Scenario analysis pilot in China - Ecological compensation standards for the Xijiang River basin in Guangxi

Research Center for Eco-Environmental Sciences, CAS

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Beijing
2019.11

Outline

- Background
- Research Question
- Methodology
- Preliminary Results
- Next Work

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What Is Ecosystem Service?

Humans always depend on nature for a wide range of environmental assets like clean water, nutrient cycling and soil formation.

Ecosystem services are the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfill human life (Gretchen Daily).

Ecological Protection Practices

- **Guangxi has invested large amounts of manpower, material and financial resources to protect and restore the ecological environment.**

Grain to Green Project

Rock desertification control

Pollution control for livestock breeding

Towards harmony human-nature coexistence

- **Resulting in huge opportunity costs for social and economic development.**

Ecological Compensation Policies

Guangxi has carried out ecological compensation practices in many fields, including ecological compensation for:

- ecological benefits of forests;
- control of soil erosion and rocky desertification;
- protection and restoration of water environment;
- establishment of ecological function conservation areas.

2007

The Department of Finance of Guangxi Zhuang Autonomous Region issued the "Measures for the Collection and Use of the compensation for water and soil conservation facilities and for the control of soil erosion".

2013

Guangxi increased the ecological compensation for the state- and collective-owned public welfare forests by 0.36 billion.

2014

The autonomous region added 6 counties to the list of key ecological function conservation areas with transfer payments.

2015

Guangxi and Guangdong jointly introduced the "Jiuzhou River Basin Water Environment Compensation Implementation Plan".

2016

Guangxi and Guangdong signed the "Agreement on Horizontal Ecological Compensation for the Upstream and Downstream of the Jiuzhou River Basin"

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Why We Do Scenario Analysis

By performing scenario analysis of ecological compensation, we aimed to:

- evaluate the impacts of different development strategies on ecological compensation standards;
- improve the equitability of the distribution of the costs and benefits of conservation between beneficiaries and suppliers of ecosystem services;
- link water regulation service to the benefits;
- inform the sustainability of trans-provincial watershed management.

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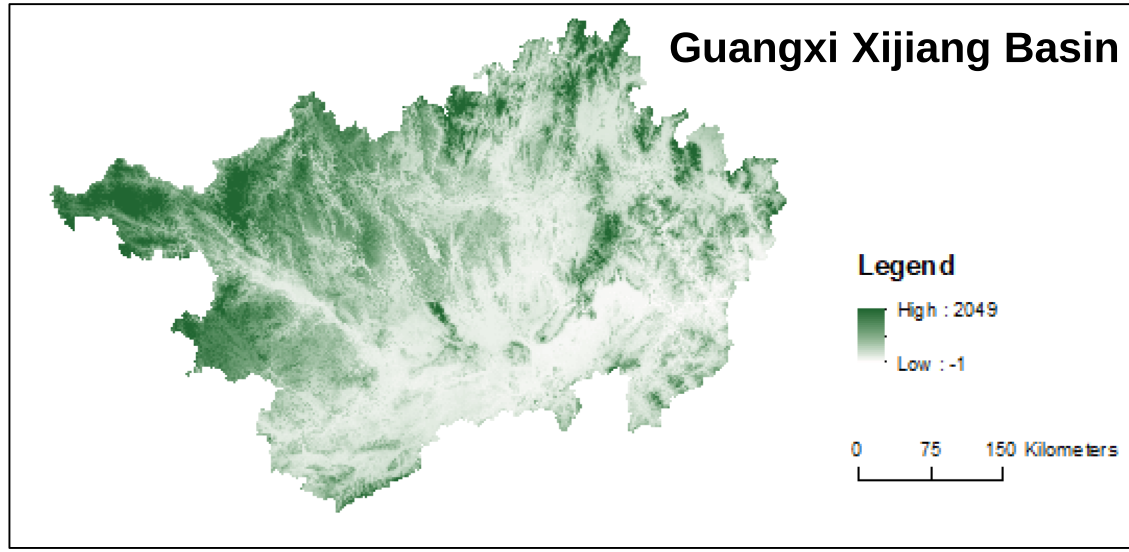
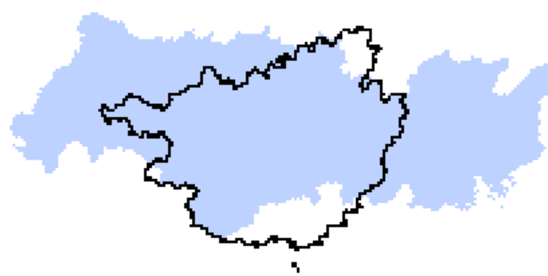
Location of Xijiang River Basin

- upper reaches of the Pearl River Basin
- the main stream of the Pearl River
- a drainage area of 355,000 km^2, of which 204,900 km^2 is in Guangxi Zhuang Autonomous Region, accounting for 57.7% of the entire Xijiang River Basin





Guangxi Zhuang Autonomous Region

Xijiang Basin

Overall Route

Scenarios include:

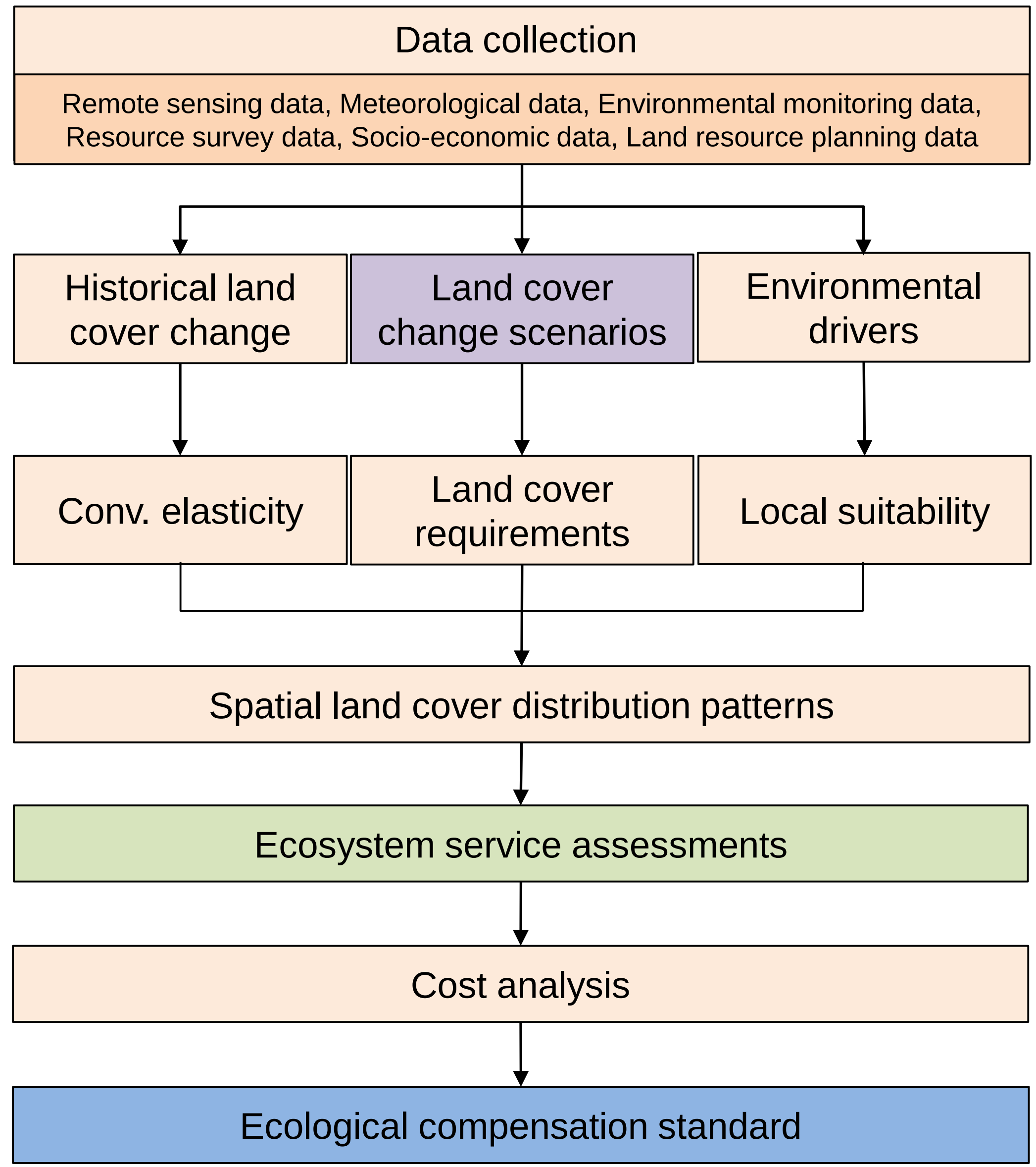
- ➢Business As Usual
- ➢Ecological Protection Priority
- ➢Agricultural Development Priority
- ➢Economic Development Priority
- ➢Integrated Development

Ecosystem services including:

- ➢Water retention
- ➢Flood mitigation
- ➢Carbon storage and sequestration
- ➢Sediment retention
- ➢Biodiversity conservation

Models:

- ➢Cellular Automate - Markov
- ➢Empirical ecosystem service (ES) models, InVEST, SWAT



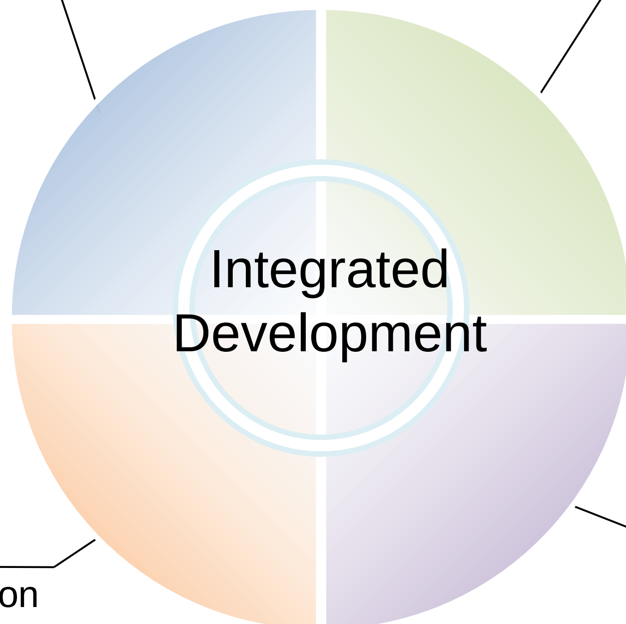
Land Cover Scenarios

➢ Business As Usual

The historical trend of land cover changes from 2000 to 2015 is assumed to continue over the next 15 years (2015-2030).

➢ Ecological Protection Priority

This scenario focuses on the protection and restoration of ecological lands including forest, grassland and wetland. Under this scenario, the areas of ecological lands will be increased based on the historical trend of land cover changes.



➢ Agricultural Development Priority

This scenario focuses on the protection of cropland which contributes greatly to local agricultural yields. Under this scenario, the declining trend of cropland areas will be mitigated by decreasing the rate of cropland conversion to other land cover types.

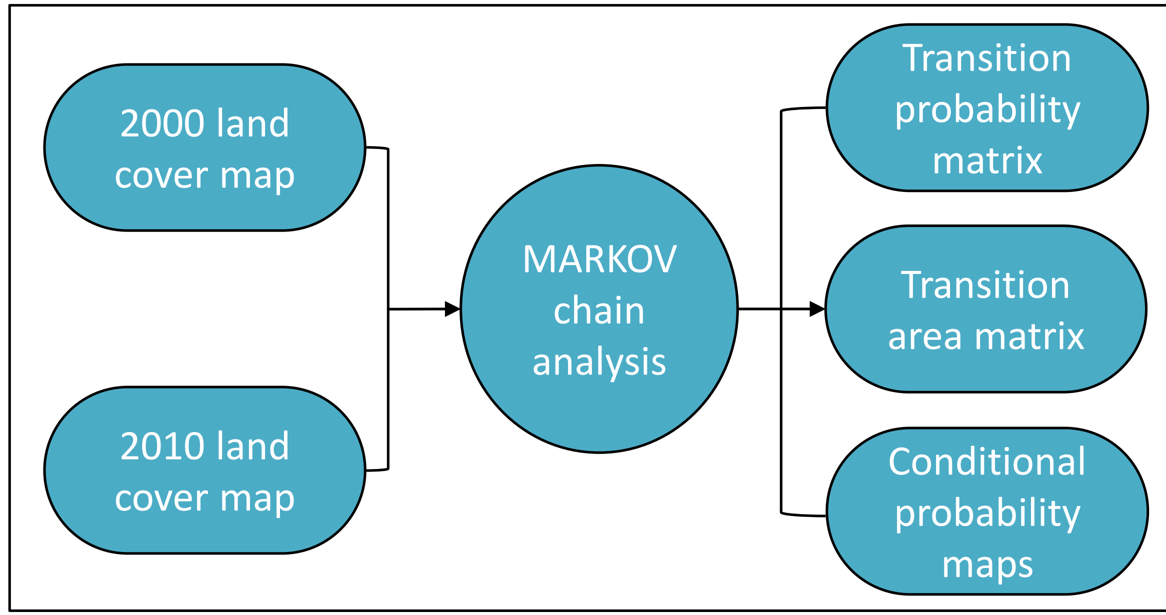
➢ Economic Development Priority

This scenario focuses on economic development. Under this scenario, the area of built-up lands will be expanded by increasing the conversion rates of cropland and forest to built-up lands.

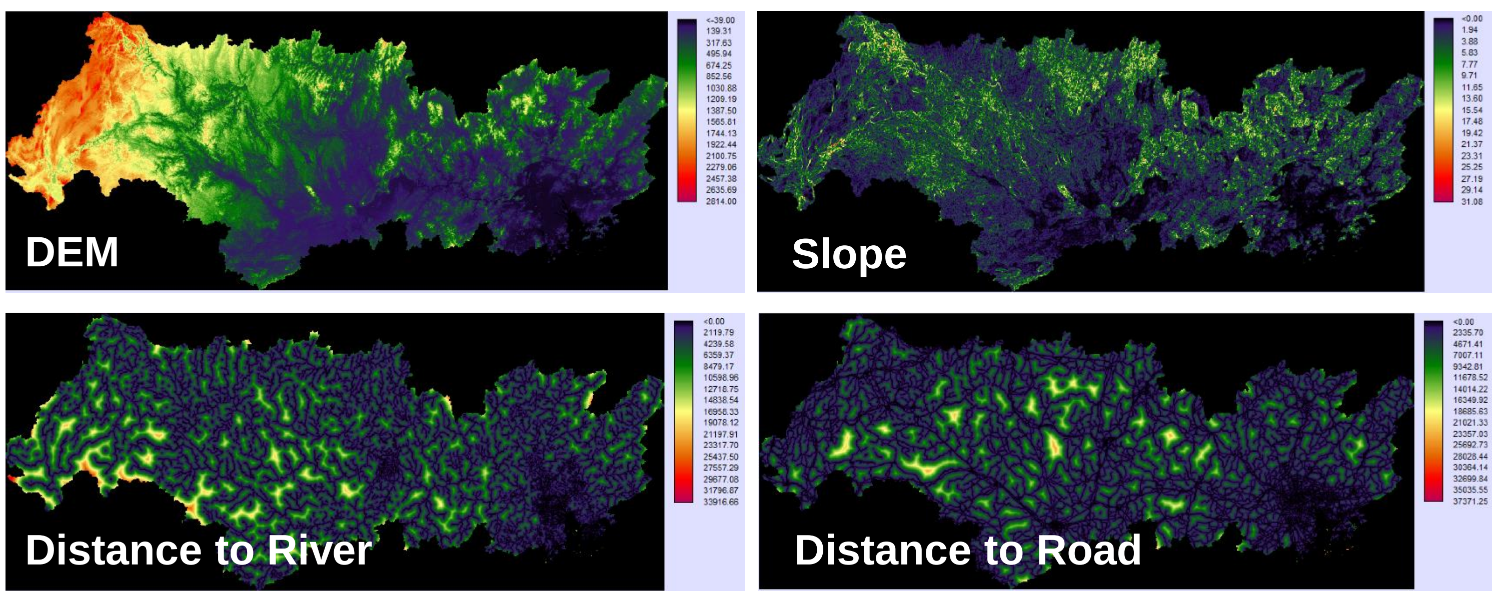
Land Cover Simulation

Cellular Automate - Markov Chain

- Following a procedure of decision-making exercise of multiple criteria evaluation



Key drivers



Ecosystem Service Modelling

Empirical Models

Ecosystem service	Equation
Water Retention	$WR_i = \sum_{m=1}^{12}(P_{i,m} - R_{i,m} - AET_{i,m}) \times 10^{-3} \times A$
Flood Mitigation	$FM = FM_{vegetation} + FM_{lake} + FM_{reservoir}$
Soil Retention	$SR_i = R_i \times K_i \times LS_i \times (1 - C_i)$
Carbon Sequestration	$CS_i = (\sum_{i=1}^{n} BCS_{i,t2} - \sum_{i=1}^{n} BCS_{i,t1})/(t_2 - t_1)$

Key paramet

- WR, water rete
  evapotranspirat
- FM, flood mitiga
  (m^3); FM_{lake}, the
  of reservoirs (m
- SR, the soil rete
  erodibility facto
- ACS, the avera
- i, pixel i; A, the

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REPORT

Improvements in ecosystem services from investments in natural capital

Zhiyun Ouyang[1,*], Hua Zheng[1], Yi Xiao[1], Stephen Polasky[2], Jianguo Liu[3], Weihua Xu[1], Qiao Wang[4], Lu Zhang[1], Yang Xiao[1], E...
+ See all authors and affiliations

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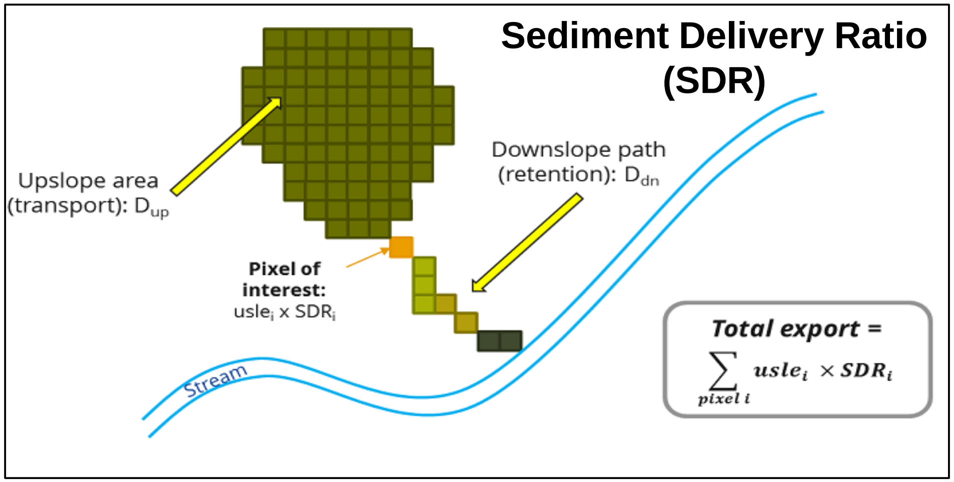
DOI: 10.1126/science.aaf2295

Ecosystem Service Modelling

Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST)



Three modules including:

- SWY for Water Retention
- SWY for Water Retention
- SDR for Sediment Retention
- CSS for Carbon sequestration

PNAS

Realizing the values of natural capital for inclusive, sustainable development: Informing China's new ecological development strategy

Hua Zheng[a,b], Lijuan Wang[a,b], Wenjia Peng[a,b], Cuiping Zhang[c], Cong Li[d], Brian E. Robinson[e], Xiaochen Wu[c], Lingqiao Kong[a,b], Ruonan Li[a,b], Yi Xiao[a,b], Weihua Xu[a,b], Zhiyun Ouyang[a,b,1], and Gretchen C. Daily[f,g,h,1]

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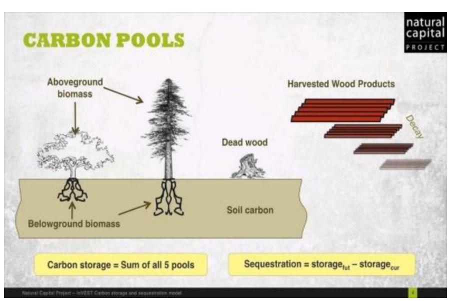
Contributed by Gretchen C. Daily, February 21, 2019 (sent for review November 19, 2018; reviewed by Nick M. Haddad and Jun Yang)

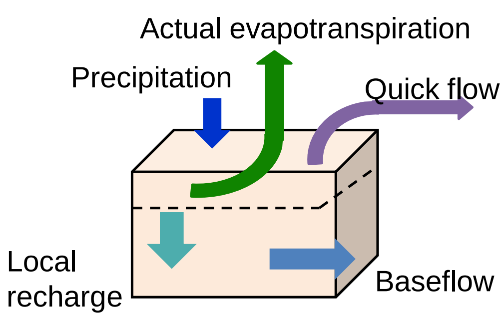
A major challenge in transforming development to inclusive, sustainable pathways is the pervasive and persistent trade-off between provisioning services (e.g., agricultural production) on the one hand and regulating services (e.g., water purification, flood control) and biodiversity conservation on the other. We report on an application of China's new Ecological Development Strategy, now being formally tested and refined for subsequent scaling nationwide, which

quantify and manage trade-offs between immediate, local human needs and future, regional requirements (8–11). Stemming from underlying biophysical processes, some trade-offs are innate, such as between carbon sequestration and water provision in some grassland and shrubland regions (12, 13). However, it has been repeatedly suggested that some trade-offs (e.g., crop product provision and nutrient retention) can be lessened or even neutralized

Carbon Storage and Sequestration (CSS)

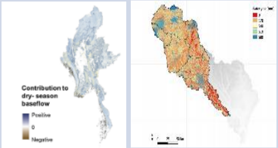
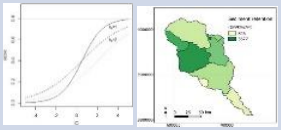
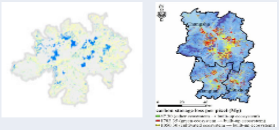


Seasonal Water Yield (SWY)



Ecosystem Service Modelling

Biophysical model - InVEST

Ecosystem service	Major equation	Main outputs
Water Retention	$WR_i = \sum_{m=1}^{12}(P_{i,m} - QF_{i,m} - AET_{i,m}) \times 10^{-3} \times A$	Indices including: Quick flow Local recharge Base flow 
Flood Mitigation	$FM_i = \sum_{m=1}^{12}(P_{i,m} - QF_{i,m}) \times 10^{-3} \times A$	
Sediment Retention	$SR_i = R_i \times K_i \times LS_i \times (1 - C_i)$	Indices including: Sediment retention Sediment export 
Carbon Sequestration	$CS_i = (\sum_{i=1}^{n} BCS_{i,t2} - \sum_{i=1}^{n} BCS_{i,t1})/(t_2 - t_1)$	Indices including: Carbon storage and Its differences 

Key parameters

- WR, water retention capacity (m^3); P, precipitation (mm); QF, quick flow (mm); AET, actual evapotranspiration (mm); A, area of each pixel (m).
- FM, flood mitigation capacity of the entire region (m^3).
- SR, the soil retention capacity ($t\ ha^{-1}$); R, the rainfall erosivity factor ($MJ\ mm\ ha^{-1}\ h^{-1}\ yr^{-1}$); K, the soil erodibility factor ($t\ ha\ h\ ha^{-1}\ MJ^{-1}\ mm^{-1}$); LS, the topographic factor; C, the vegetation cover factor.
- ACS, the average annual carbon sink (Tg C/yr); BCS, the biomass carbon storage.
- i, pixel i; A, the area of each pixel (m^2).

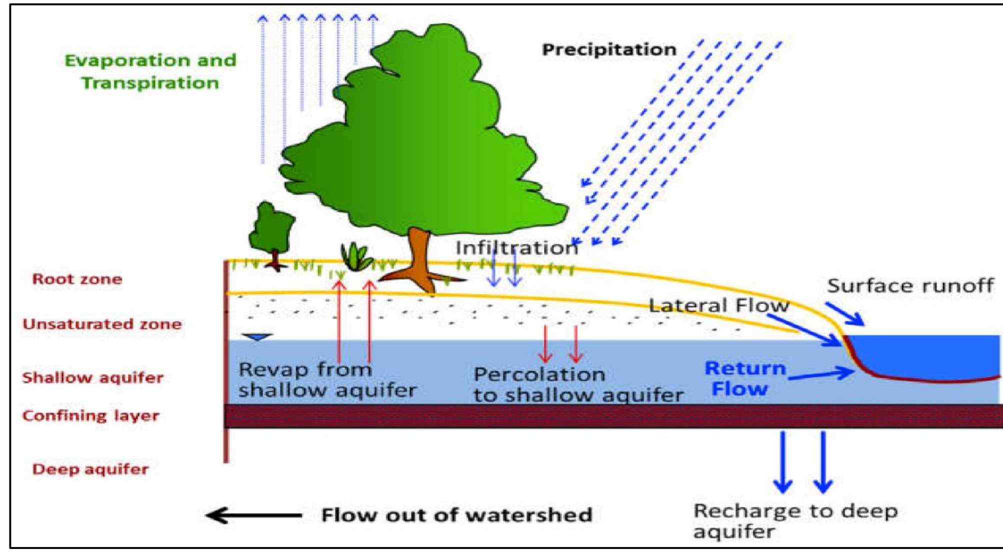
Ecosystem Service Modelling

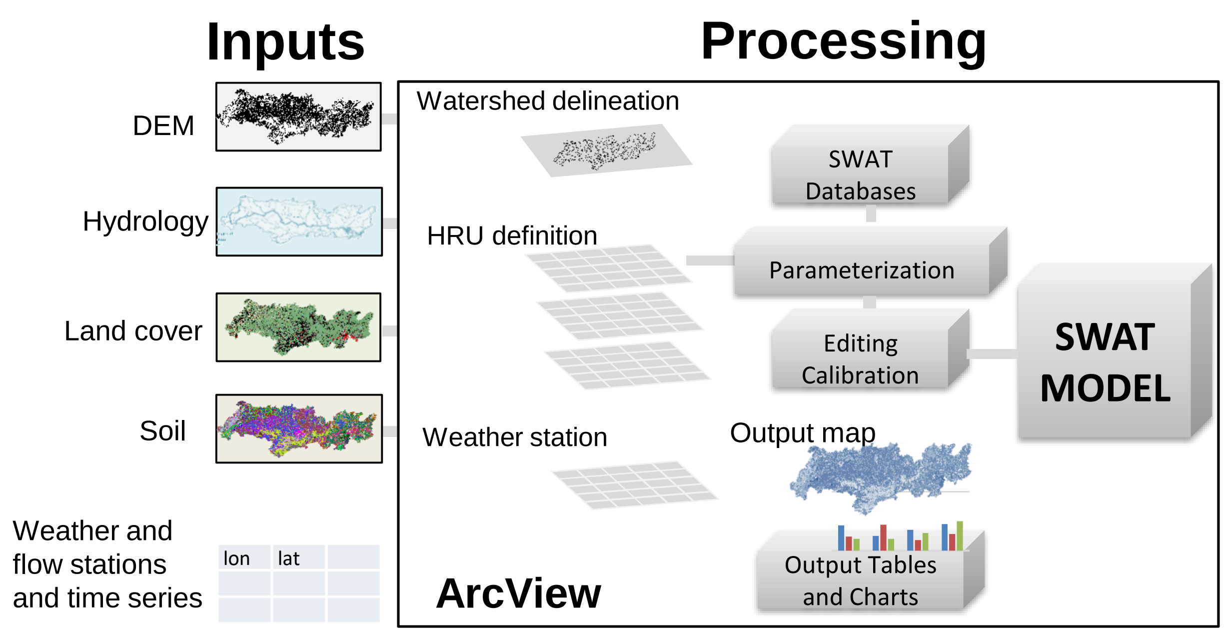
Soil & Water Assessment Tool (SWAT)

For evaluating the impacts of development and land management practices on the watershed water balance.

Ecosystem services including:

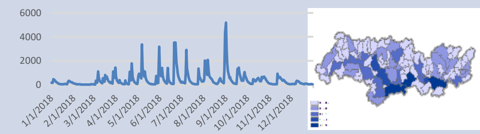
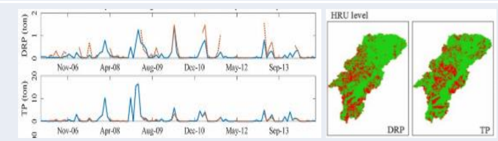
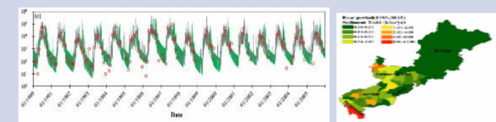
- Spatial distribution of water yield
- Sediment delivery





Ecosystem Service Modelling

Biophysical model - SWAT

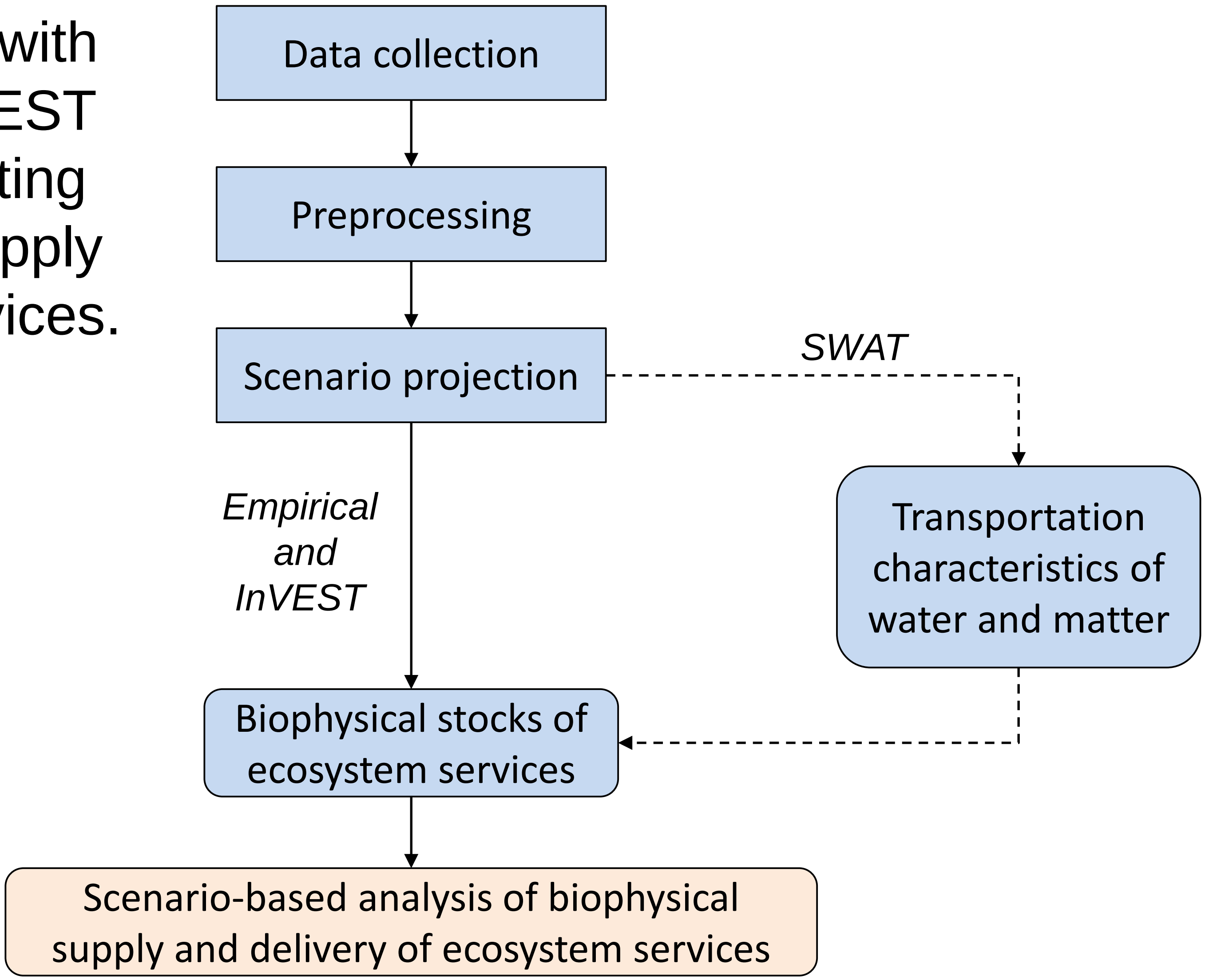
Ecosystem service	Major equation	Main outputs
Water yield	$SW_t = SW_0 + \sum_{n=1}^{t}(P_n - R_n - W_n - E_n - Q_n)$	Daily changes In inflow and outflow 
Water quantity		Daily changes In water quantity metrics like TN, TP 
Sediment regulation	$SED' = 11.8(Q_{surf} q_{peak} area_{hru})^{0.56} K_{USLE} C_{USLE} P_{USLE} LS_{USLE} CF$	soil erosion and sediment yield from each HRUs 

Key parameters

- SW_0 and SW_{tn} are the initial and total soil water content on day n (mm); P_n is the precipitation (mm); R_n is the surface runoff on day n (mm); W_n is the amount of percolation and bypass flow exiting the soil profile bottom on day n (mm); E_n is the evapotranspiration on day n (mm); Q_n is the amount of return flow on day n (mm).
- SED' is the sediment yield (metric tons); Q_{surf} is the surface runoff (mm/ha); q_{surf} is the peak runoff (m3/s); $area_{hru}$ is the area of hydrologic response unit (ha); K_{USLE} is the soil erodibility factor (0.013 metric ton m2 ha/(m3 metric ton cm); C_{USLE} is the cover and management factor; P_{USLE} is the support practice factor; LS_{USLE} is the topographic factor; C_{FRG} is the coarse fragment factor)

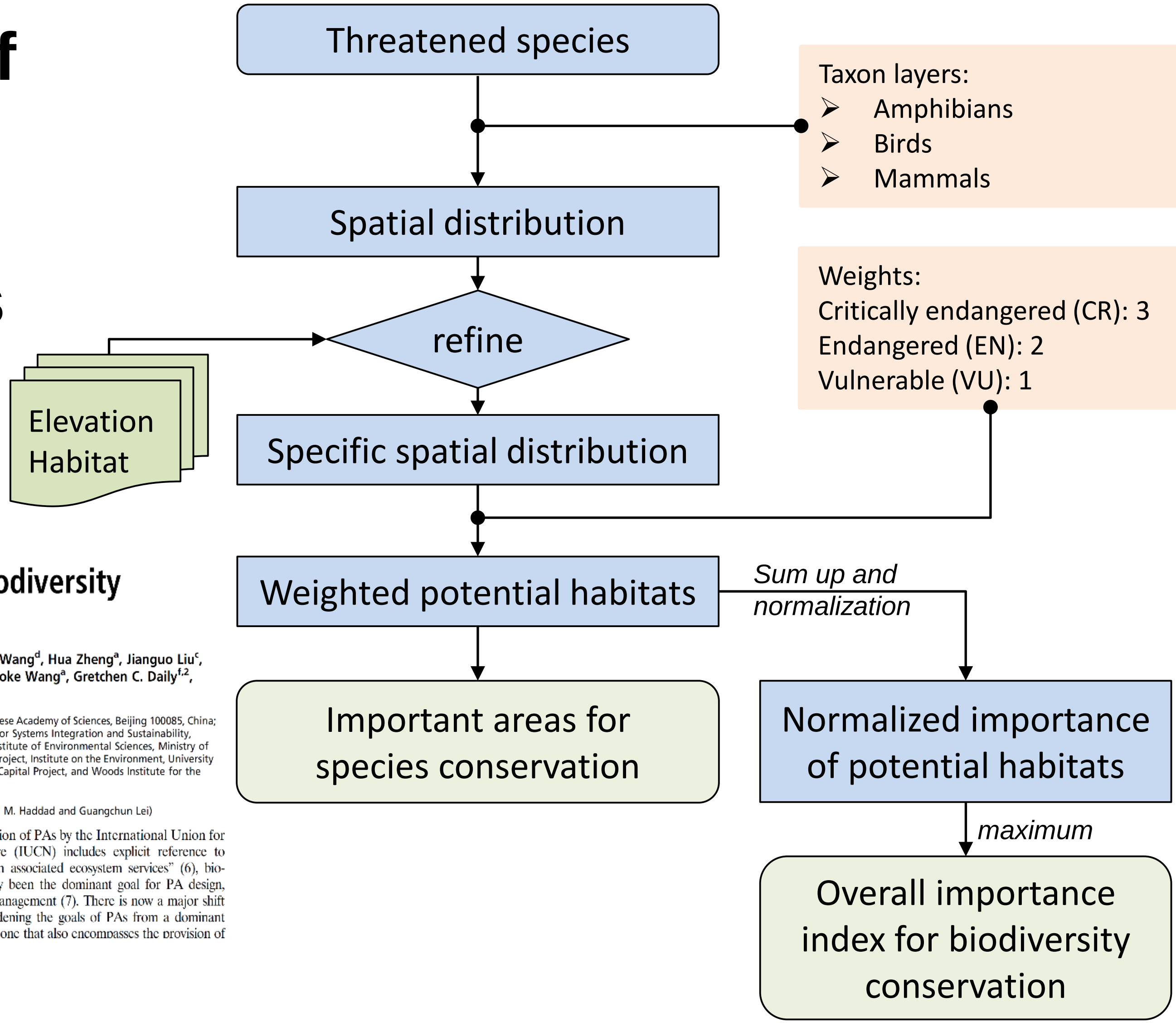
Ecosystem Service Modelling

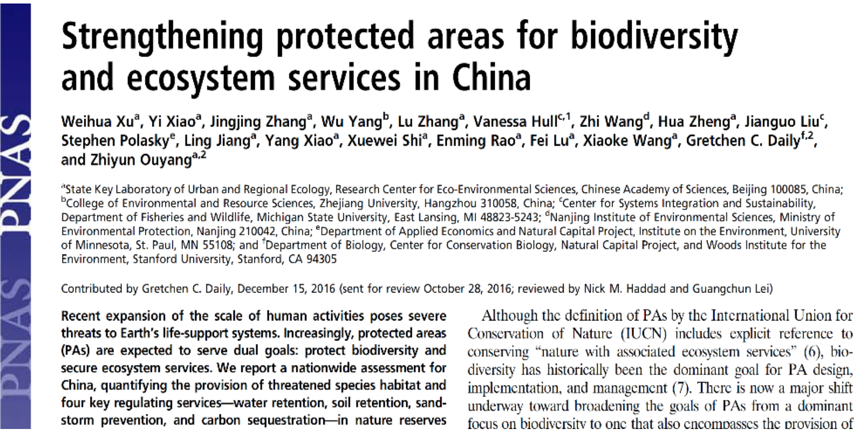
Linkage of SWAT with empirical and InVEST models for estimating the biophysical supply of ecosystem services.



Biodiversity Conservation

Quantification of the provision of threatened species habitats for biodiversity conservation.





PNAS

Strengthening protected areas for biodiversity and ecosystem services in China

Weihua Xu[a], Yi Xiao[a], Jingjing Zhang[a], Wu Yang[b], Lu Zhang[a], Vanessa Hull[c,1], Zhi Wang[d], Hua Zheng[a], Jianguo Liu[c], Stephen Polasky[e], Ling Jiang[a], Yang Xiao[a], Xuewei Shi[a], Enming Rao[a], Fei Lu[a], Xiaoke Wang[a], Gretchen C. Daily[f,2], and Zhiyun Ouyang[a,2]

[a]State Key Laboratory of Urban and Regional Ecology, Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences, Beijing 100085, China; [b]College of Environmental and Resource Sciences, Zhejiang University, Hangzhou 310058, China; [c]Center for Systems Integration and Sustainability, Department of Fisheries and Wildlife, Michigan State University, East Lansing, MI 48823-5243; [d]Nanjing Institute of Environmental Sciences, Ministry of Environmental Protection, Nanjing 210042, China; [e]Department of Applied Economics and Natural Capital Project, Institute on the Environment, University of Minnesota, St. Paul, MN 55108; and [f]Department of Biology, Center for Conservation Biology, Natural Capital Project, and Woods Institute for the Environment, Stanford University, Stanford, CA 94305

Contributed by Gretchen C. Daily, December 15, 2016 (sent for review October 28, 2016; reviewed by Nick M. Haddad and Guangchun Lei)

Recent expansion of the scale of human activities poses severe threats to Earth's life-support systems. Increasingly, protected areas (PAs) are expected to serve dual goals: protect biodiversity and secure ecosystem services. We report a nationwide assessment for China, quantifying the provision of threatened species habitat and four key regulating services—water retention, soil retention, sand-storm prevention, and carbon sequestration—in nature reserves

Although the definition of PAs by the International Union for Conservation of Nature (IUCN) includes explicit reference to conserving "nature with associated ecosystem services" (6), biodiversity has historically been the dominant goal for PA design, implementation, and management (7). There is now a major shift underway toward broadening the goals of PAs from a dominant focus on biodiversity to one that also encompasses the provision of

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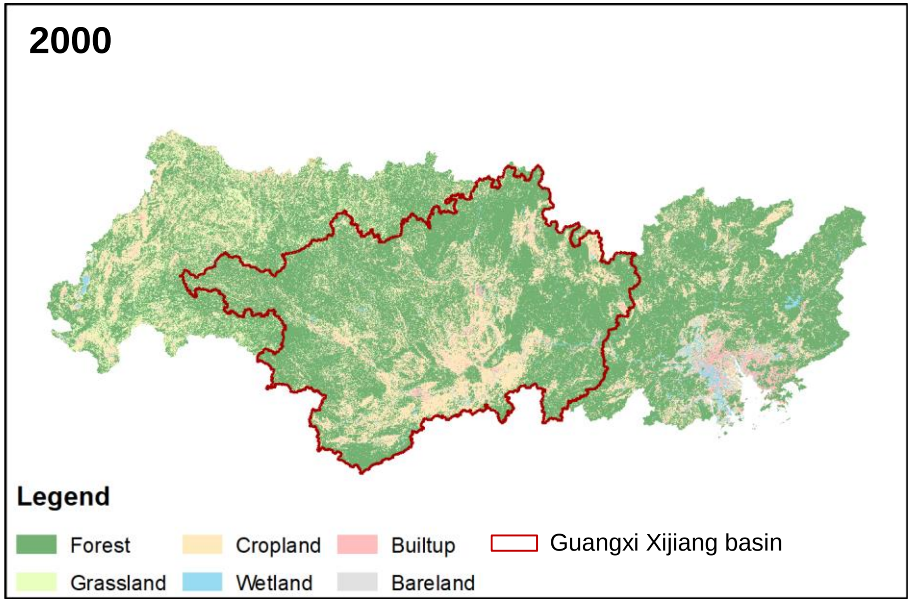
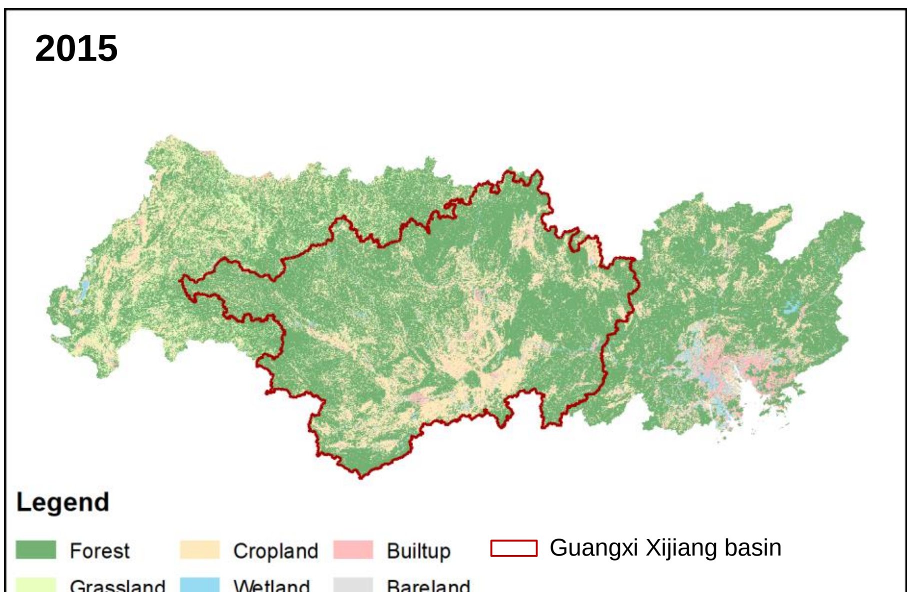
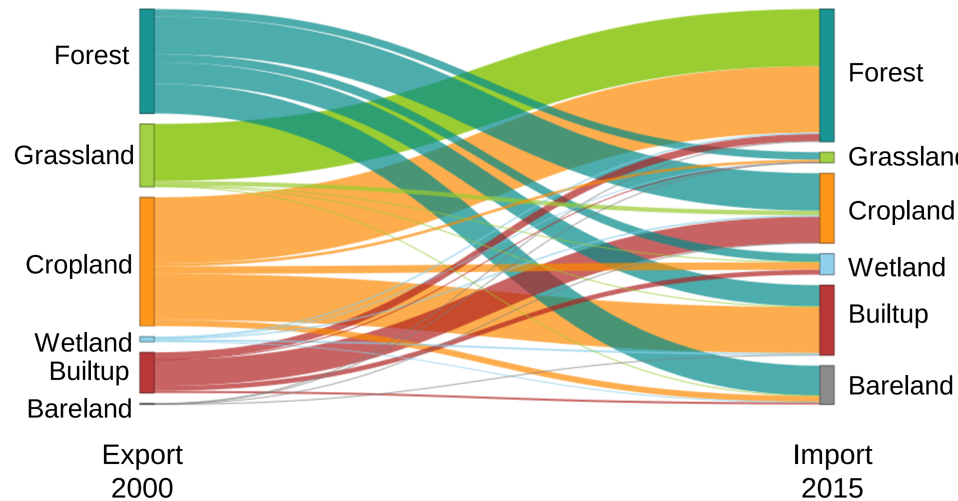
Historical Land Cover Changes





Export and import characteristics

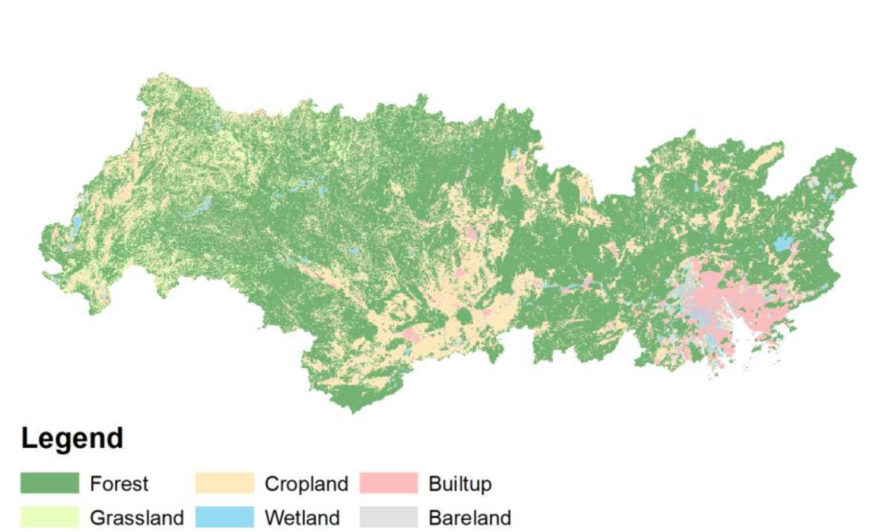


Land cover areas (km^2)

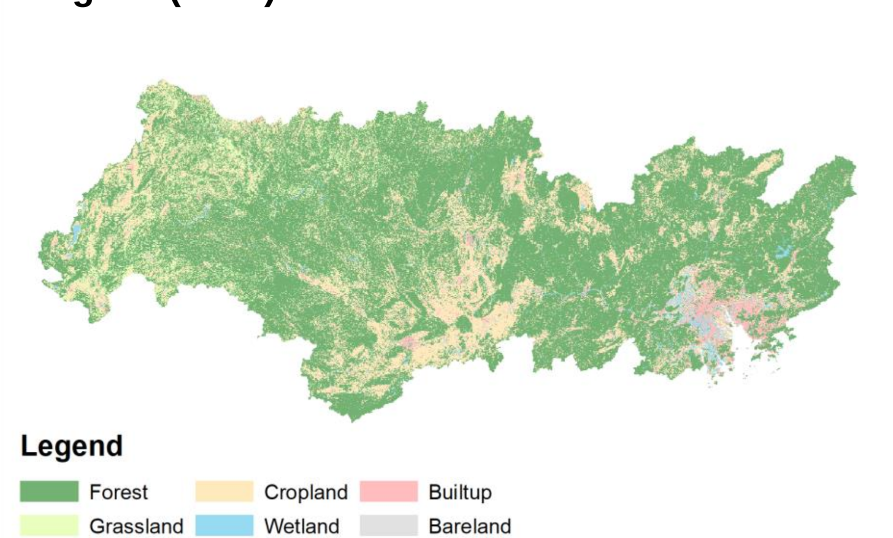
Land Cover	2000		2015	
	Xijang basin	Xijiang basin (Guangxi)	Xijang basin	Xijiang basin (Guangxi)
Forest	286925	135039	287782	135407
Grassland	28019	4704	27607	4022
Cropland	104237	54792	99153	54024
Wetland	10144	3181	10209	3386
Builtup	12719	4383	16679	4767
Bareland	814	16	1428	509

Simulation of Land Cover

Simulated (2015)



Original (2015)



Difference between simulated and original land cover areas (km^2)

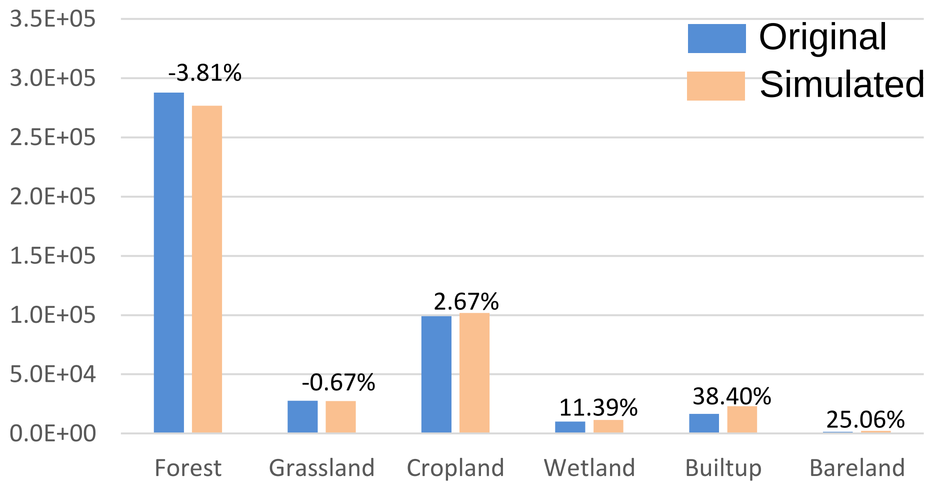
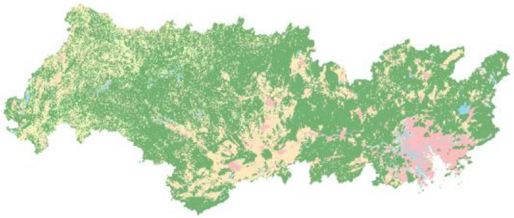


Image similarity:

Chi-square = 3.29×10^6
df = 36
P-level = 0.000
Cramer's V = 0.8289
Kappa = 0.9465

Prediction of Future Land Cover

Baseline map



2015

Business As Usual

2030

EPP

Ecological Protection Priority

ADP

Agricultural Dvpt. Priority

EDP

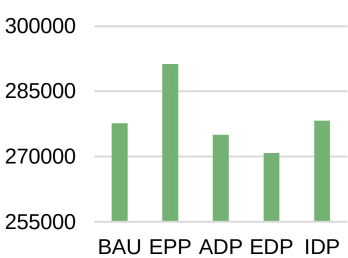
Economic Dvpt. Priority

IDP

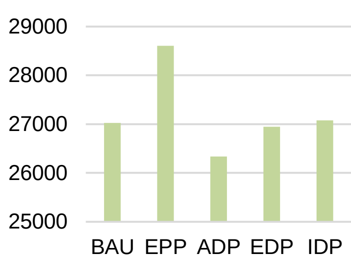
Integrated Dvpt.

Land cover areas (km²) under different scenarios

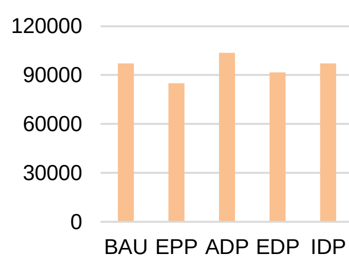
Forest



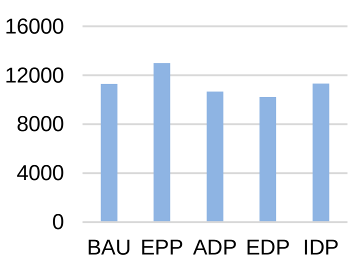
Grassland



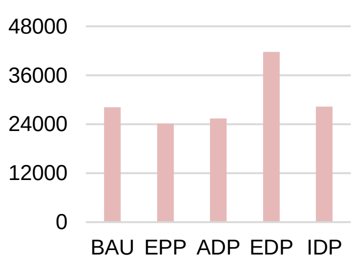
Cropland



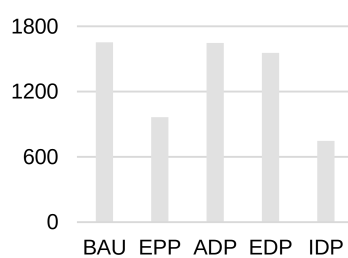
Wetland



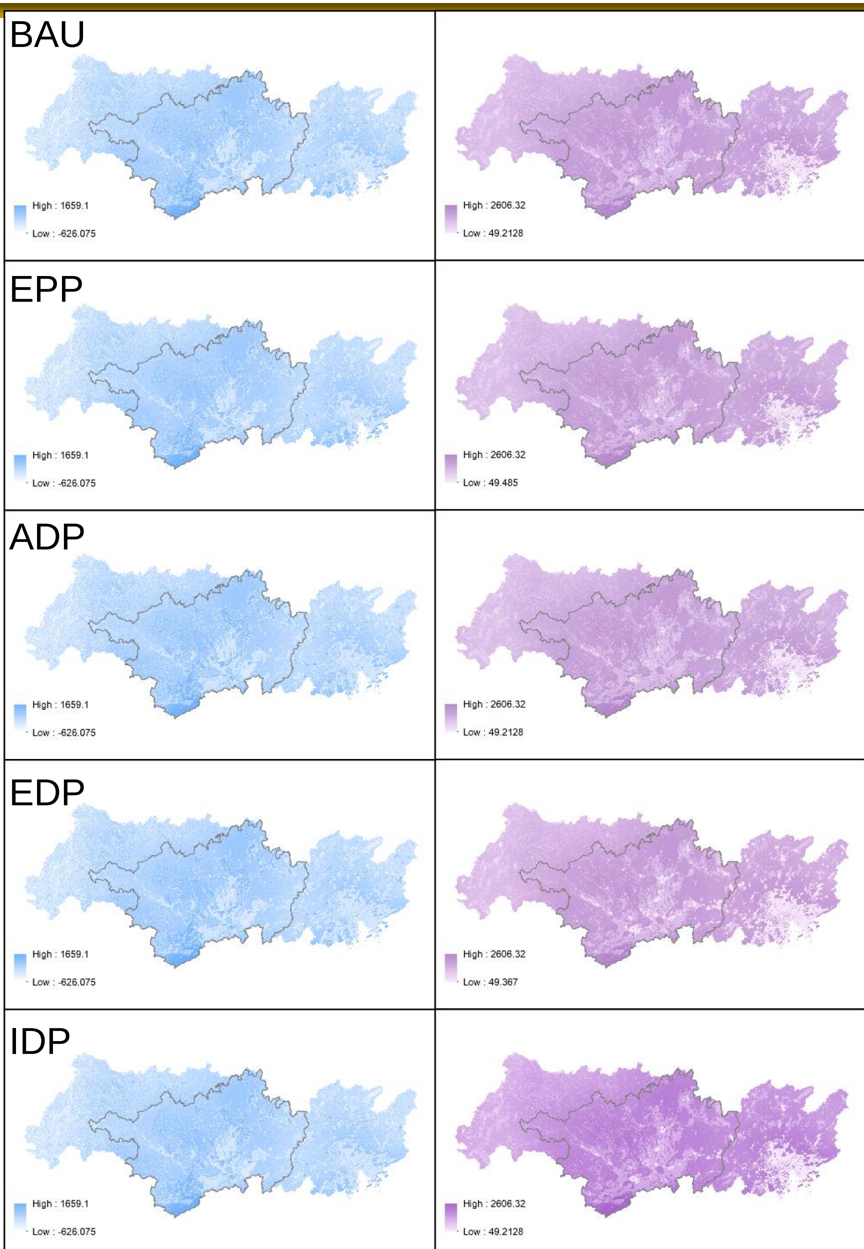
Builtup



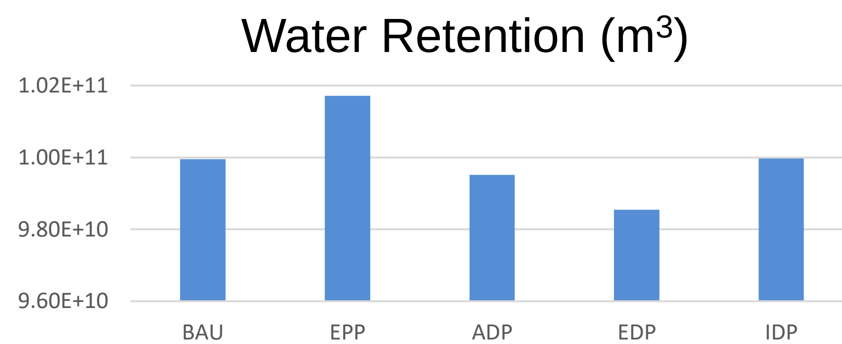
Bareland

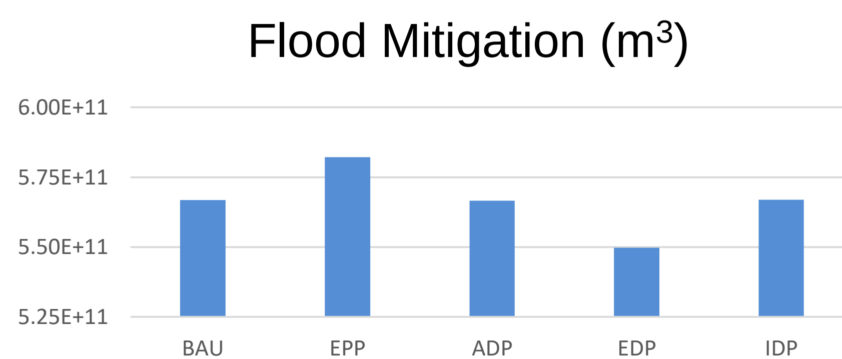


Biophysical ES Supply



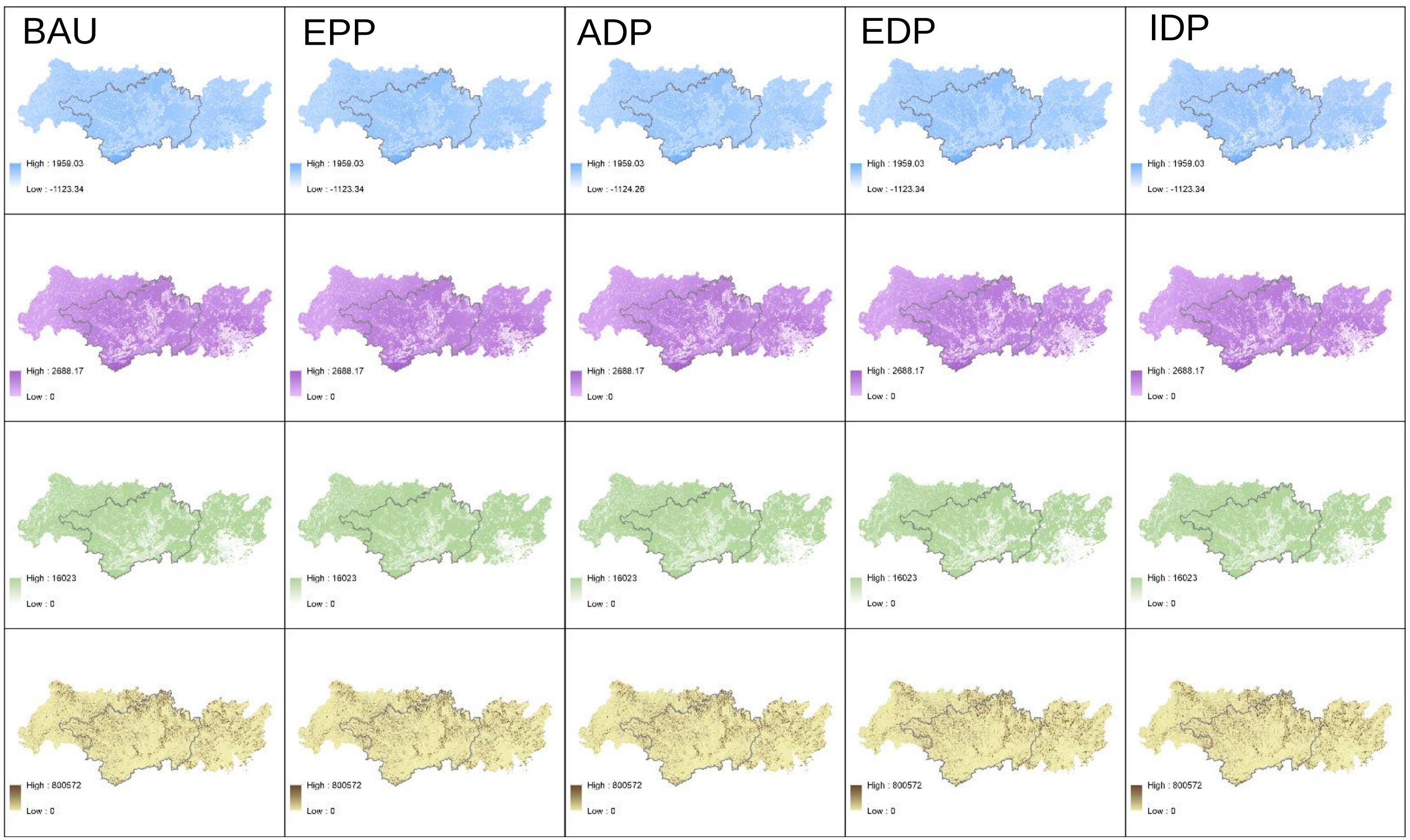
Relatively higher water retention and flood mitigation services for the EPP scenario as indicated by the traditional ecosystem service models

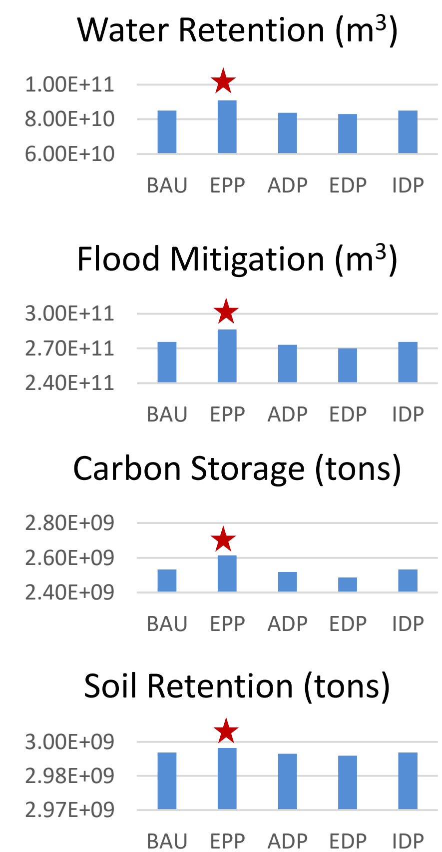




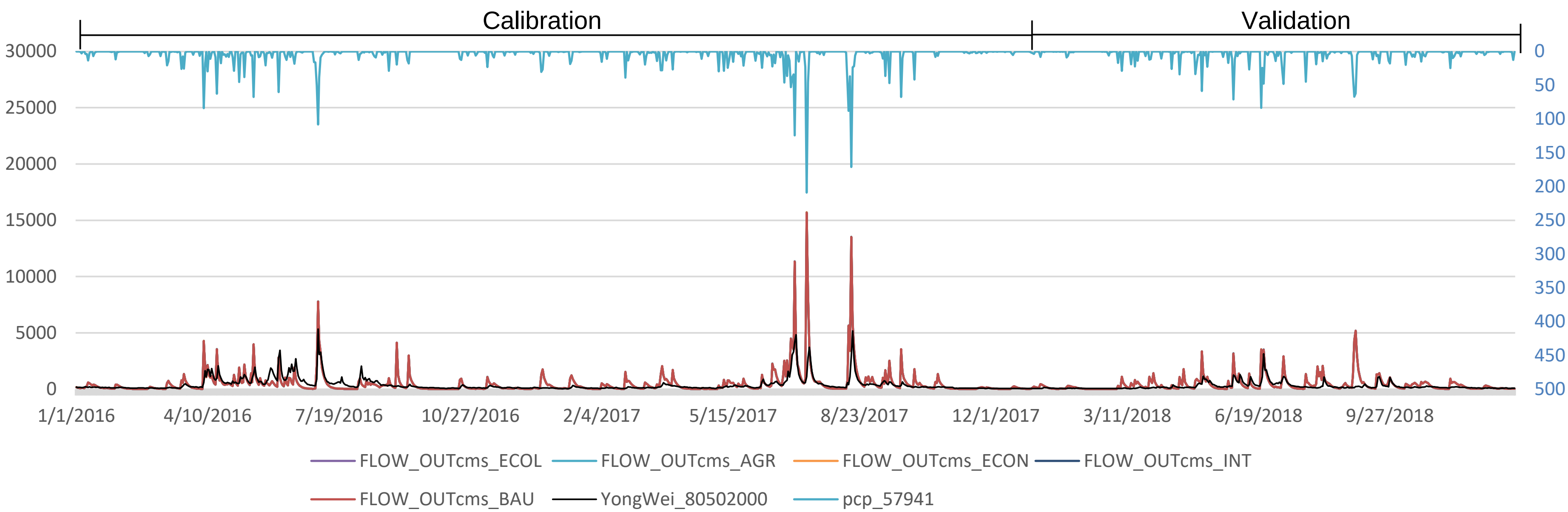
Biophysical ES Supply - InVEST

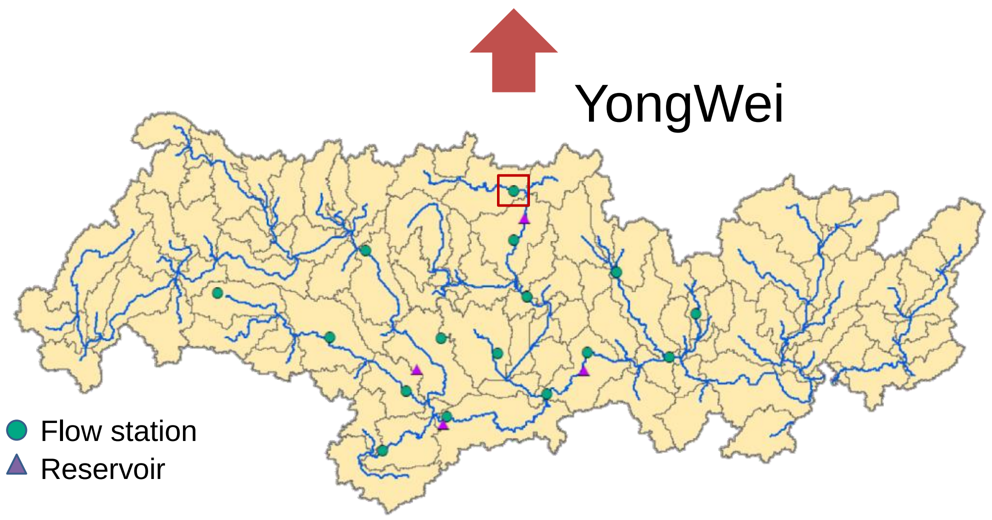
As indicated by the InVEST model outputs, relatively higher biophysical supply of ecosystem services were observed under the EPP scenario.

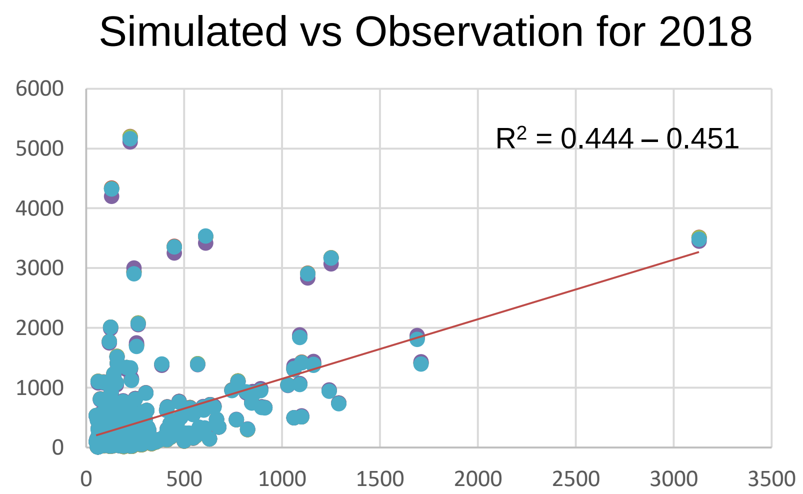




Biophysical ES Supply - SWAT



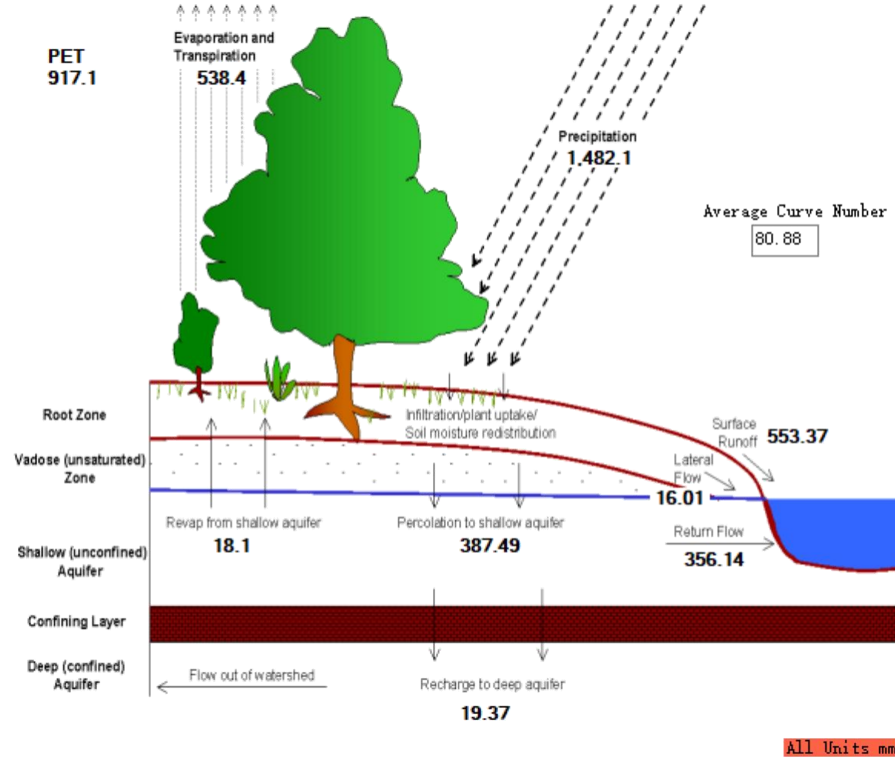




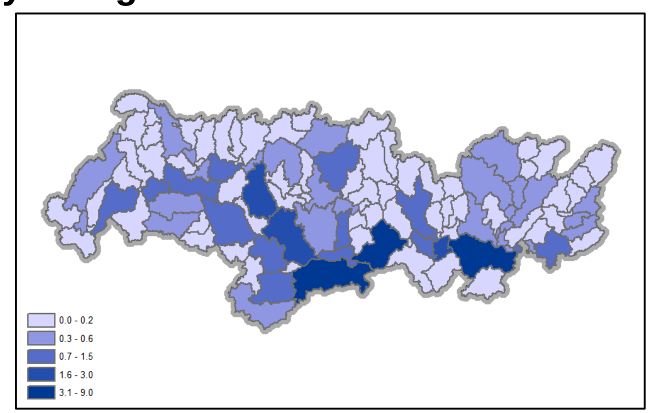
Biophysical ES Supply - SWAT

Sensitive parameters used for estimating hydrological processes including:

Name	Description
r__CN2	Curve number
v__ALPHA_BF	Baseflow alpha factor
v__GW_DELAY	Delay time based on aquifer recharge
v__GWQMN	Water depth in the shallow aquifer required for return flow to occur
v__GW_REVAP	Groundwater revap coefficient
v__REVAPMN	Water depth in the shallow aquifer for revap or percolation to the deep aquifer to occur.
v__ESCO	Soil evaporation compensation factor
r__HRU_SLP	Average slope steppness
r__OV_N	Manning's n value for overland flow

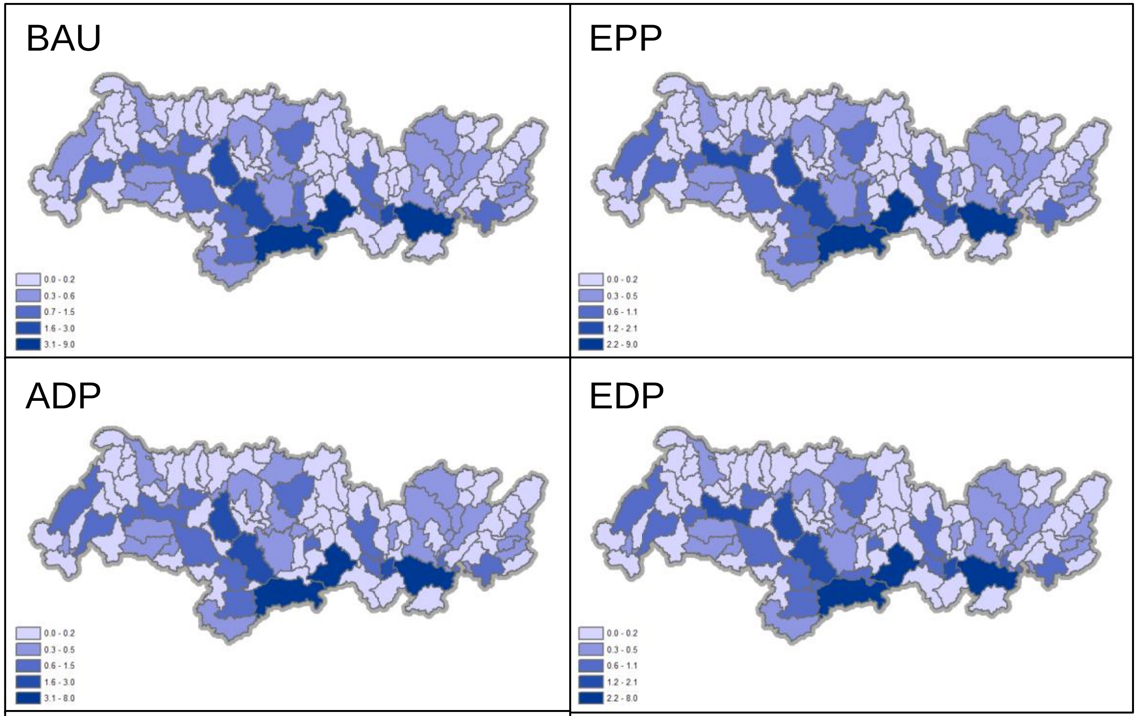


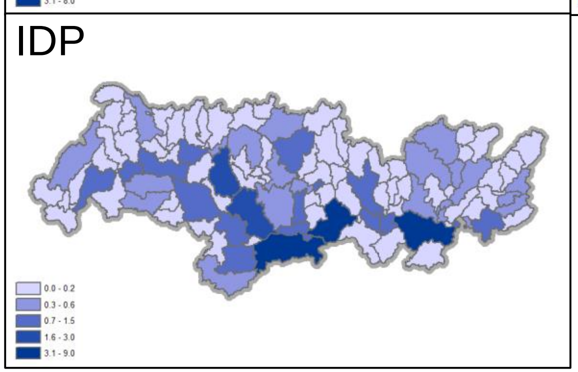
Hydrological balance for the whole basin



Biophysical ES Supply - SWAT

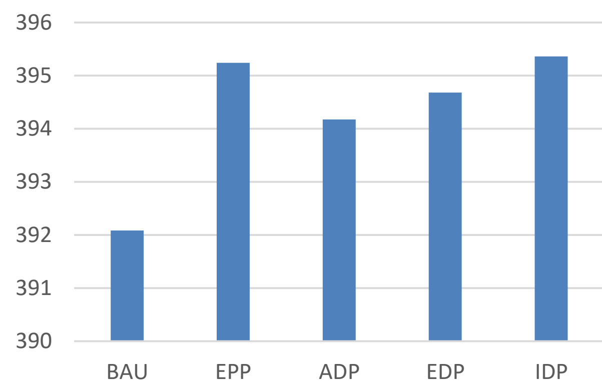
Water yield capacity without management effects



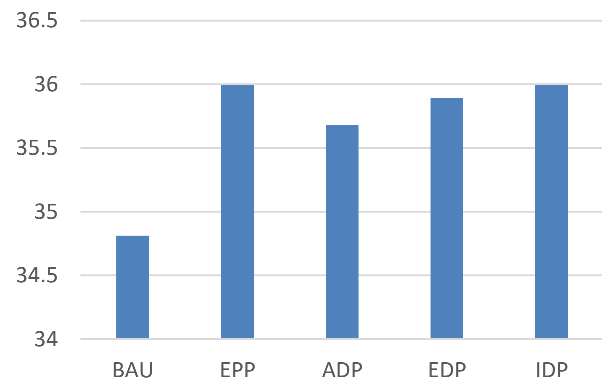


125 model sub-basins
2899 HRUs

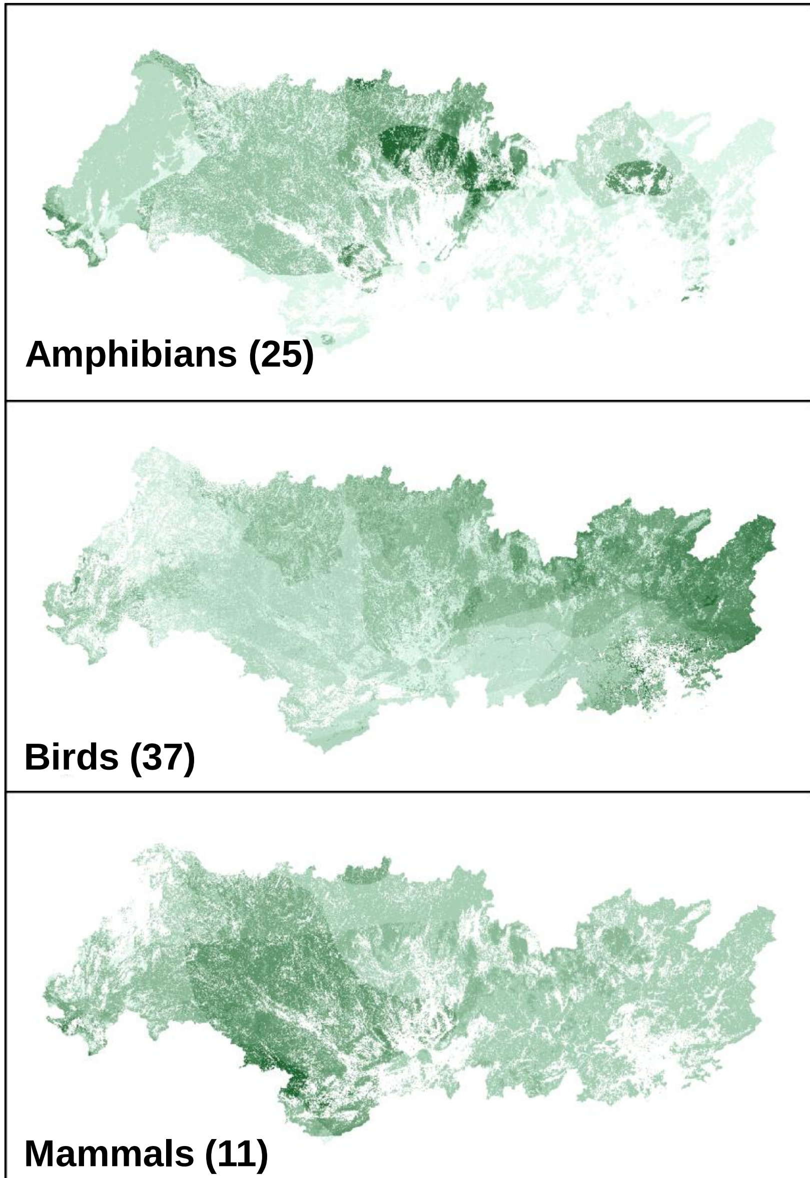
Xijiang basin (m^3/s)



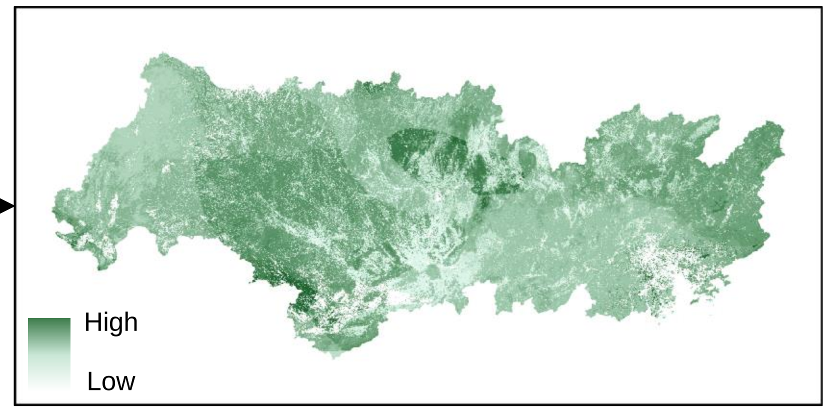
Guangxi (m^3/s)



Biodiversity Conservation



Importance index for biodiversity conservation

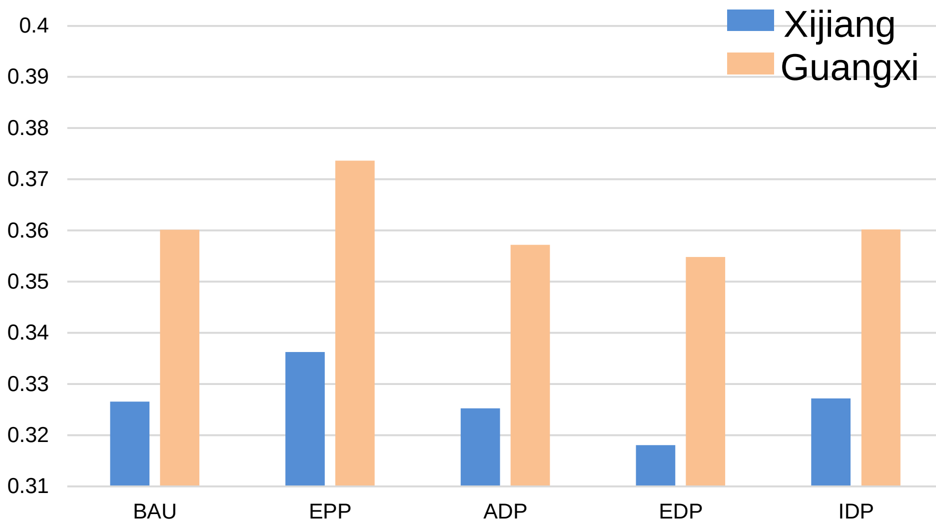


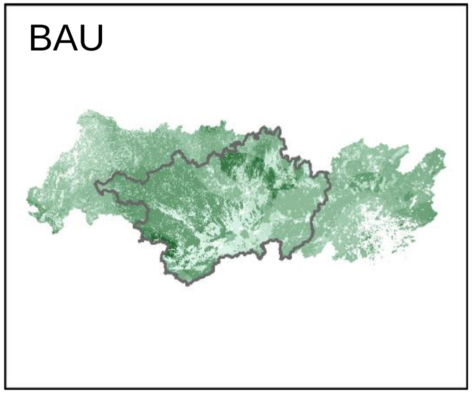
Red List Category

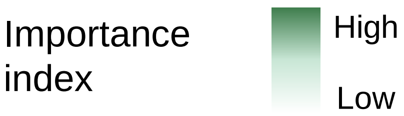
- Vulnerable (VU): 39
- Endangered (EN): 24
- Critically Endangered (CR): 10

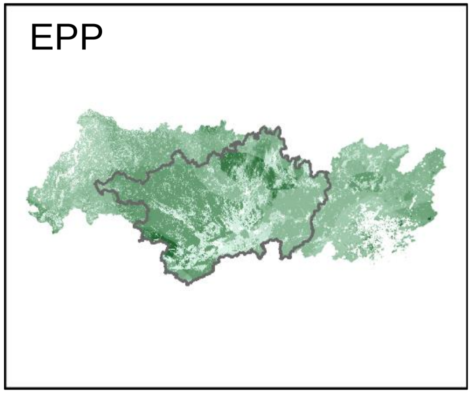
Biodiversity Conservation

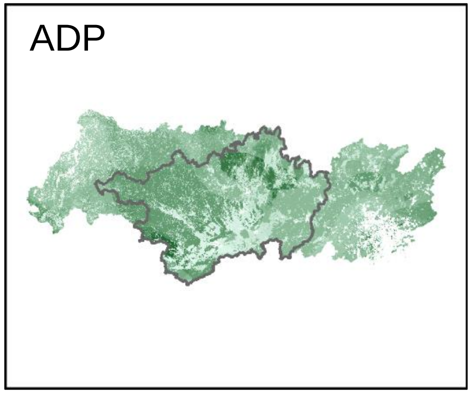
Mean importance index for biodiversity conservation under different scenarios

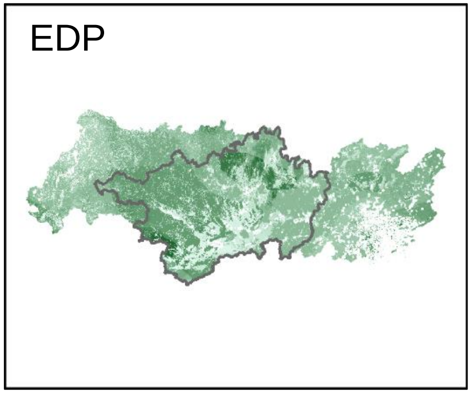


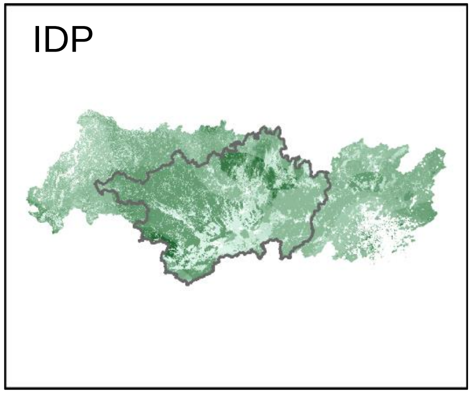












Outline

- Background
- Research Question
- Methodology
- Preliminary Results
- **Next Work**

Yet To Do

- Estimation and refining of the spatial distribution of biophysical metrics including water yield, sediment delivery based on SWAT model;
- Valuation of ecosystem services under different scenarios;
- Measurement of ecological compensation standards between the upstream and downstream regions.


Thanks for your attention!