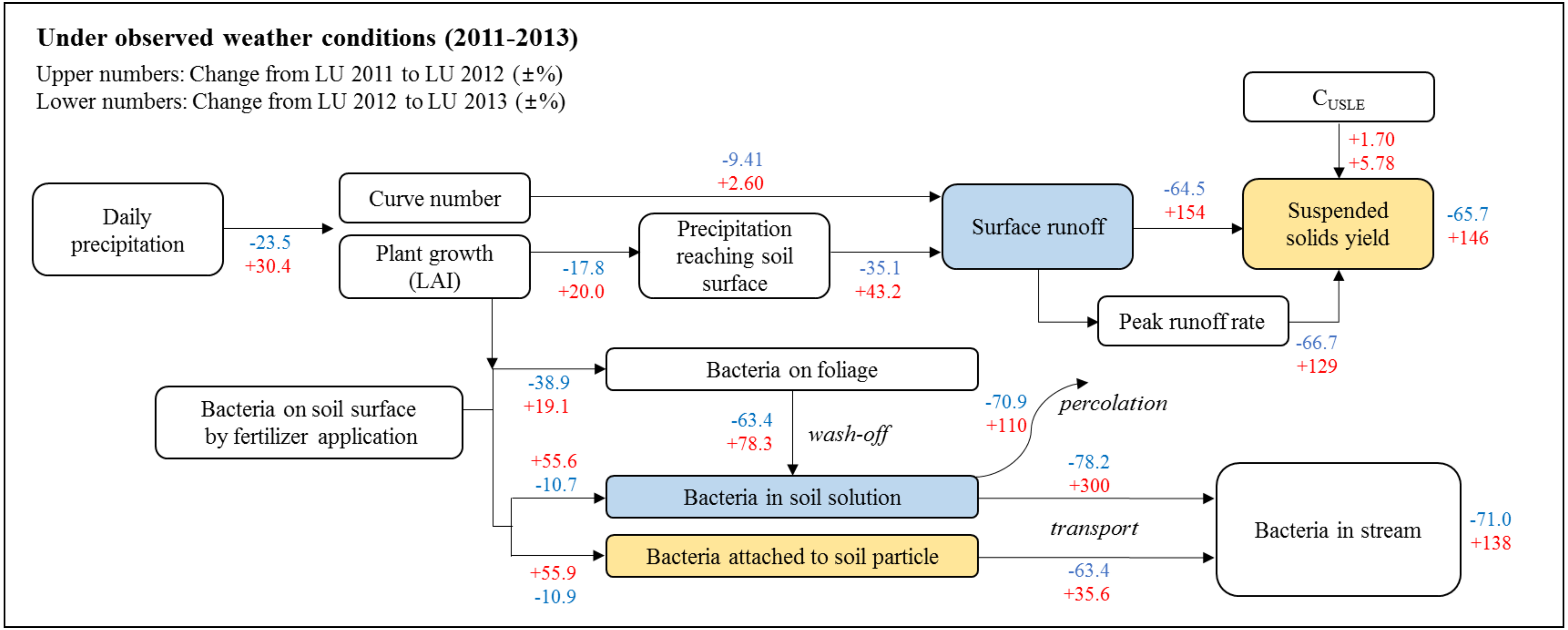




Index	Multiple-year composite land use map (2011-2013)		
	Discharge	Suspended solids	Bacteria
R^2	0.71	0.57	
Nash and Sutcliffe coefficient	0.70	0.56	
p-factor	0.74	0.80	
r-factor	0.60	2.97	
RMSE			492

3. Result

Averaged daily rainfall (wet season): 10.39mm (2011), 7.95mm (2012), 10.37mm (2013)



Results at the watershed scale, averaged daily results during the rainy season.

3. Result

Impacts of land use change under identical weather conditions:

Land use scenarios		Under identical weather conditions (2011–2013)		
		2011	2012	2013
Precipitation (mm d^{-1})			9.57 (1.15)†	
Curve number (d^{-1})		80(4.4)	80(3.6)	79(4.0)
Leaf area index (d^{-1})		1.59(0.04)	1.28(0.01)	1.54(0.02)
Maximum canopy storage (mm d^{-1})		25.0(0.58)	20.8(0.20)	23.3(0.12)
Precipitation reaching soil surface (mm d^{-1})		6.33(1.41)	6.80(1.34)	6.28(1.39)
Surface runoff (mm d^{-1})		2.03(0.88)	2.10(0.85)	2.05(0.87)
Peak runoff rate (10^{-4} m^3 s^{-1} d^{-1})		5.7(2.6)	5.9(2.8)	6.1(3.2)
Suspended solids in surface runoff (tonne d^{-1})		0.050(0.024)	0.049(0.026)	0.055(0.029)
Initial *E. coli* (MPN‡ m^{-2} d^{-1})	On foliage	6372(219)	3973(81)	4781(160)
	In soil solution	88(4.4)	137(1.6)	121(3.2)
	Attached to soil particle	4331(215)	6733(78)	5916(157)
	Wash-off	2230(455)	1409(315)	1709(374)
E. coli transported (MPN m^{-2} d^{-1})	In soil solution	13.1(6.5)	10.3(4.8)	11.4(5.4)
	Attached to soil particle	9.0(4.2)	9.0(4.4)	11.1(5.2)
	In stream	22.1(9.9)	19.3(8.3)	22.5(9.7)

† Mean (standard deviation).

‡ MPN, most probable number.

- **Under identical weather conditions**,
the amount of surface runoff, peak runoff rate, and suspended solids was almost
constant for the three land use scenarios.

- The initial number of *E. coli* was important in simulating *E.coli* transport, and **LAI was a main factor in determining the initial number of *E. coli*** on the soil surface.

- In the case of **perennial plants without a harvest and kill operation**,
there was no provision of nutrients by residue decomposition; thus, **plant growth was reduced** compared with the plant growth in the previous year due to the relative nutrient deficiency.

4. Discussion

Limitations of SWAT:

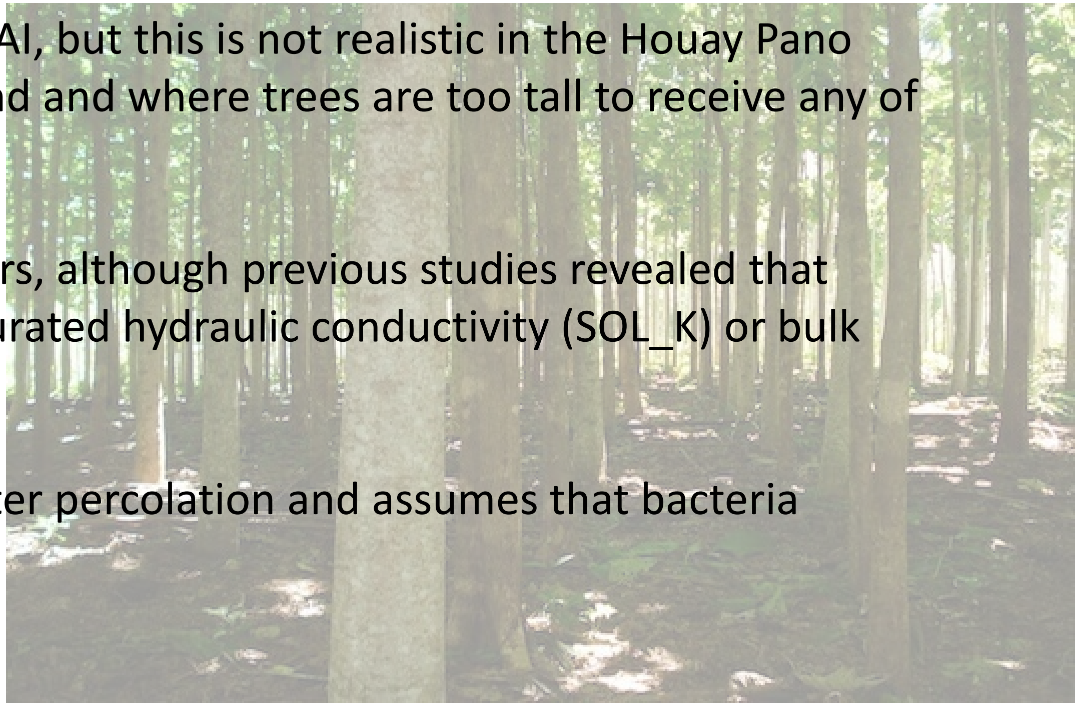
1) SWAT allows only one fertilizer application at a time for the continuous fertilizer operation (MGT_OP = 14).

2) SWAT does not consider the erosion of manure but determines daily bacteria from the daily amount of fertilizer applied.

3) SWAT unconditionally assigns *E. coli* to foliage based on LAI, but this is not realistic in the Houay Pano watershed, where manure is applied directly to the ground and where trees are too tall to receive any of the applied manure.

4) SWAT separates soil and land use management parameters, although previous studies revealed that different land use can change soil properties, such as saturated hydraulic conductivity (SOL_K) or bulk density (SOL_BD).

5) SWAT does not consider the bacteria in the soil profile after percolation and assumes that bacteria migrate out of the system.



5. Conclusion

1) Under observed weather conditions from 2011 to 2013, **precipitation** was important in simulating surface runoff, and it consequently controlled the variation in suspended solids and *E. coli* transferred from the soil surface to the stream.

2) Under identical weather condition, the amount of surface runoff and suspended solids was constant and the initial number of *E. coli* was important in simulating *E. coli* transport, and LAI was a main factor in determining the initial number of *E. coli* on the soil surface.

3) On the basis of these results, this study reports several limitations and improvement suggestions for future modeling with the SWAT model.

Thanks for
your attention ☺