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Evaluating the impact of land use on soil organic carbon spatial distribution by SWAT-C model – a case study of the Wu River Basin, Taiwan

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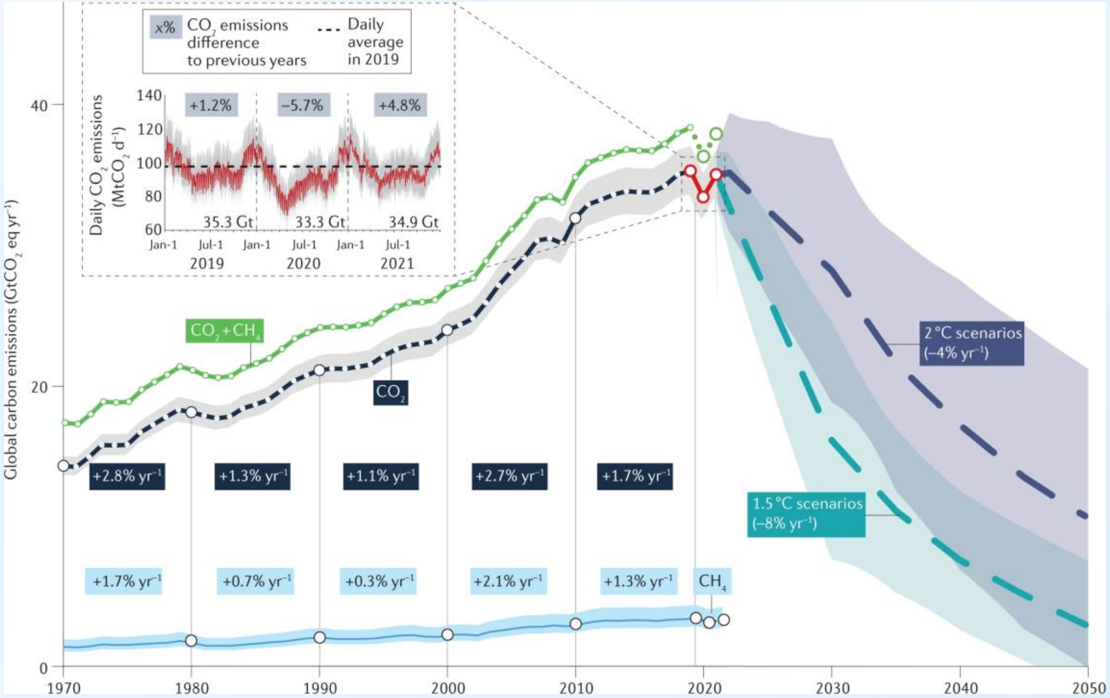
The impact of climate change

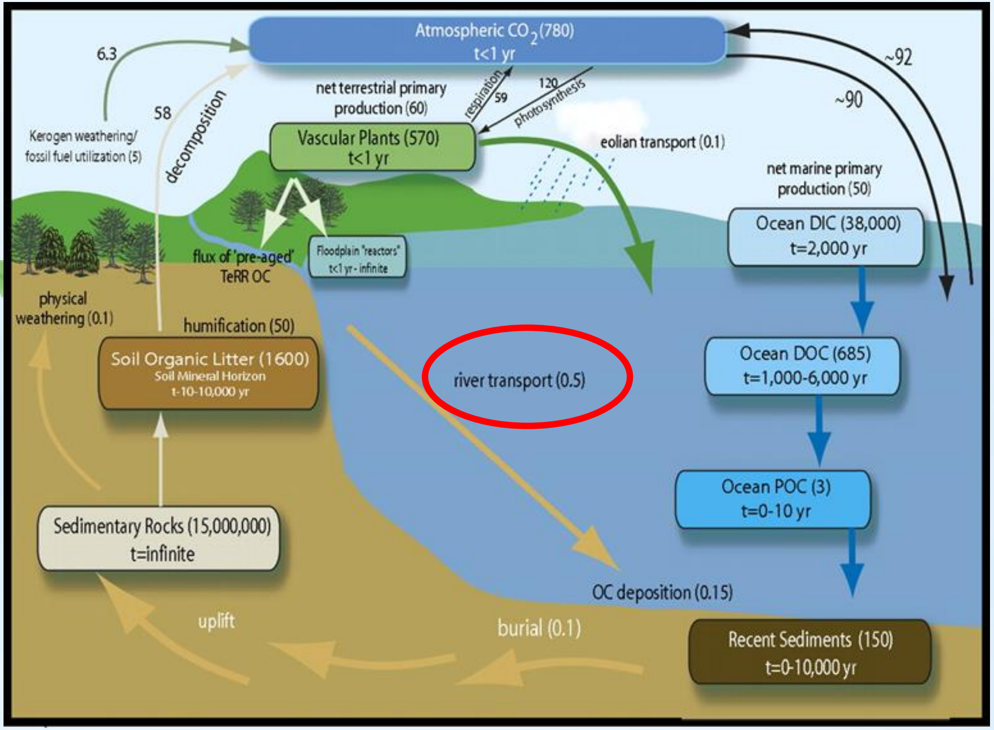


Liu et al., (2024)

- Over the past two decades, CO_2 emissions have shown a steady upward trend, exerting increasing pressure on the global climate and pushing temperatures closer to the 1.5 °C threshold.

- Controlling carbon export is crucial for mitigating climate change.

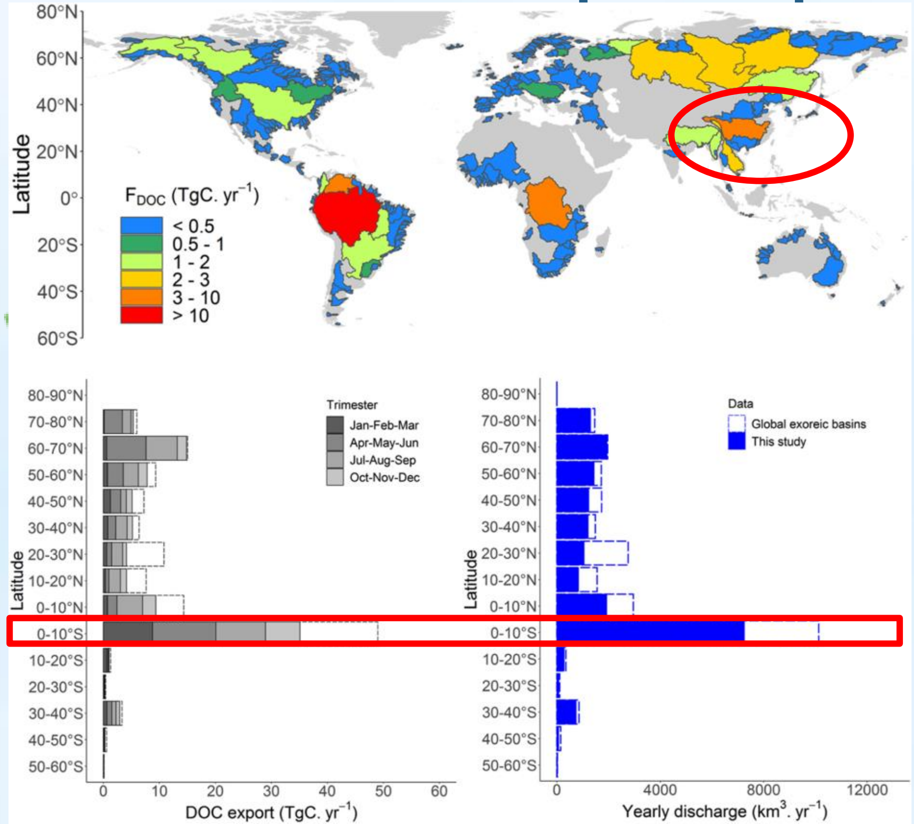
The carbon cycle and organic carbon



Barbier et al.(2011)

- Land ecosystems deliver organic carbon to rivers, but most is respired or stored in soils before reaching the ocean. Soils serve as key carbon sinks, and protecting soil carbon helps reduce emissions.
- In the ocean, terrestrial carbon may be released as CO_2, buried, or moved to deeper waters. Minimizing carbon loss and enhancing soil carbon storage are vital for climate mitigation.

DOC export pattern in the world

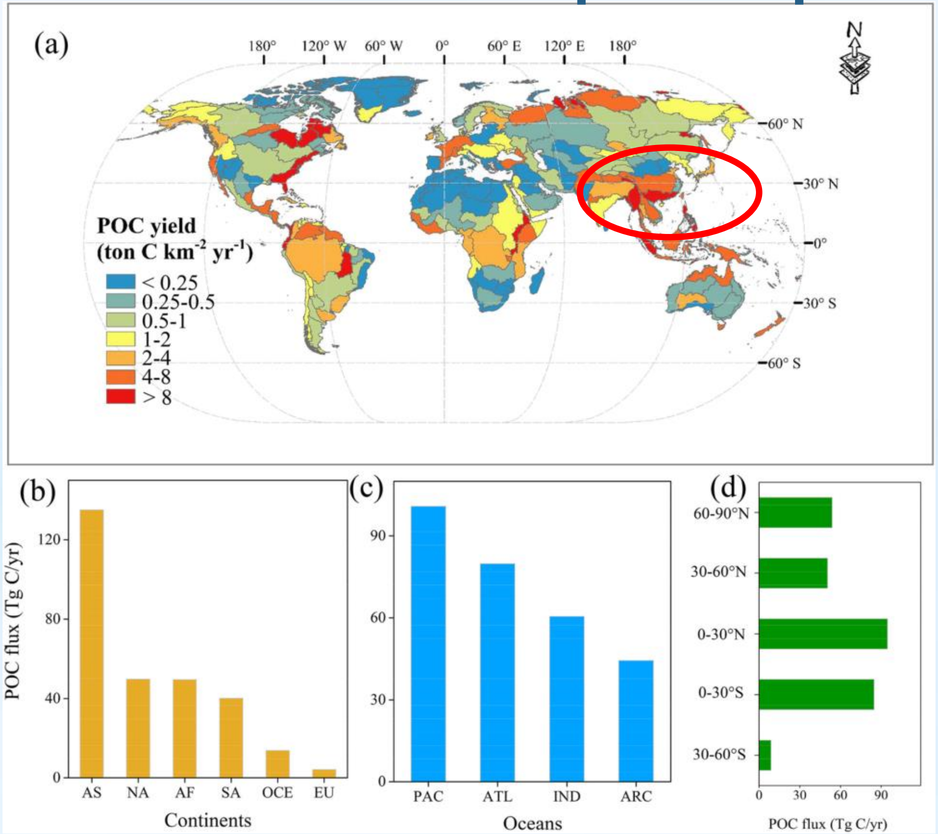


(Fabre et., 2020)

- Asia is identified as one of the major contributors to global riverine DOC export. The seasonal monsoon-driven hydrology further enhances DOC transport during peak flow periods.

- This highlights the critical role of Asian rivers in the global carbon cycle and underscores the need for regional monitoring and carbon management strategies.

POC export pattern in the world

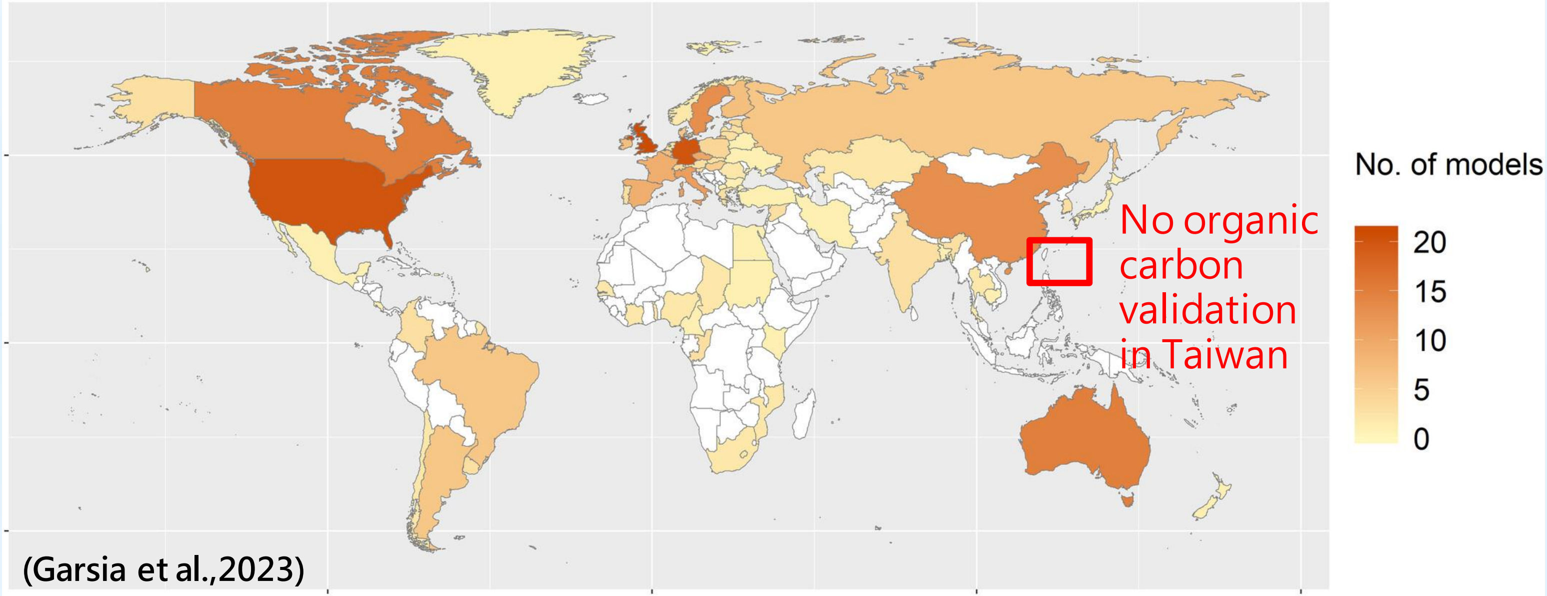


(Li et., 2022)

- The previous study shows that global POC yield varies widely, with the highest values in tropical rivers as well as in parts of Southeast Asia and high-latitude regions. The areas have yields over 8 ton/km^2, mainly due to strong rainfall, erosion, and land use impacts.

- Asia contributes the most POC flux among continents, while the Pacific Ocean receives the largest share of riverine POC.

The importance of model validation for organic carbon dynamics



- However, according to review studies on organic carbon modeling, global simulations of organic carbon often lack validation, which greatly reduces their reliability.

The research propose

Organic carbon estimation

Simulate the organic carbon
export and storage

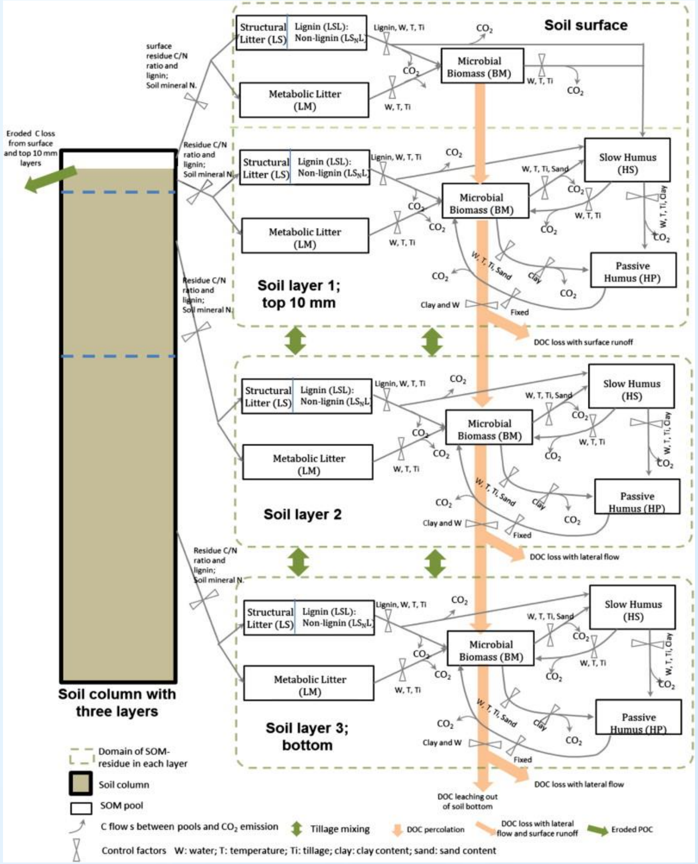
SWAT-C application

SWAT-C applied in the subtropical mountainous watershed

Land use comparison

Evaluate the organic carbon export by different land use

SWAT-C model development

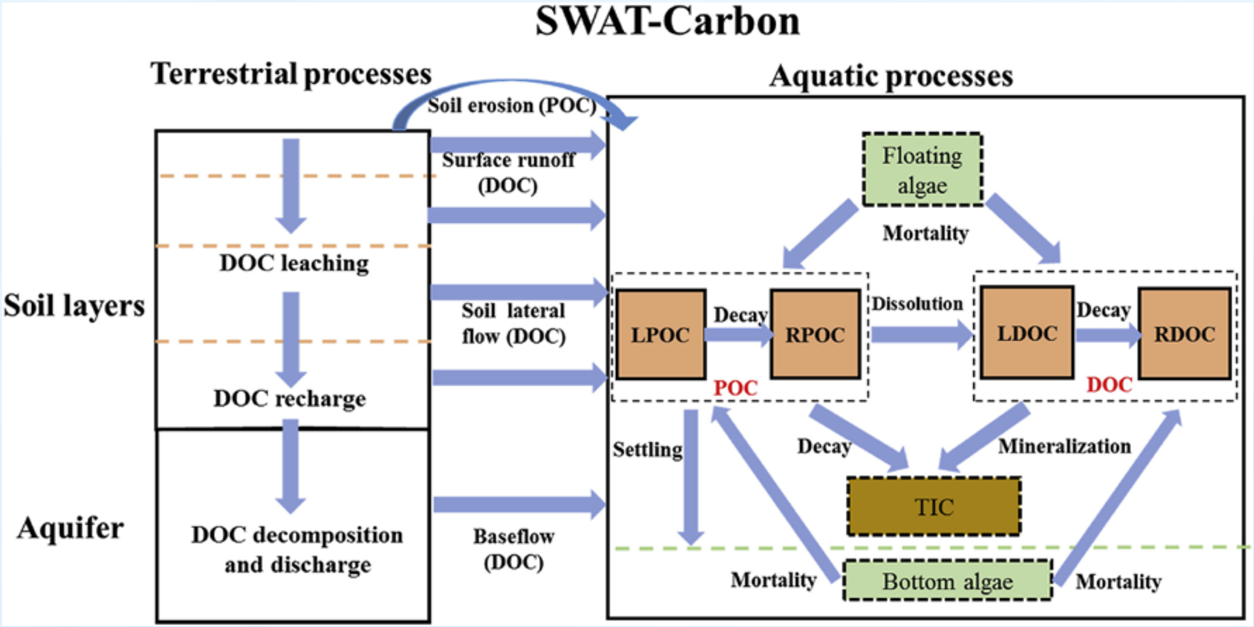


(Zhang et al., 2013)

- SWAT-C is an enhanced model built on the SWAT framework, integrating the CENTURY carbon model to simulate the soil organic carbon

- SWAT-C addresses addition, decomposition, transformation, and removal of each SOM-residue pool present in surface and subsurface soil layers.

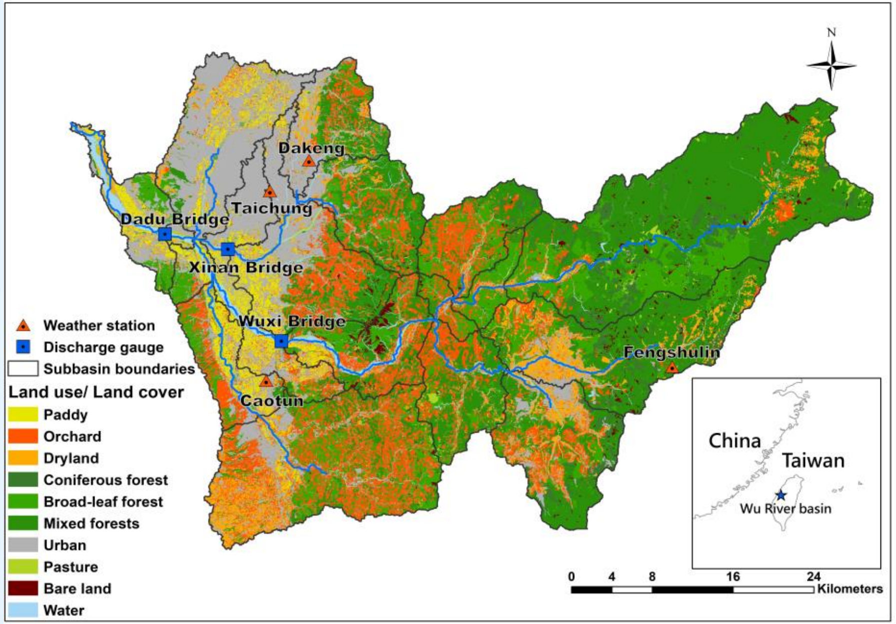
SWAT-C model development

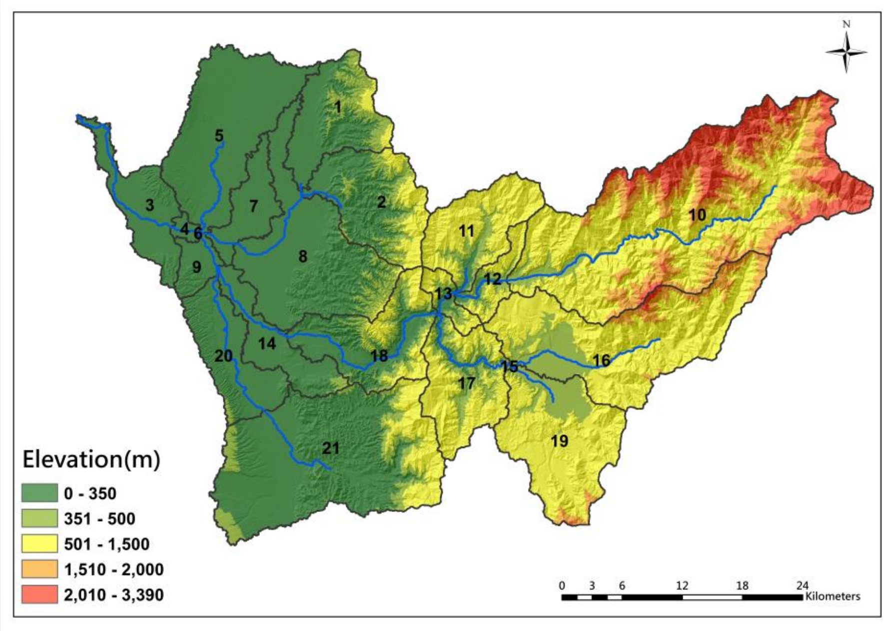


(Qi et al., 2020)

- Soil DOC can be removed from soil layers by surface runoff, lateral flow, and percolation to shallow aquifers.
- The riverine POC processes are derived from the kinetics of POC as described in the CE-QUAL-W2 and QUAL2K models.

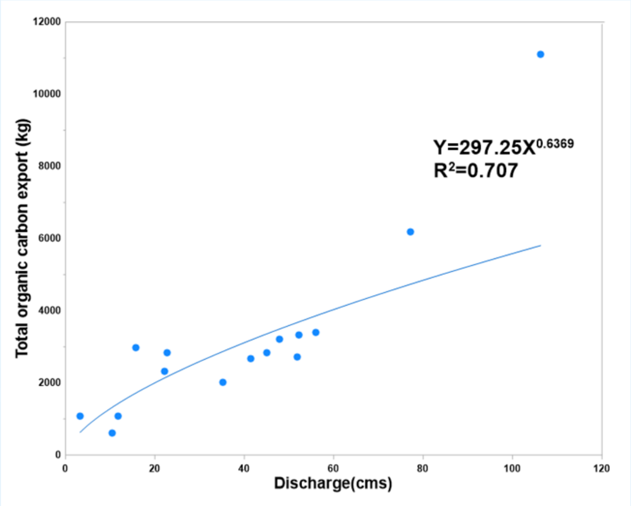
Study area

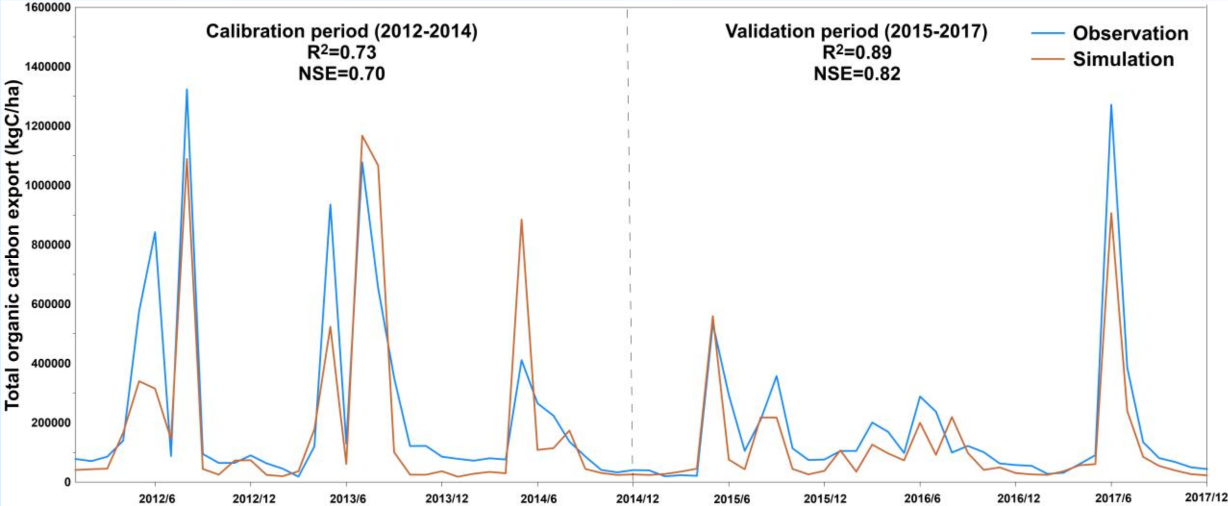




- The Wu River Basin is predominantly forested, with forests covering about 51% of the land area. Other land uses include dry lands (16%), orchards (7%), and paddy fields (4%). The midstream and upstream regions are mostly mountainous, with elevations generally above 500 meters.

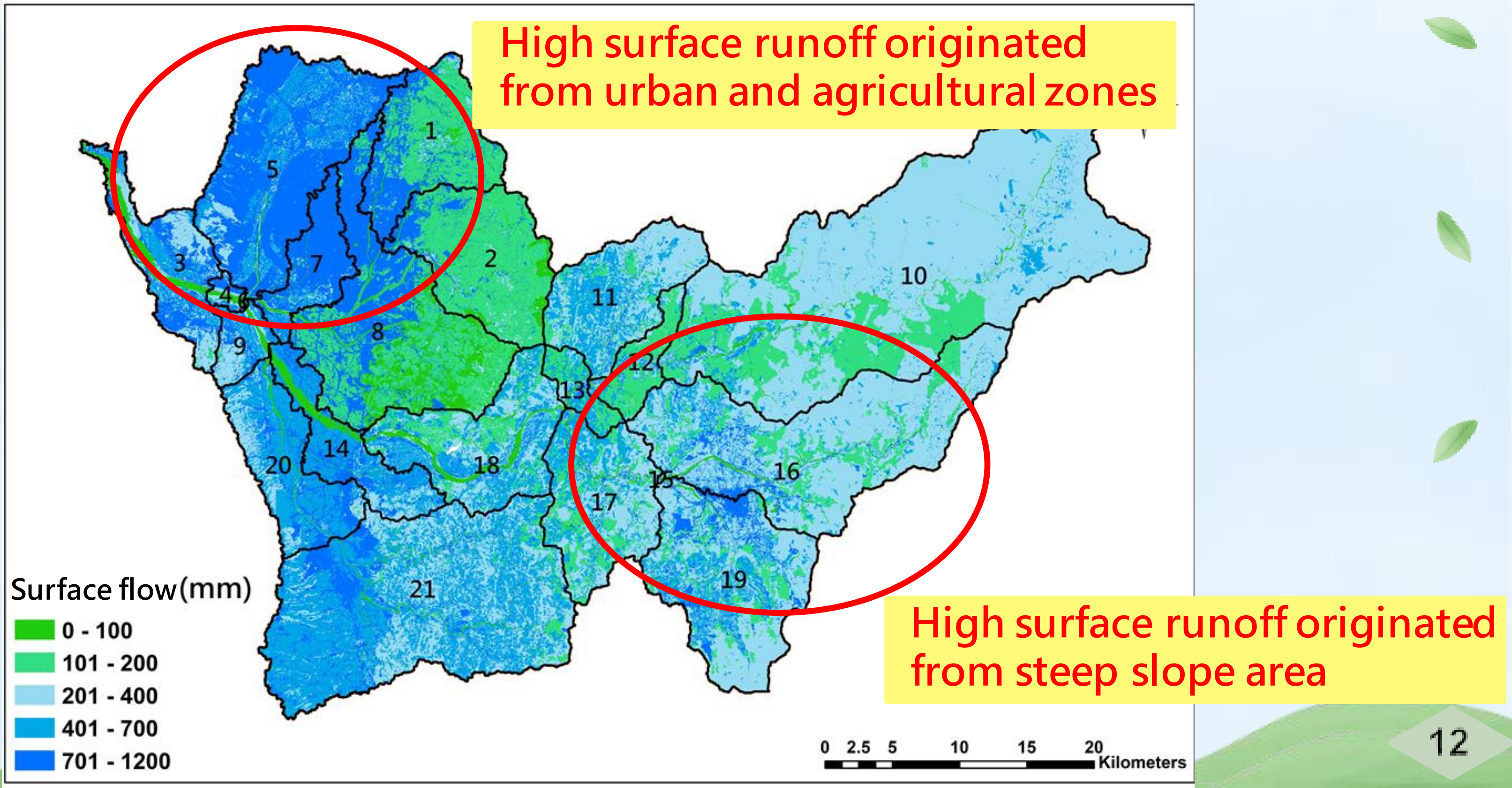
Monthly Organic Carbon Calibration



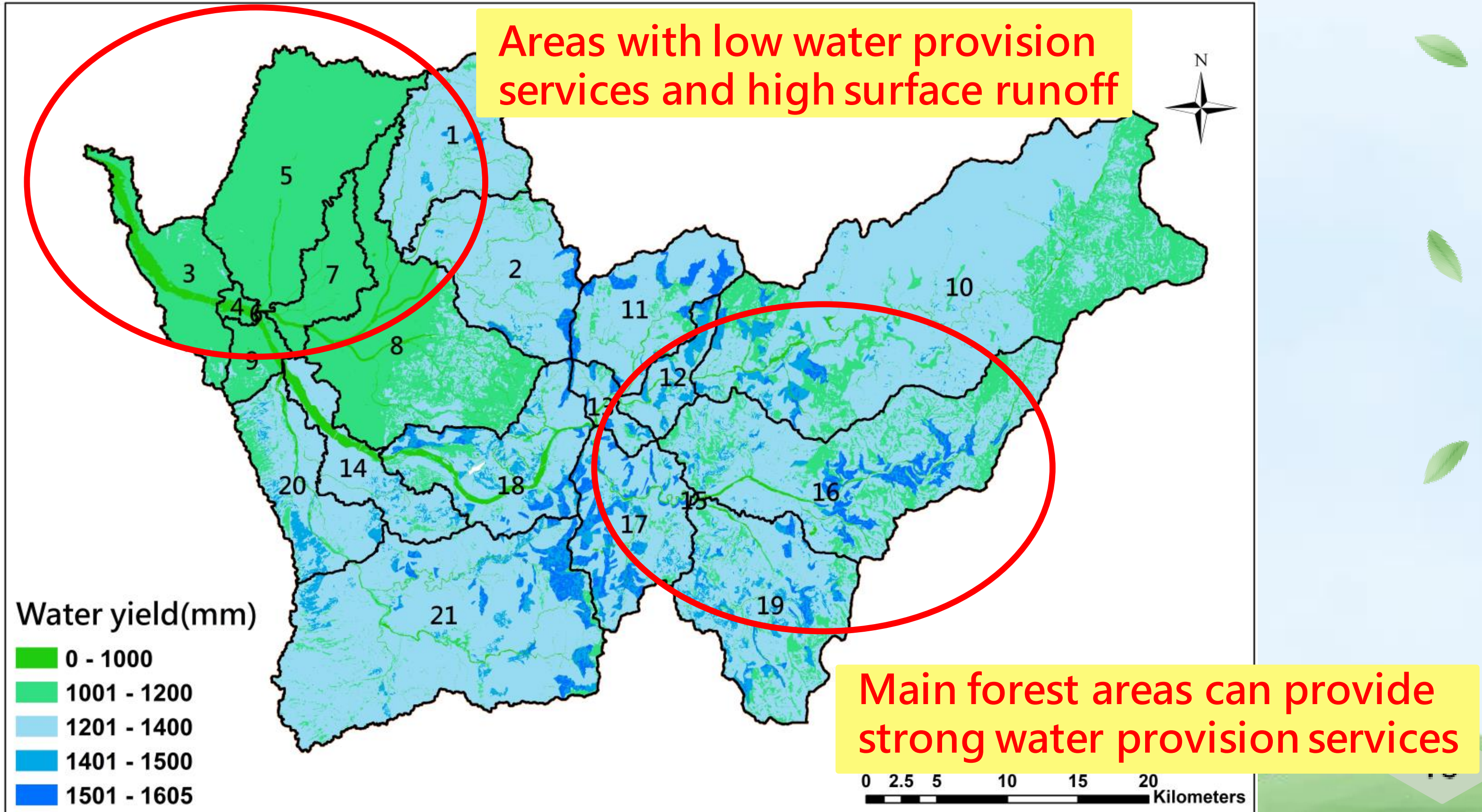


- At the Wuxi Bridge station (2010–2017), showed TOC concentrations ranging from 0.6 to 3.8 ppm.
- The calibration and validation result showed a good TOC simulation in the Wu River Basin.

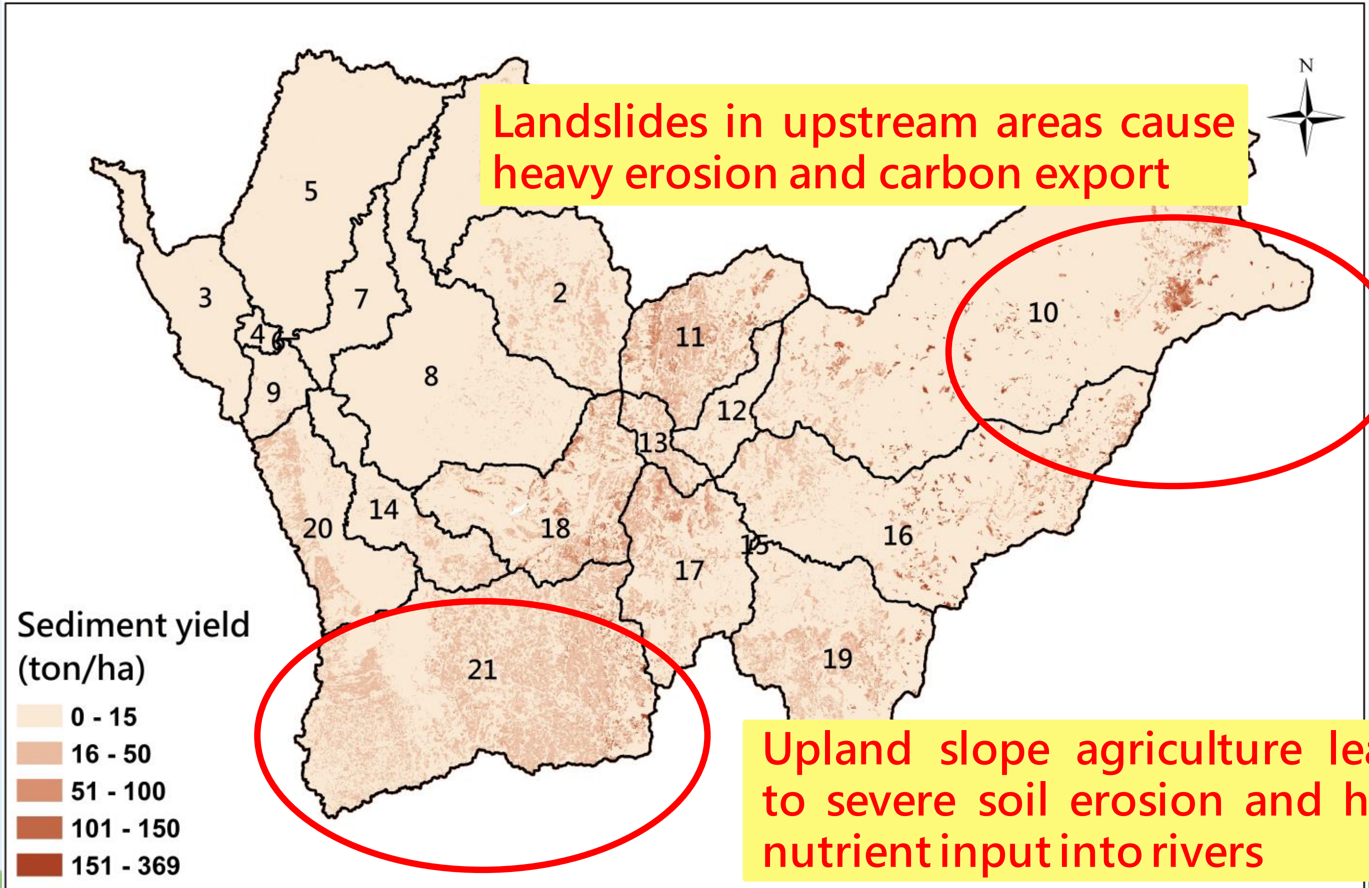
Spatial Distribution of Hydrology in Wu River Basin



Spatial Distribution of Hydrology in Wu River Basin



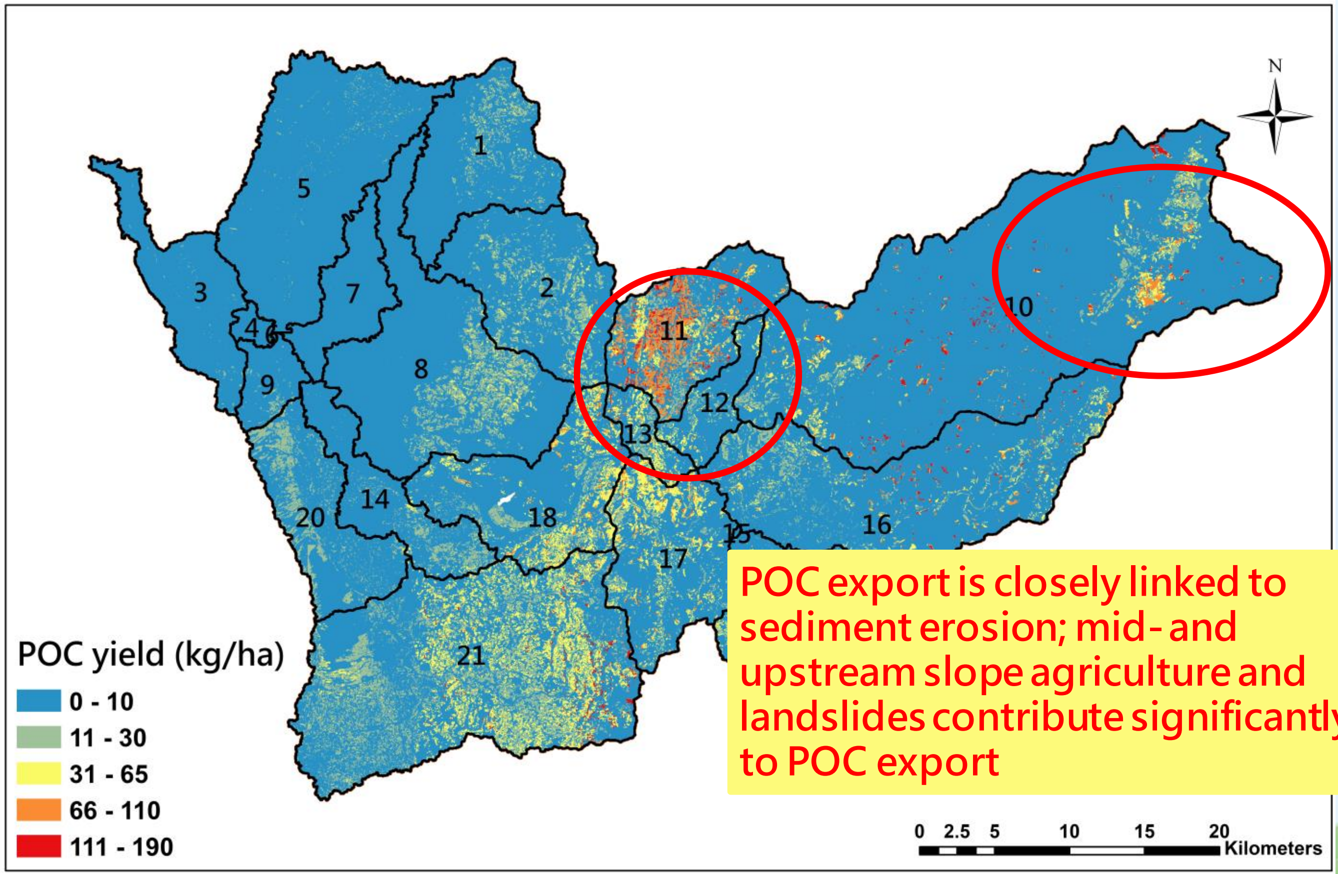
Spatial distribution of sediment in Wu River Basin



Landslides in upstream areas cause heavy erosion and carbon export

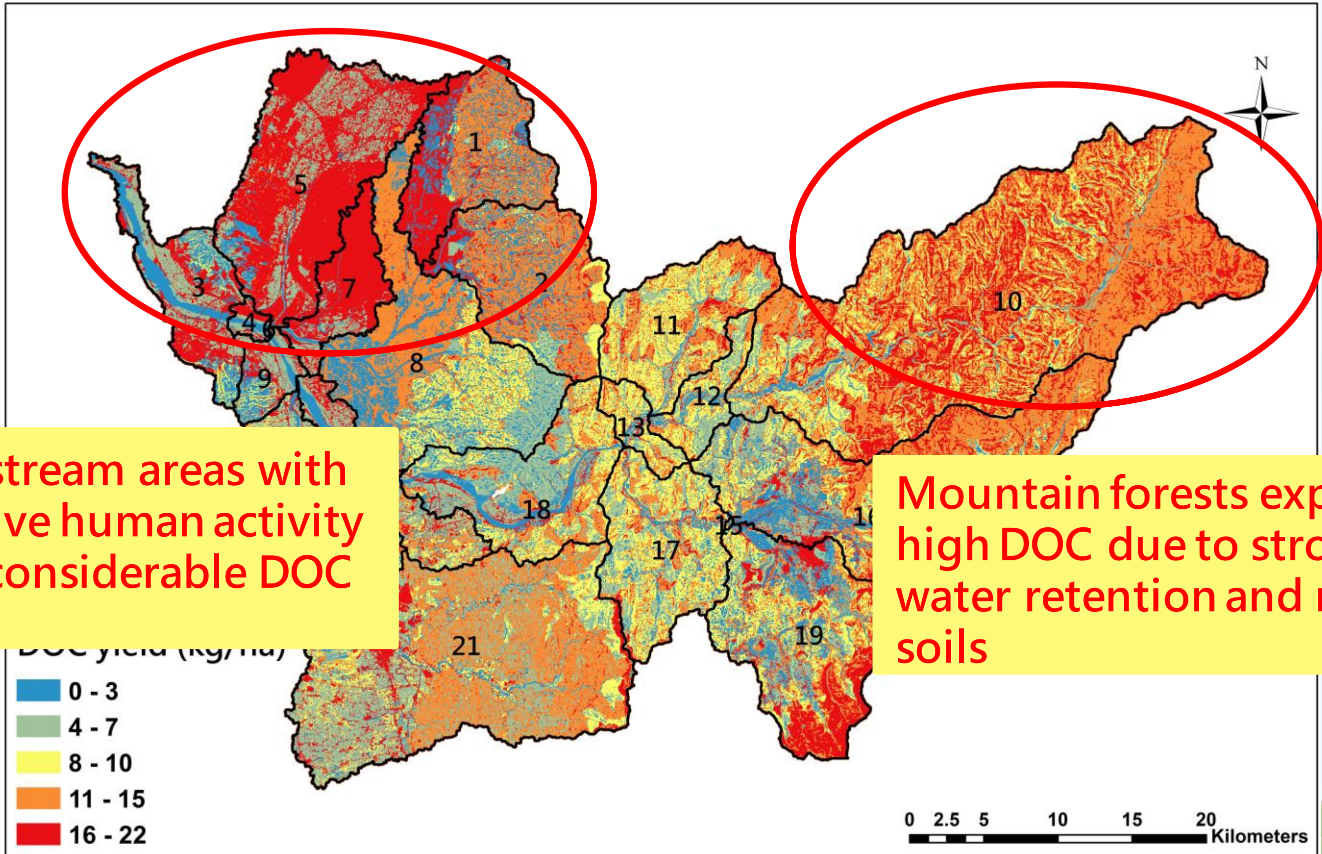
Upland slope agriculture leads to severe soil erosion and high nutrient input into rivers

Spatial Distribution of POC in Wu River Basin



POC export is closely linked to sediment erosion; mid- and upstream slope agriculture and landslides contribute significantly to POC export

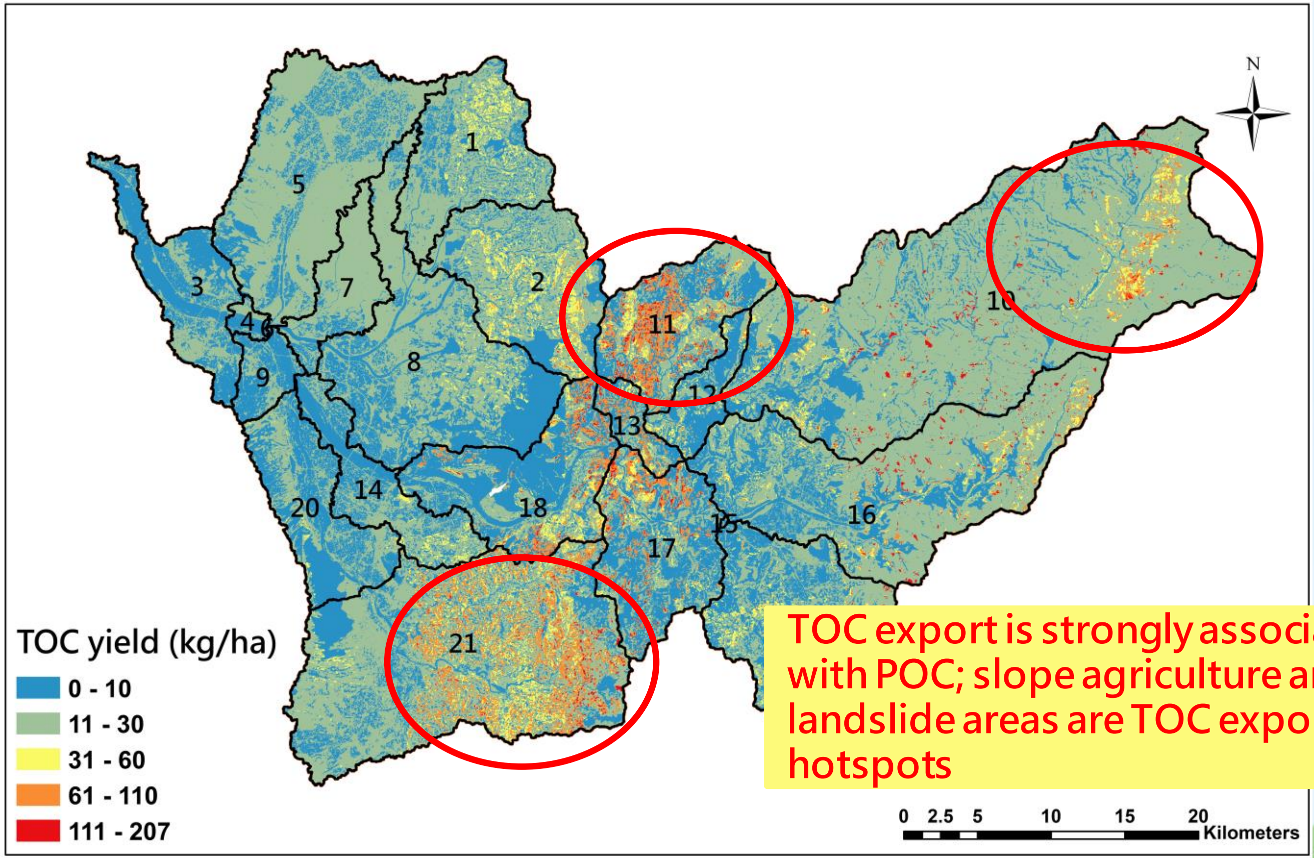
Spatial Distribution of DOC in Wu River Basin



Downstream areas with intensive human activity show considerable DOC export

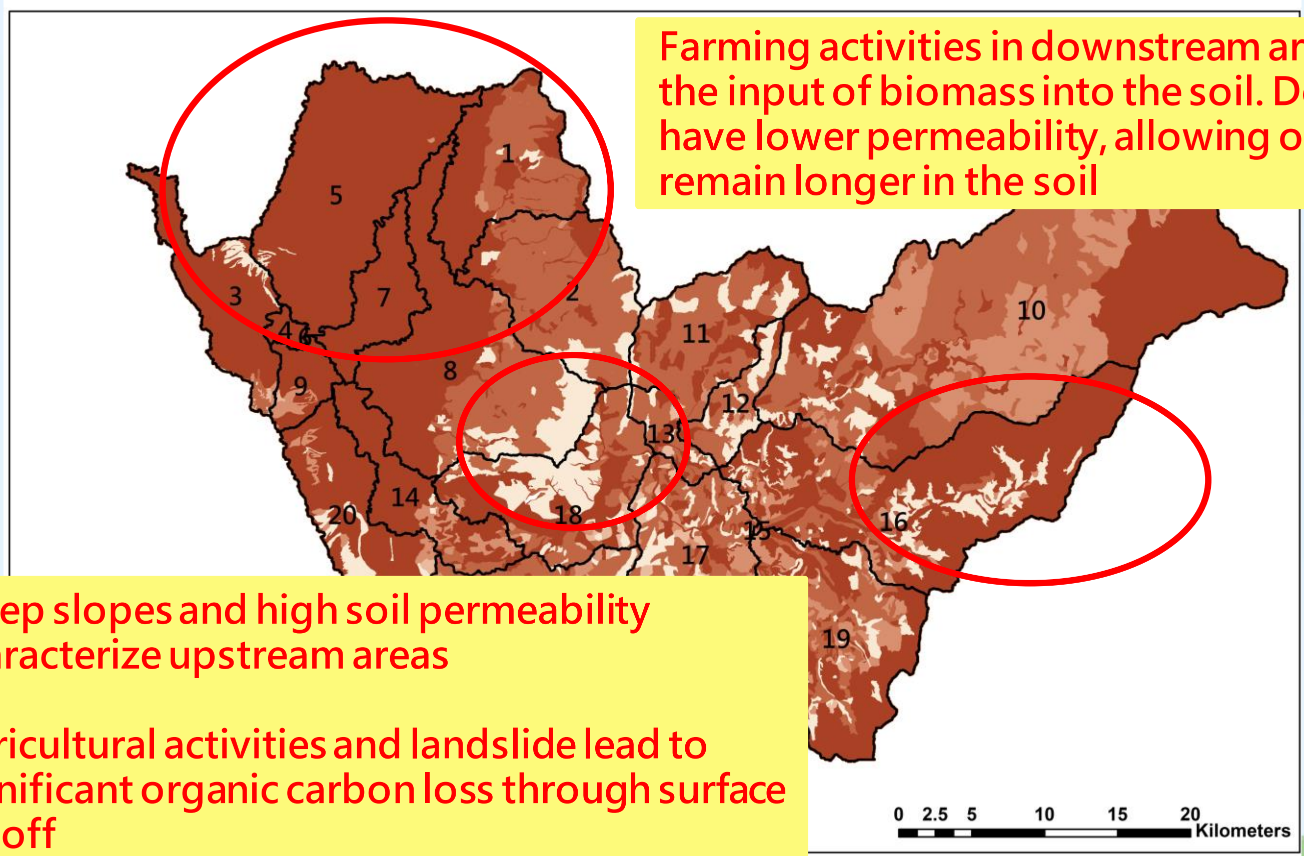
Mountain forests export high DOC due to strong water retention and moist soils

Spatial Distribution of TOC in Wu River Basin



TOC export is strongly associated with POC; slope agriculture and landslide areas are TOC export hotspots

Spatial Distribution of SOC in Wu River Basin



Farming activities in downstream areas accelerate the input of biomass into the soil. Downstream soils have lower permeability, allowing organic matter to remain longer in the soil

Steep slopes and high soil permeability characterize upstream areas

Agricultural activities and landslide lead to significant organic carbon loss through surface runoff

Different Organic Carbon Process in Different Land Cover

Land use	Bare land	Urban	Forest	Orchard	Pasture	Rice	Sweet potato
POC (kgC/ha)	67	0.9	0.1	9.4	0.01	0.1	32
DOC (kgC/ha)	12	15	12	4	7.3	4.5	7.8
SOC (ton/ha)	155	220	205	246	225	294	180

- Bare land & sweet potato → high POC export
- Urban areas → high DOC export
- SOC is affected by DOC & POC export
- Forest of small mountain watersheds → high DOC export high lateral flow

Organic Carbon Export in the World

	Region	Basin	DOC(kg/ha)	POC(kg/ha)	SOC(kg/ha)	Reference
	America	Yakima River	4.4	1.1		Fuhrer et al., (2004)
	America	Maple Creek	2.8	11		Fredrick et al.,(2016)
Subtropical watershed	China	Haihe River	8.8	-	-	Yan et al., (2023)
	China	Yangtze River	8.2	-	-	
	China	Huaihe River	10.2	-	-	
	China	Yellow River	1.6	-	-	
Subtropical and tropical watershed	India	Mahanadi River		6.62		Krishna et al., (2023)
	India	Sabarmati River		6.85		
	Oceania	Sepik River	4.26	14.42	-	Burns et al., (2008)
	New Zealand	Buller River	29	14		Carey et al., (2005)
		Whangaehu River	16	26		
	Taiwan	Li-Wu River	28.6	-	196	Lee et al., (2019)
		Chi-Chia-Wan River	11.1	-	136	
		Bei-Shi River	18.8	-	223	
		Tseng-Wen River	37	-		Shih et al., (2019)
		Wu River	10.4	6.9	224	This study

- The DOC export in Taiwan is comparable to that of subtropical river basins in China, where the annual DOC export ranges from approximately 8.2 to 10.2 kg/ha
- In terms of POC export, the Wu River Basin shows values similar to observed in India and Oceania(tropical river basins), all falling within the range of 6 to 26 kg/ha

Conclusion

Organic carbon export (DOC and POC) is closely linked to land use; slope farming and development areas are major sources of TOC, impacting carbon sequestration

The bare land and dry farming is the main source of TOC, how to reduce the POC export is important for carbon management strategies

The integration of hydrology and carbon simulation provides an effective method for identifying ecosystem service degradation hotspots and supporting climate adaptation strategies in mountainous basins

Thanks!

Does anyone have any questions?

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