U.S.-China Loess Exchange




Soil moisture across scales in the Loess Plateau, China

Jia, Xiaoxu (jiaxx@igsnrr.ac.cn)

Institute of Geographic Sciences & Natural Resources Research

Chinese Academy of Sciences

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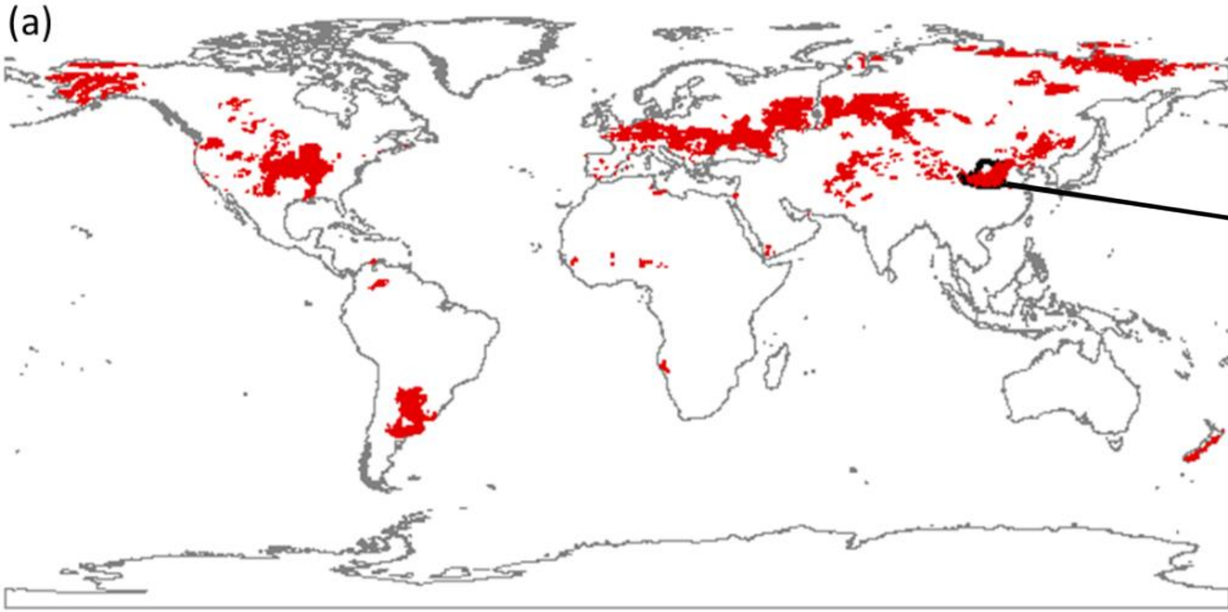

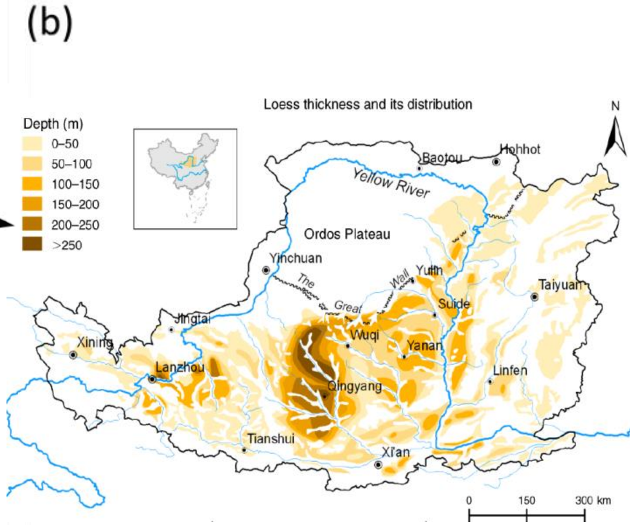

Loess

- *Global loess distribution (a) derived from the Global Unconsolidated Sediments Map database (GUM) as was reported by Börker et al. (2018, source: https://doi.org/10.1594/PANGAEA.884822);*
- *Loess thickness ranges from 50 to 200 m, some area even exceeded 300 m (b) (Wang et al., 2010);*
- *Area of the China's Loess Plateau is 64 $\times 10^4$ km^2; 100 million population.*

Loess in Iran

China's Loess Plateau

Loess profile in China

Loess profile in USA

southwestern Nebraska, USA; Marin-Spiotta et al., 2014, Nature Geoscience

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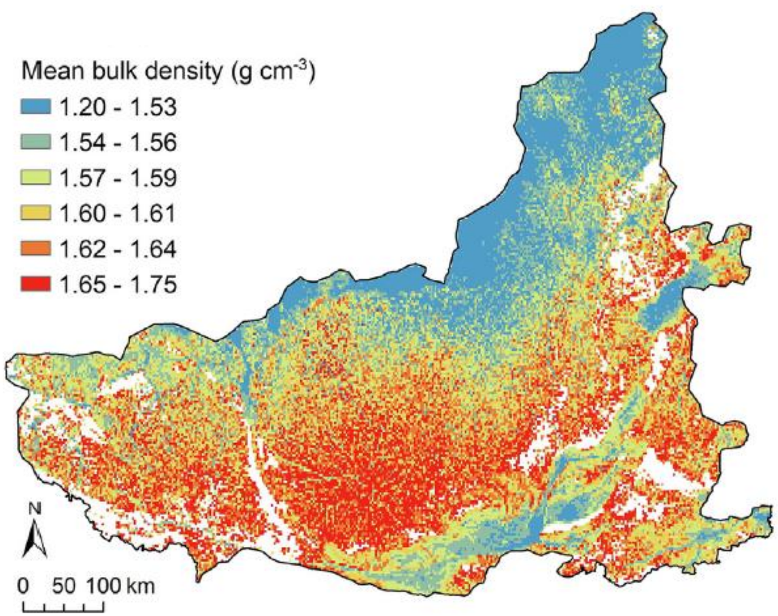
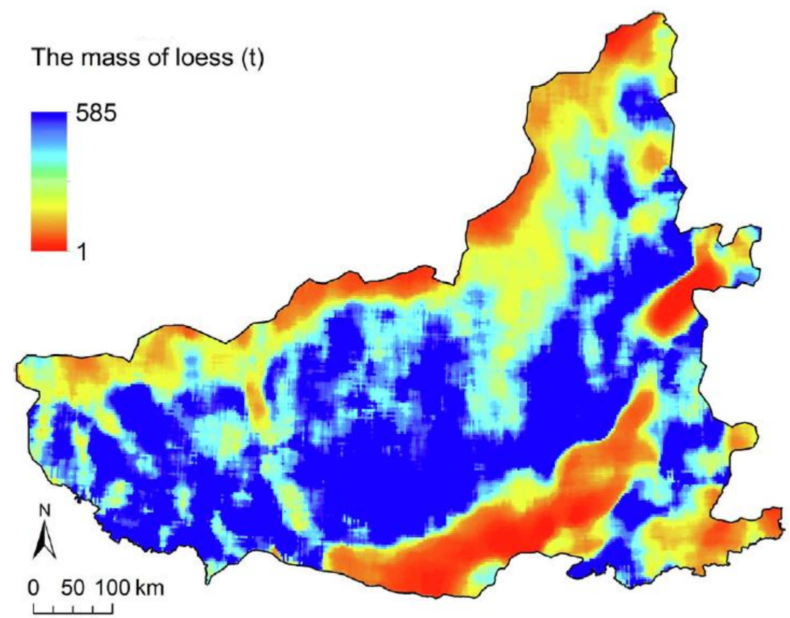
Article

What is the mass of loess in the Loess Plateau of China?

Yuanjun Zhu [a,c,d,*,1], Xiaoxu Jia [b,d,1], Jiangbo Qiao [a], Ming'an Shao [a,b,c,d]

[a] *State Key Laboratory of Soil Erosion and Dryland Farming on the Loess Plateau, Northwest A&F University, Yangling 712100, China*
[b] *Key Laboratory of Ecosystem Network Observation and Modeling, Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, Beijing 100101, China*
[c] *Institute of Soil and Water Conservation, Chinese Academy of Sciences & Ministry of Water Resources, Yangling 712100, China*
[d] *College of Resources and Environment, University of Chinese Academy of Sciences, Beijing 100190, China*

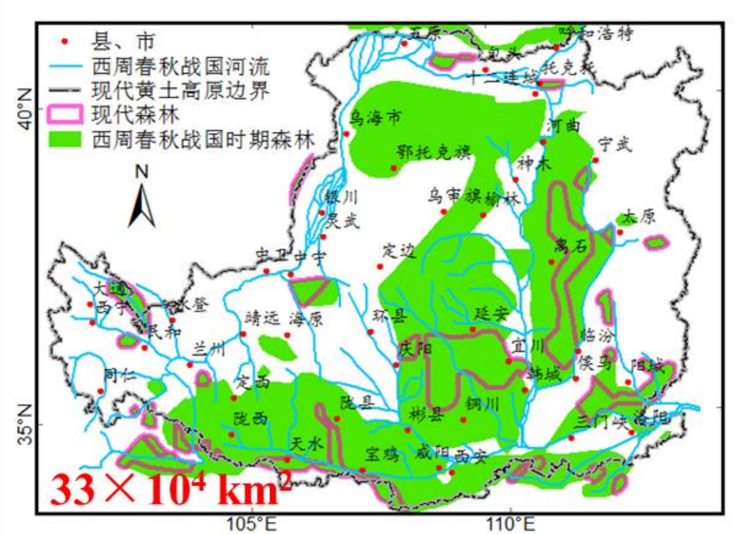




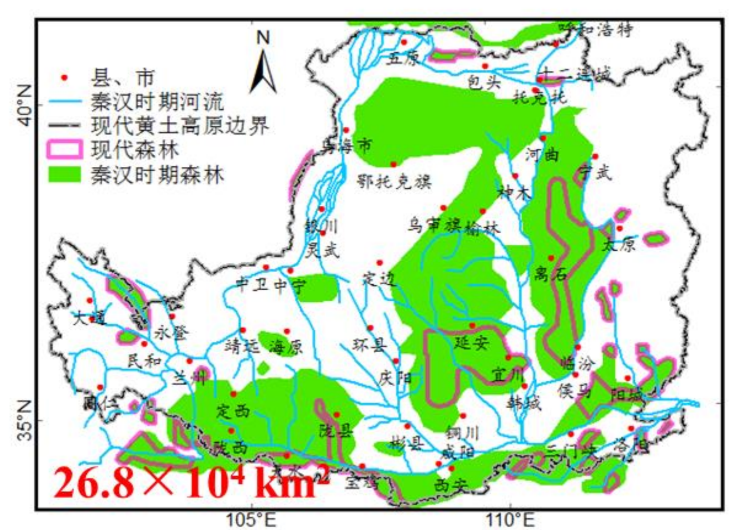
The total loess mass is approximately 5,450 billion tons, and the average loess mass over an area of 1 m^2 is 169 tons, ranging from 1.36 to 585 tons.

- ***The typical loess landforms are "Yuan" (a large flat surface with little erosion), "Liang" (a long narrow range of hills), "Mao" (an oval or round loess hill) and gullies;***
- ***Soil and water processes may be quite different from other arid or semi-arid regions.***

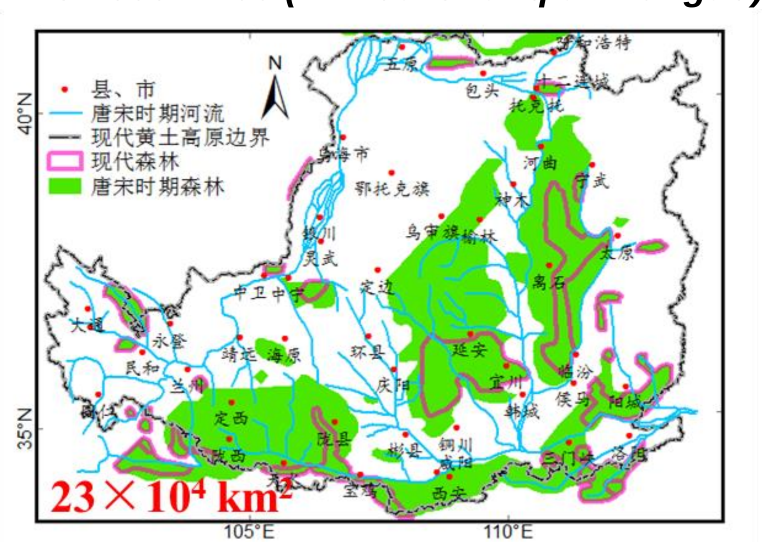
Historically, forest cover has gradually declined



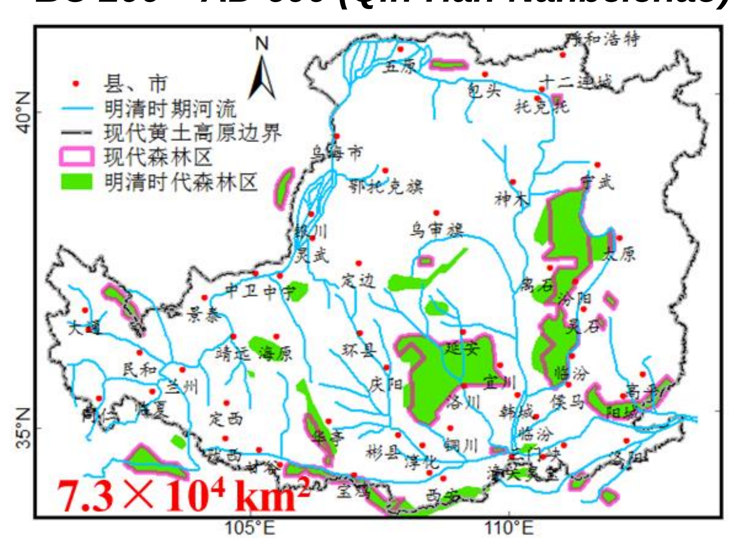
BC 1000 – 200 (Xizhou-Chunqiu-Zhanguo)



BC 200 – AD 600 (Qin-Han-Nanbeichao)



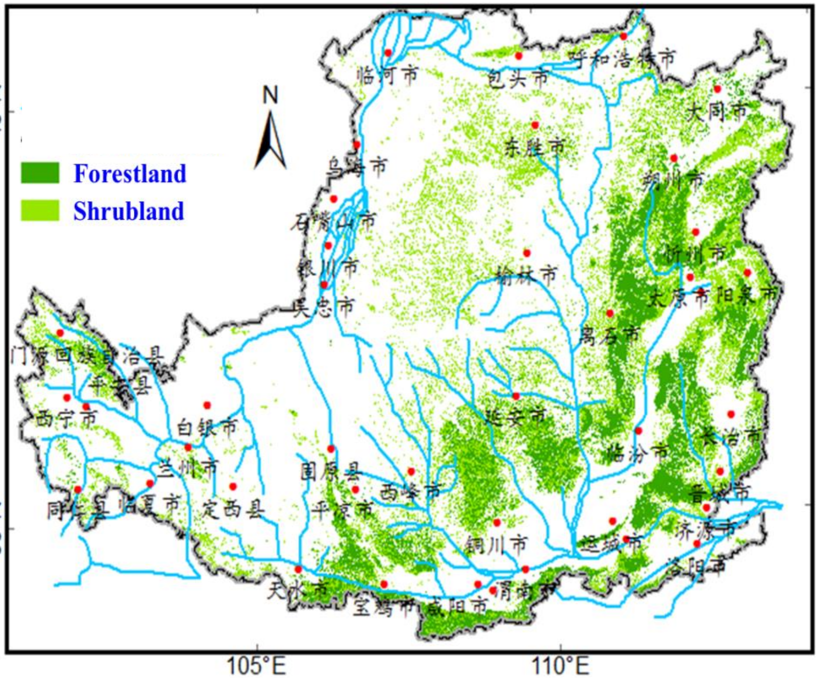
AD 600 – 1300 (Tang-Song)



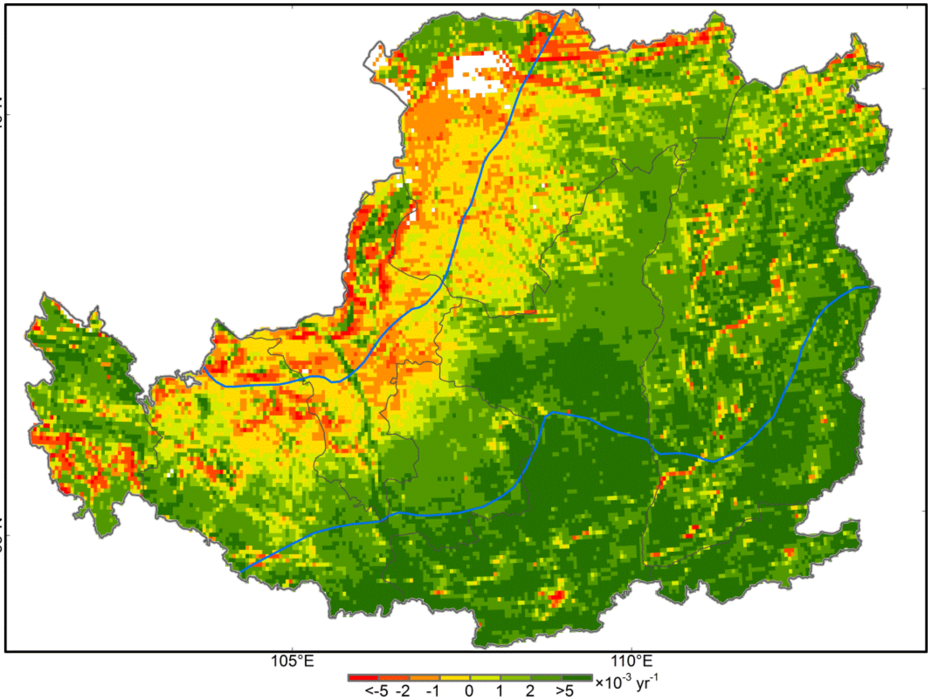
AD 1300 – 1900 (Ming-Qing)

Historical forest distribution on the Loess Plateau (Shi, Nianhai., 2001)

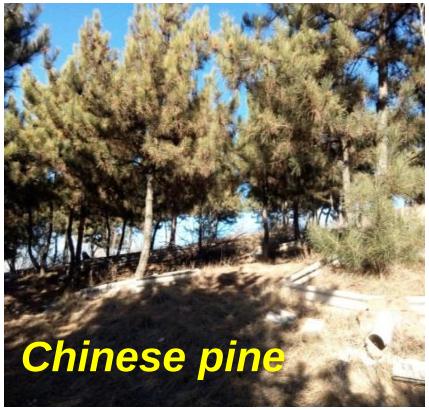
"Grain-for-Green" program improved vegetation cover

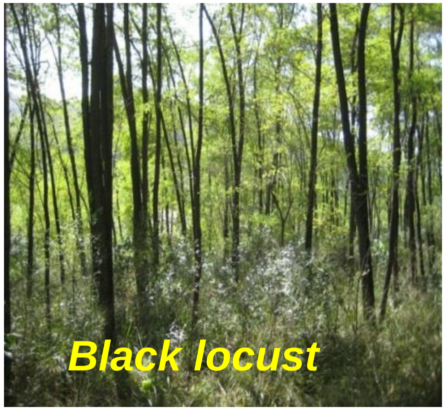


2010



Spatial distribution of NDVI trends in the Loess Plateau during the growing season in 1982-2011

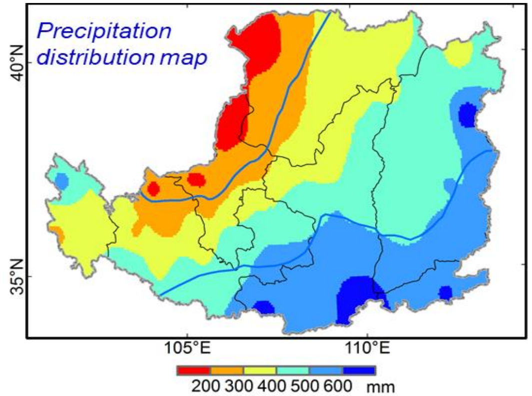


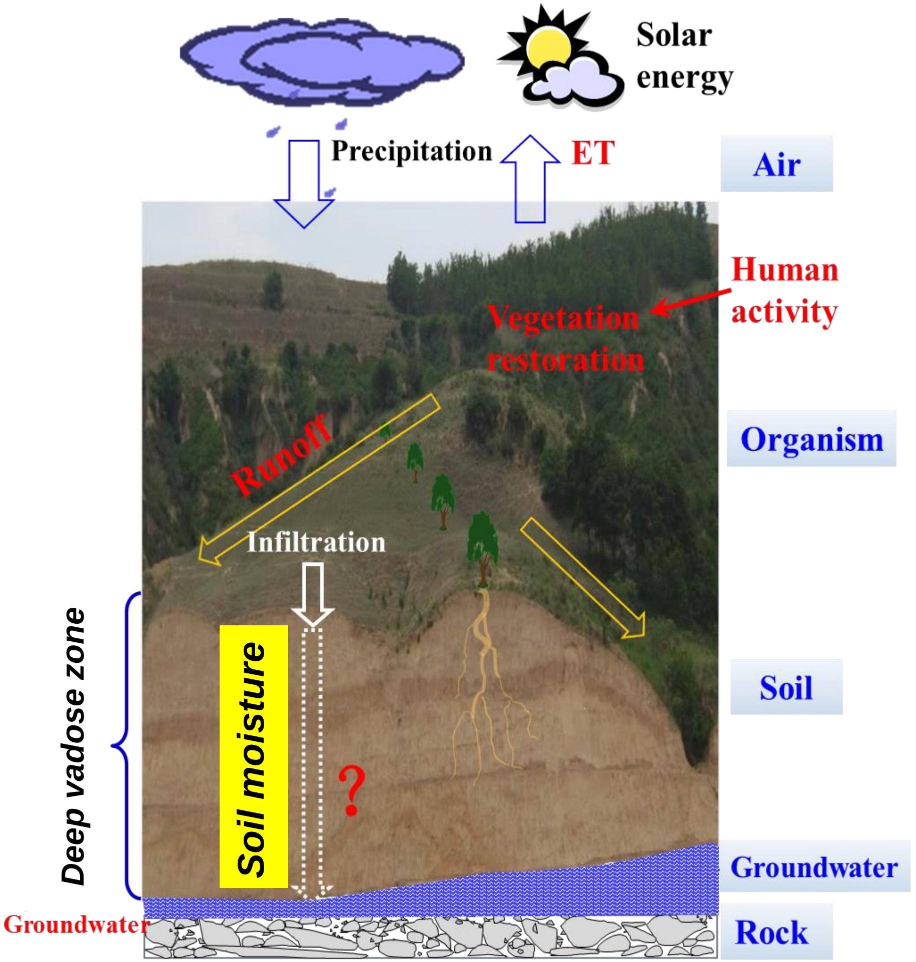


Water determines ecosystem functions and stability

- **Soil water**: *derived from limited precipitation*
- **Groundwater**: *deep groundwater level, 30-100 m*
- **Rainfall conditions**: *low, unevenly distributed*
- **Evapotranspiration**: *increasing*
- **Inappropriate vegetation restoration measures and mismanagement**: *introduction of exotic plant species and high-density planting*
- **Artificial plants intensify soil drought**: *a dry soil layer*

- *Soil degradation;*
- *Regional vegetation die-off;*
- *Failure of afforestation;*
- *Aridity in the local climatic environment, etc.*



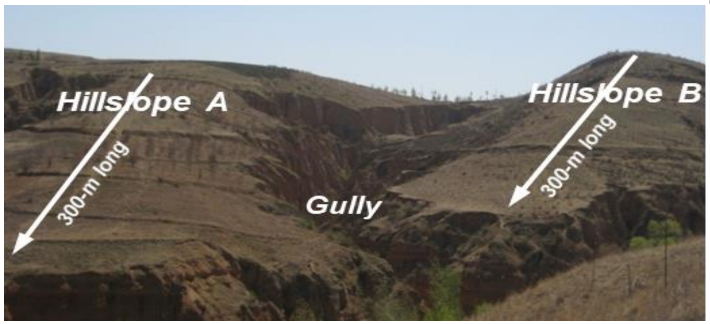


Hydrological processes in the critical zone of the Loess Plateau


Little old man trees
(30-year-old)

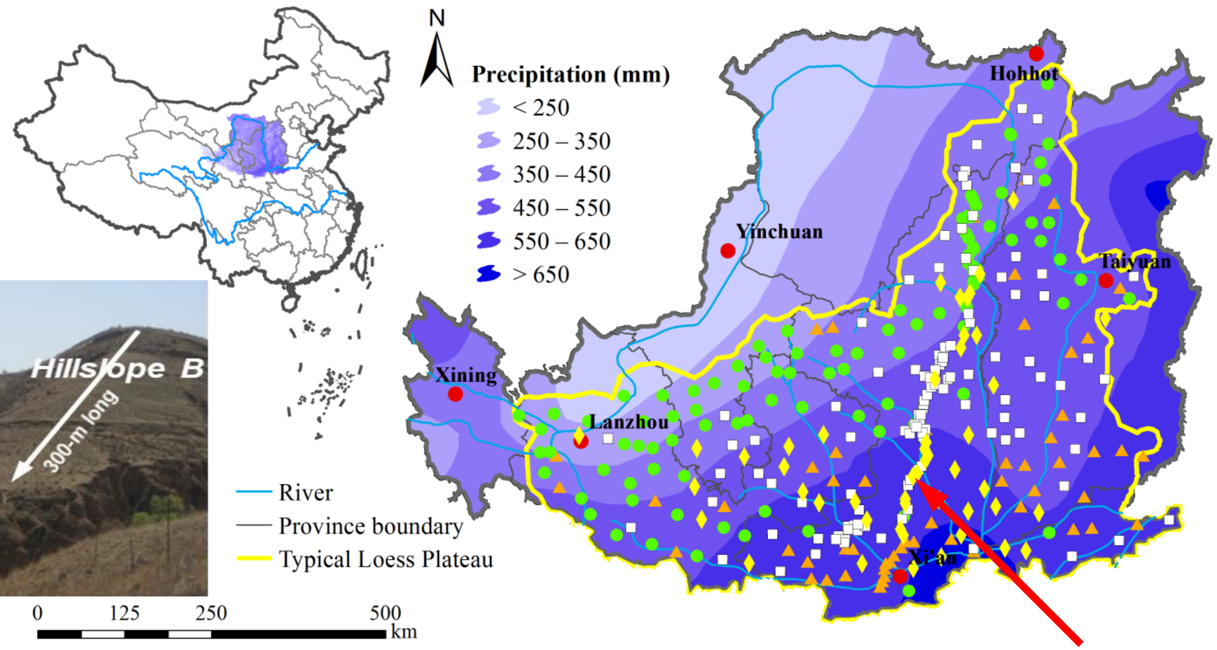

Grassland degradation

Plots with different plant species



Slope scale

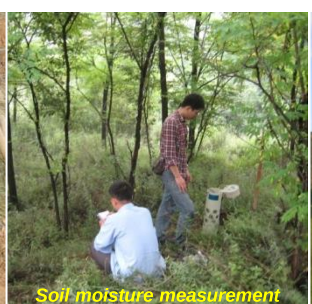
Regional scale (typical loess area, 37 ×10⁴ km²): An approximate grid-sampling design where one sampling site was deemed to represent a grid cell covering an area of 40 km × 40 km

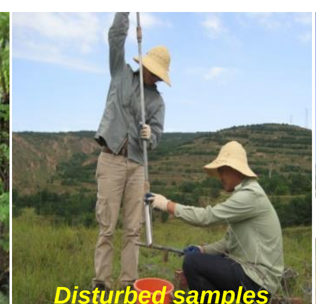


South-North transect
Number of sites: 86
Length: 860 km

Observations and measurements:

- *Soil moisture, soil texture, hydraulic properties, etc;*
- *Climatic conditions;*
- *Land use type;*
- *Vegetation type, plant coverage, etc;*
- *Topographic characteristics.*

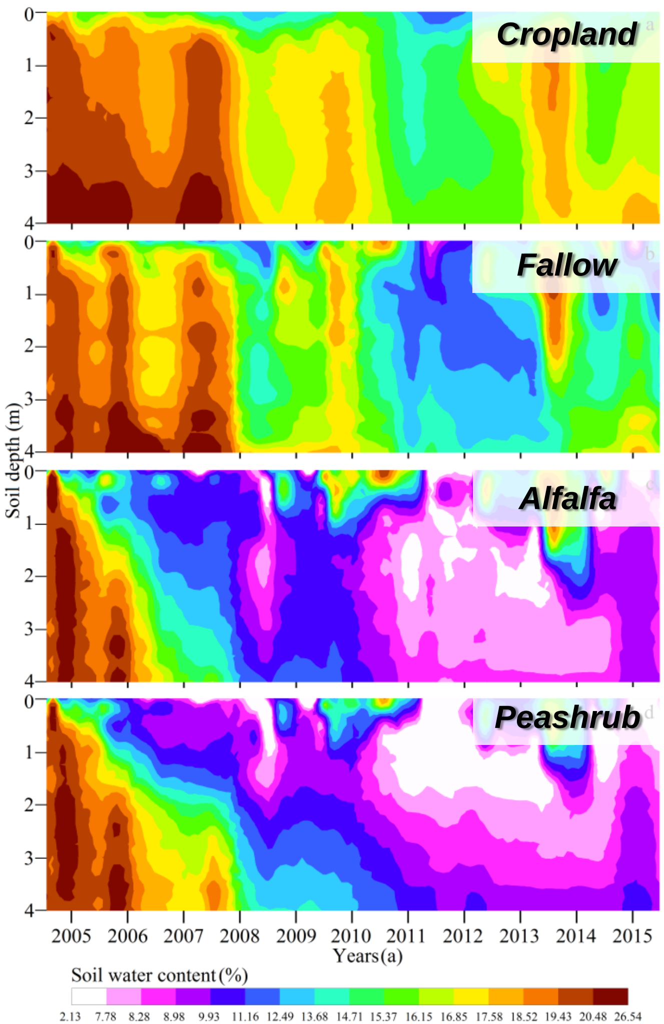




Location	Rainfall (mm)	Depth (m)
Yangling	660	105
Changwu	585	205
Fuxian	550	190
An'sai	505	162
Shenmu	430	56

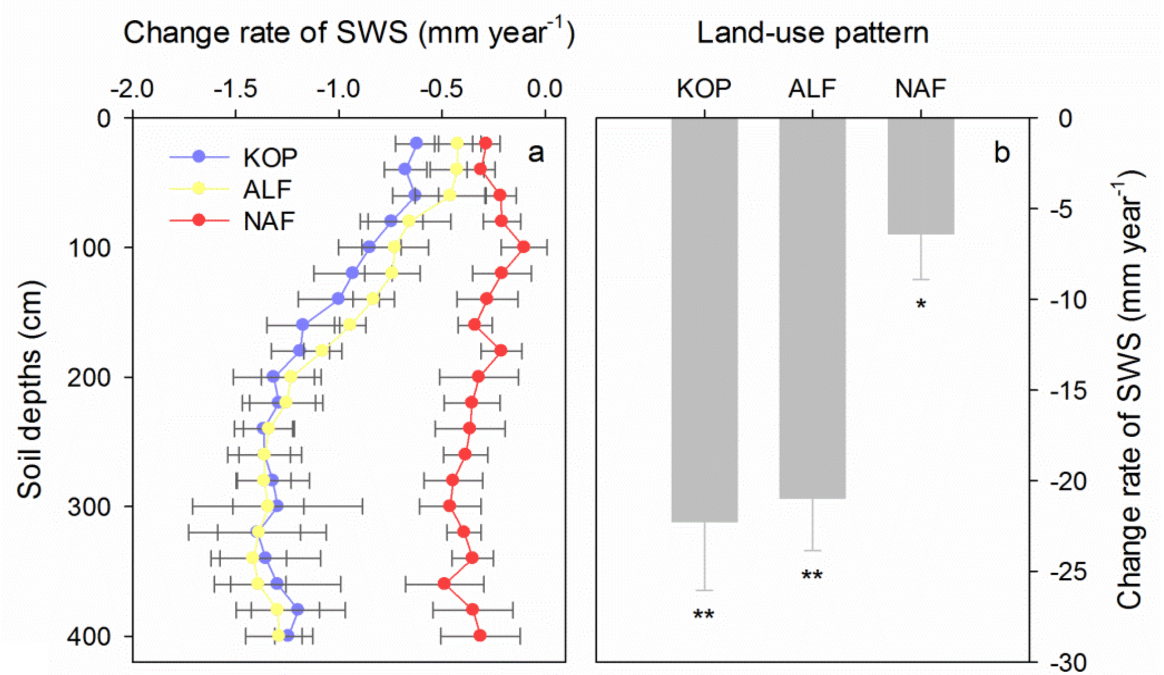
Plot scale

Re-vegetation intensifies soil moisture decline in the deep profile in the Loess Plateau



Time series of soil moisture under different vegetation types, in Shenmu County, the ***northern LP***

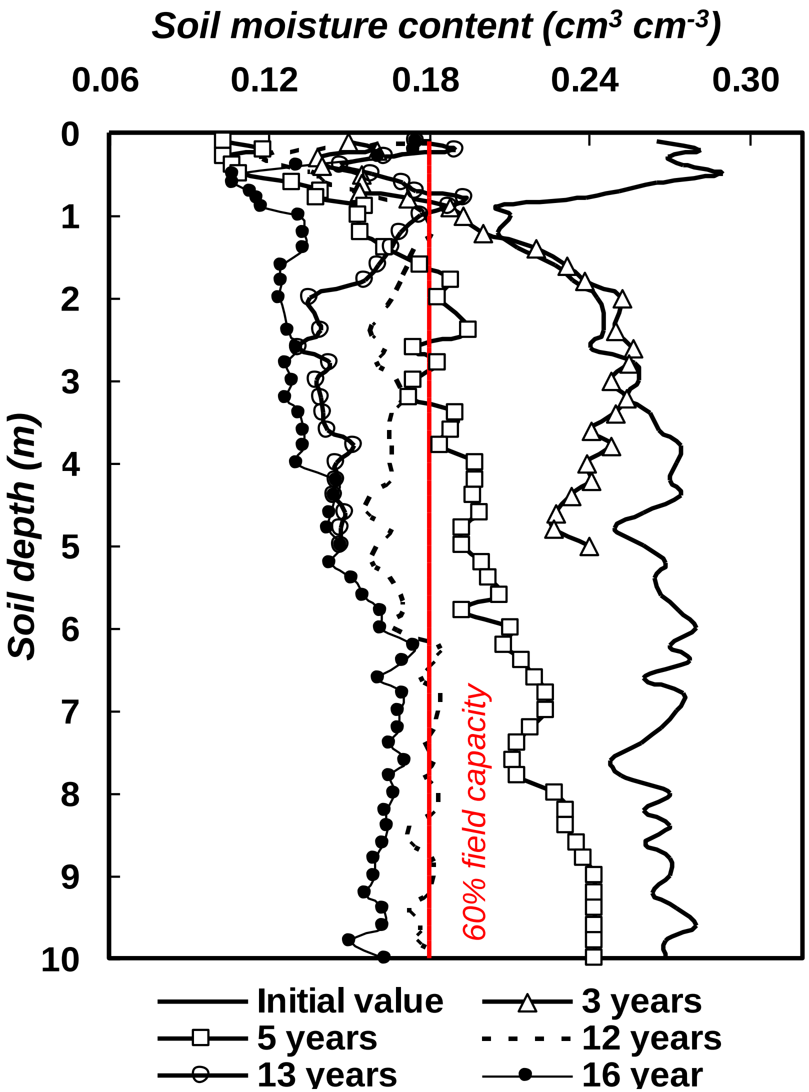
KOP: korshinsk peashrub; ALF: alfalfa; NAF: fallow land

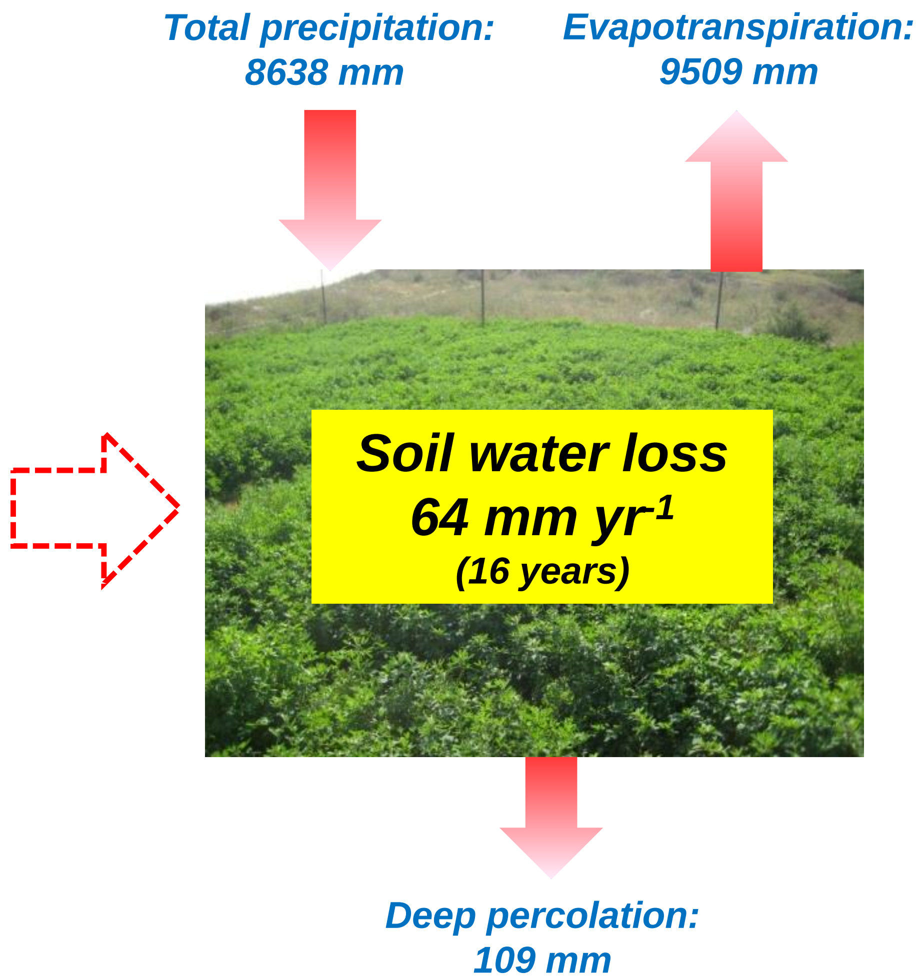


Compared with cropland and fallow land, soil water storage (SWS) in the 0–4 m soil profile considerably declined in restored ecosystems with alfalfa or peashrub.

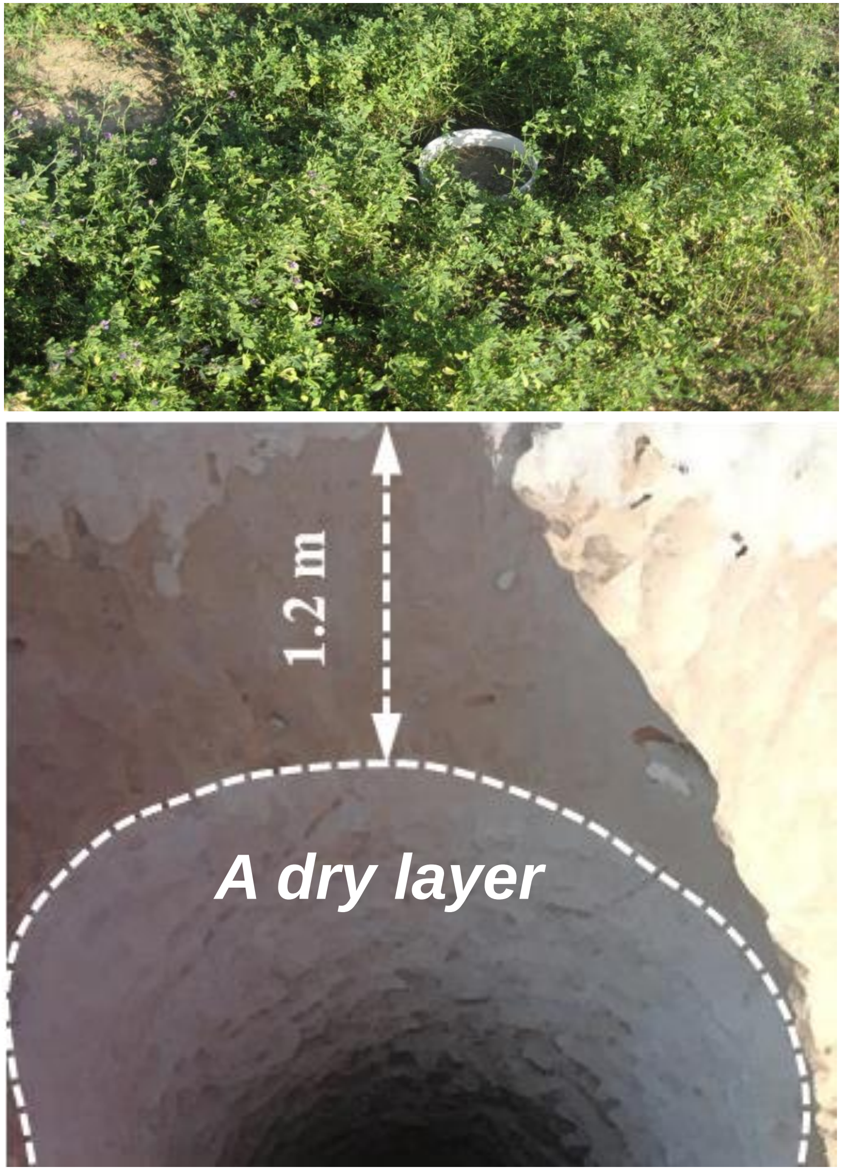
Zhang et al., 2018, J Arid Land

Alfalfa plantation breaks the balance between soil water availability and water utilization





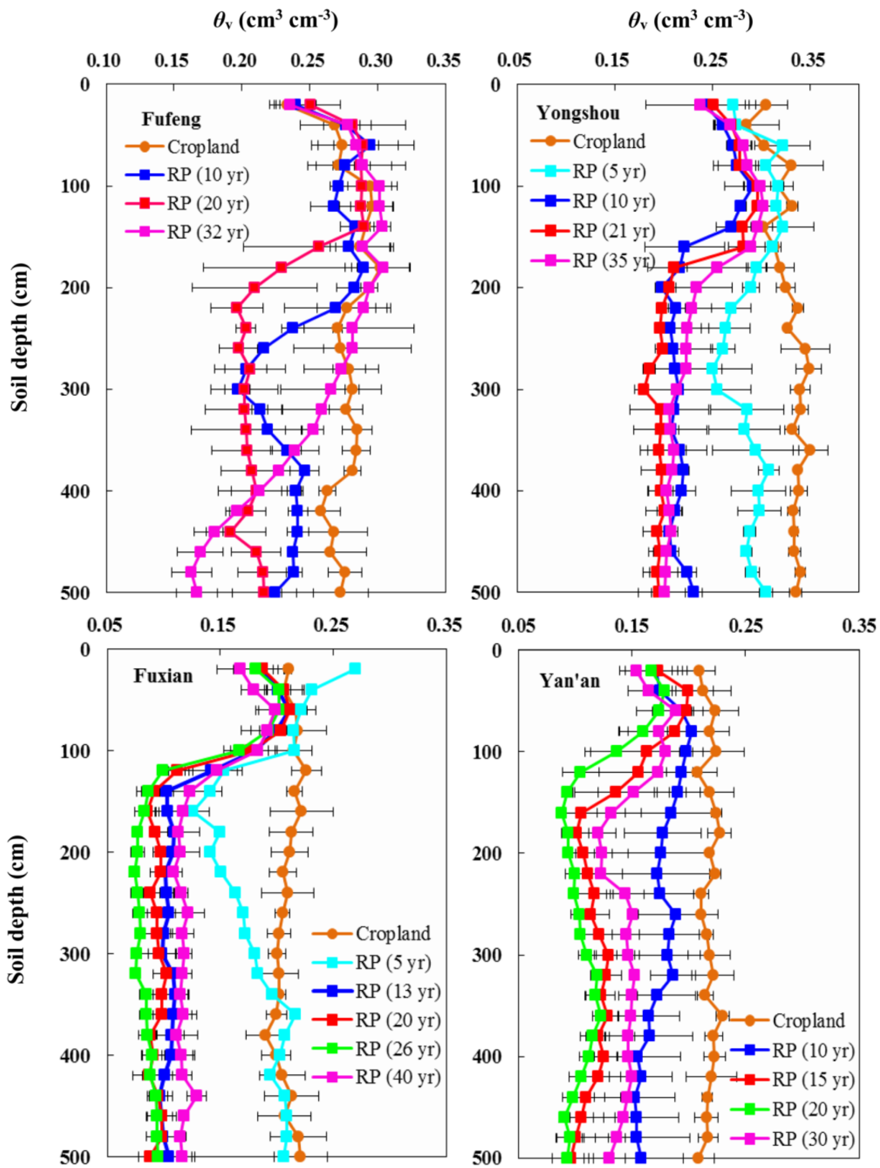
Changes of soil moisture along re-vegetation years. Data was collected for a soil under alfalfa, in Changwu County, the ***southern LP***

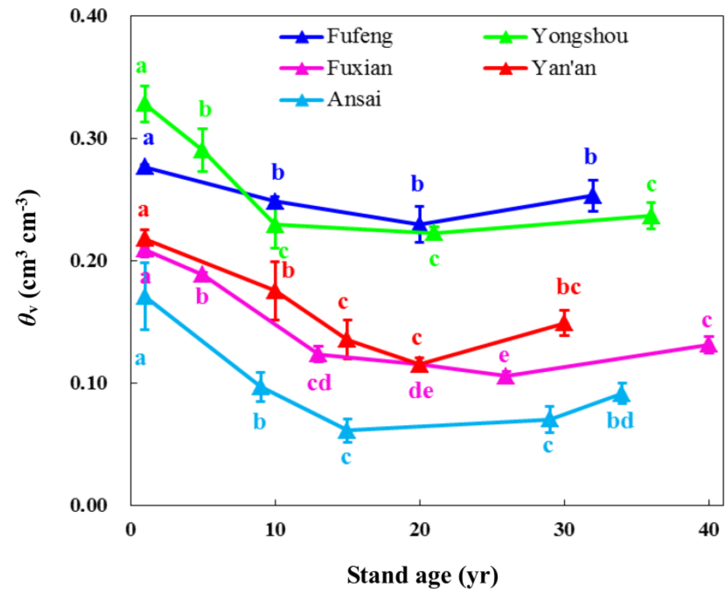


Soil profile under alfalfa in Shenmu County

Soil profile under natural grass in Shenmu County

Soil moisture variations along re-vegetation years for black locust plantation

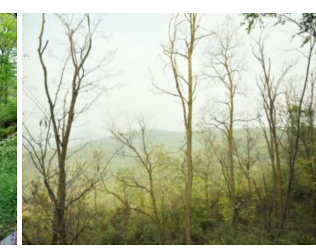




In the first 25–30 yr of growth, the depth-averaged SMC gradually decreased with stand age in black locust plantation, but SMC somehow recovered with increasing tree age over the 30-year period.

12 yr

23 yr

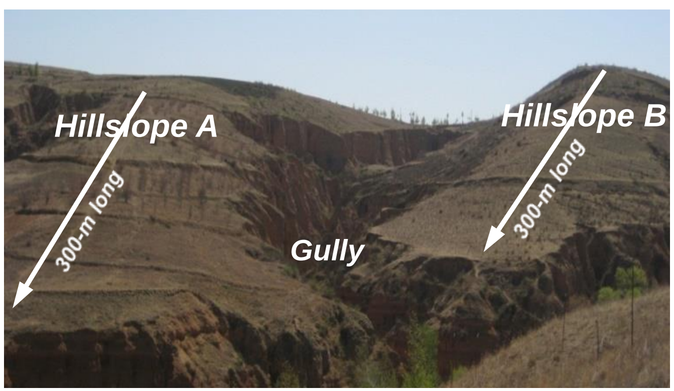


32 yr

Jia et al., 2017, J Hydrol

Slope scale

		Hillslope A			Hillslope B		
Spatial variables	Temporal statistics	0-1 m	1-2 m	2-3 m	0-1 m	1-2 m	2-3 m
Mean SWS	Mean, mm	**139.2**	**140.1**	**137.8**	**109.0**	**93.2**	**90.1**
	SD_T, mm	25.4	20.8	19.6	23.6	13.6	13.9
	CV_T, %	**18.3**	**14.9**	**14.2**	**21.7**	**14.6**	**15.5**
SD_S of SWS	Mean, mm	33.7a	46.5b	42.8b	24.6c	30.4a	38.8d
	SD_T, mm	7.0	5.9	6.0	2.4	4.3	5.6
	CV_T, %	20.8	12.7	14.0	9.6	14.1	14.4
CV_S of SWS	Mean, %	**24.4**	**33.3**	**31.1**	**23.2**	**32.7**	**43.3**
	SD_T, %	3.2	1.2	0.8	3.6	1.9	2.1
	CV_T, %	13.3	3.6	2.6	15.4	5.8	4.8



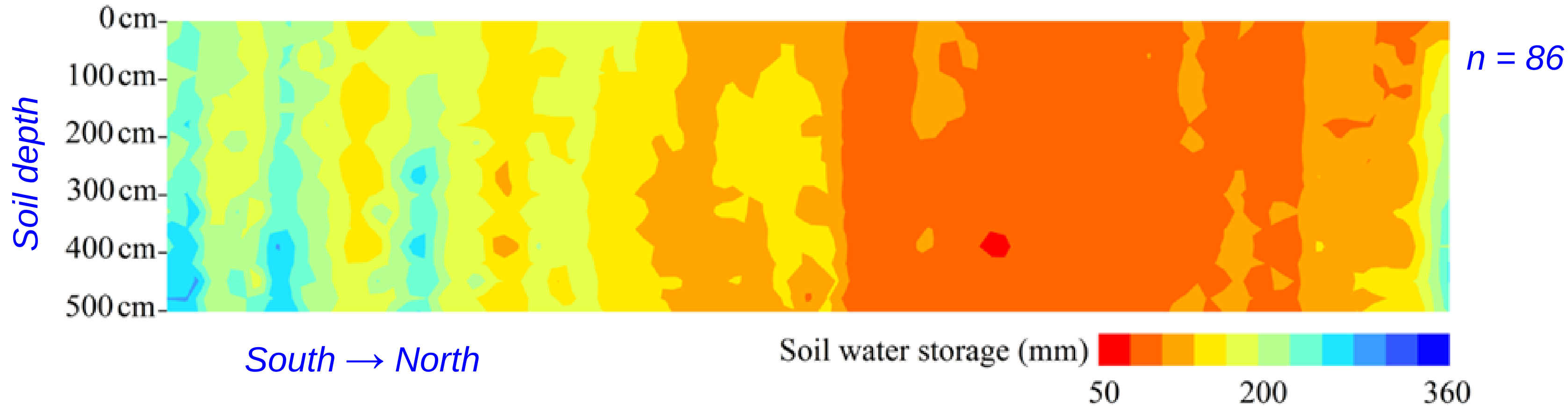
Liudaogou watershed, in Shenmu County, the northern LP

- *Temporal changes in the mean SWS decreased with increasing soil depth, while the spatial variation increased. The degree of temporal–spatial variation of SWS was strongly dependent on sampling depth.*
- ***Soil texture, elevation, and plant biomass** were the dominant factors affecting the hillslope-scale variations of SWS*

Jia et al., 2013, J Hydrol

Regional scale: South-North transect (860 km long)

Spatial variables	*Temporal statistics*	*0–1 m*	*1–2 m*	*2–3 m*	*3–4 m*	*4–5 m*
Mean SWS	*Mean, mm*	***139.7***	***141.9***	***140.7***	***142.3***	***146.3***
	SD_T, mm	*19.8*	*11.1*	*5.7*	*3.3*	*2.1*
	CV_T, %	***14.2***	***7.8***	***4.0***	***2.3***	***1.5***
SD_s of SWS	*Mean, mm*	*55.2*	*58.1*	*62.0*	*67.4*	*71.2*
	SD_T, mm	*9.3*	*5.1*	*3.1*	*1.8*	*1.6*
	CV_T, %	*16.8*	*8.8*	*5.0*	*2.8*	*2.2*
CV_s of SWS	*Mean, %*	***40.3***	***41.2***	***44.2***	***47.4***	***48.6***
	SD_T, %	*8.8*	*5.2*	*3.3*	*1.3*	*0.9*
	CV_T, %	*21.9*	*12.5*	*7.4*	*2.7*	*1.9*

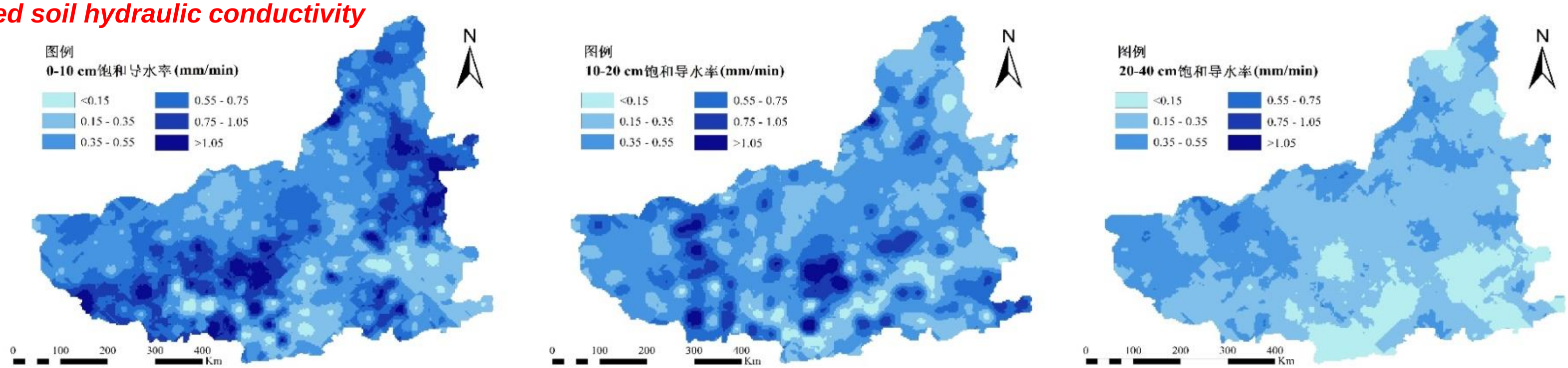


- *Mean SWS generally decreased from the south to the north;*
- *The time-averaged SWS along the transect was not significantly different among the various soil layers;*
- *Regional-scale temporal changes in the mean SWS also decreased, while the spatial variations increased with increasing soil depth.*

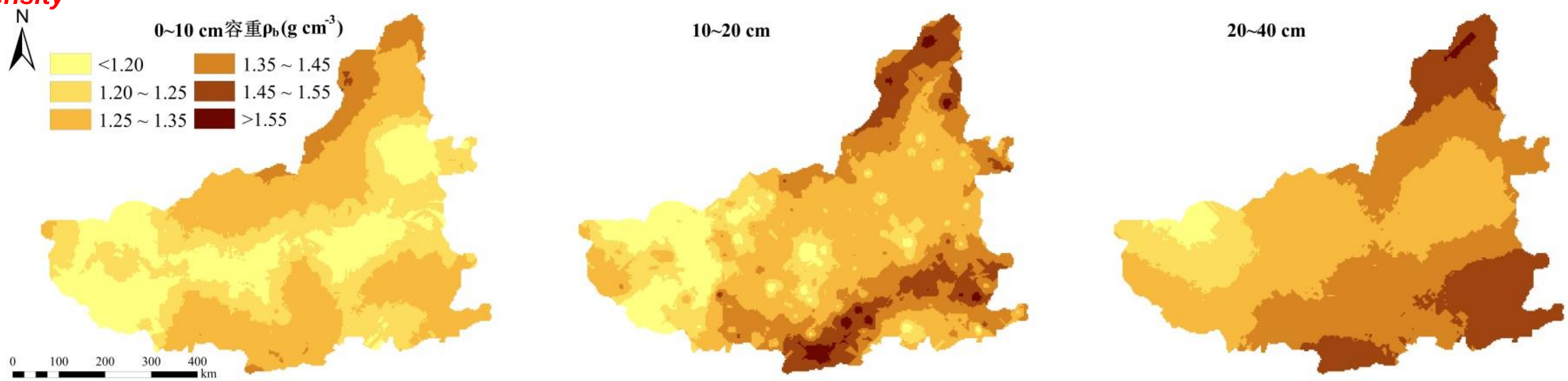
Jia et al., 2017, Clean-Soil Air Water;
Zhao et al., 2017, J Soil Sediment

Regional scale: Soil hydraulic properties (Ks, BD and FC)

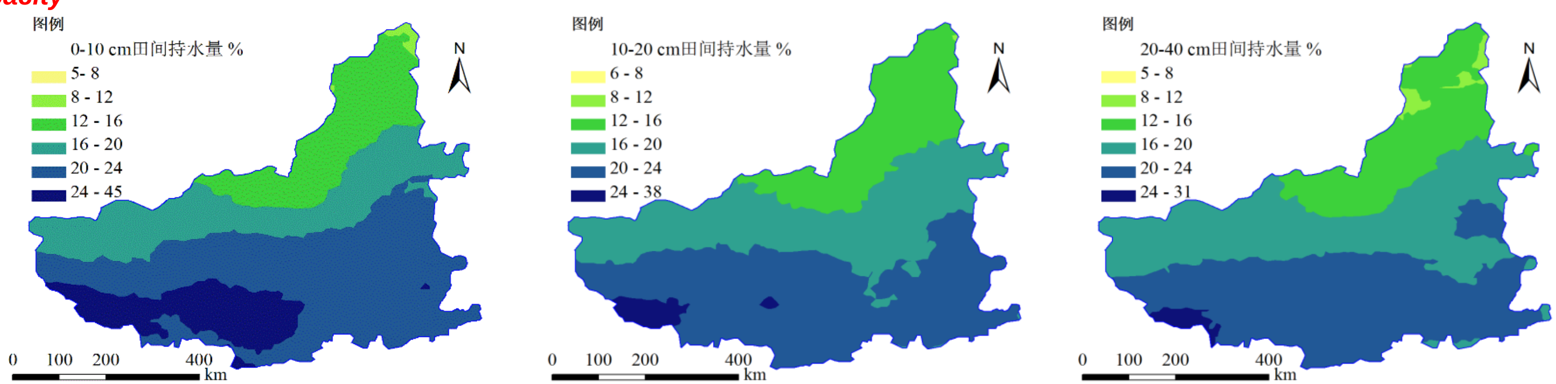
Ks: saturated soil hydraulic conductivity



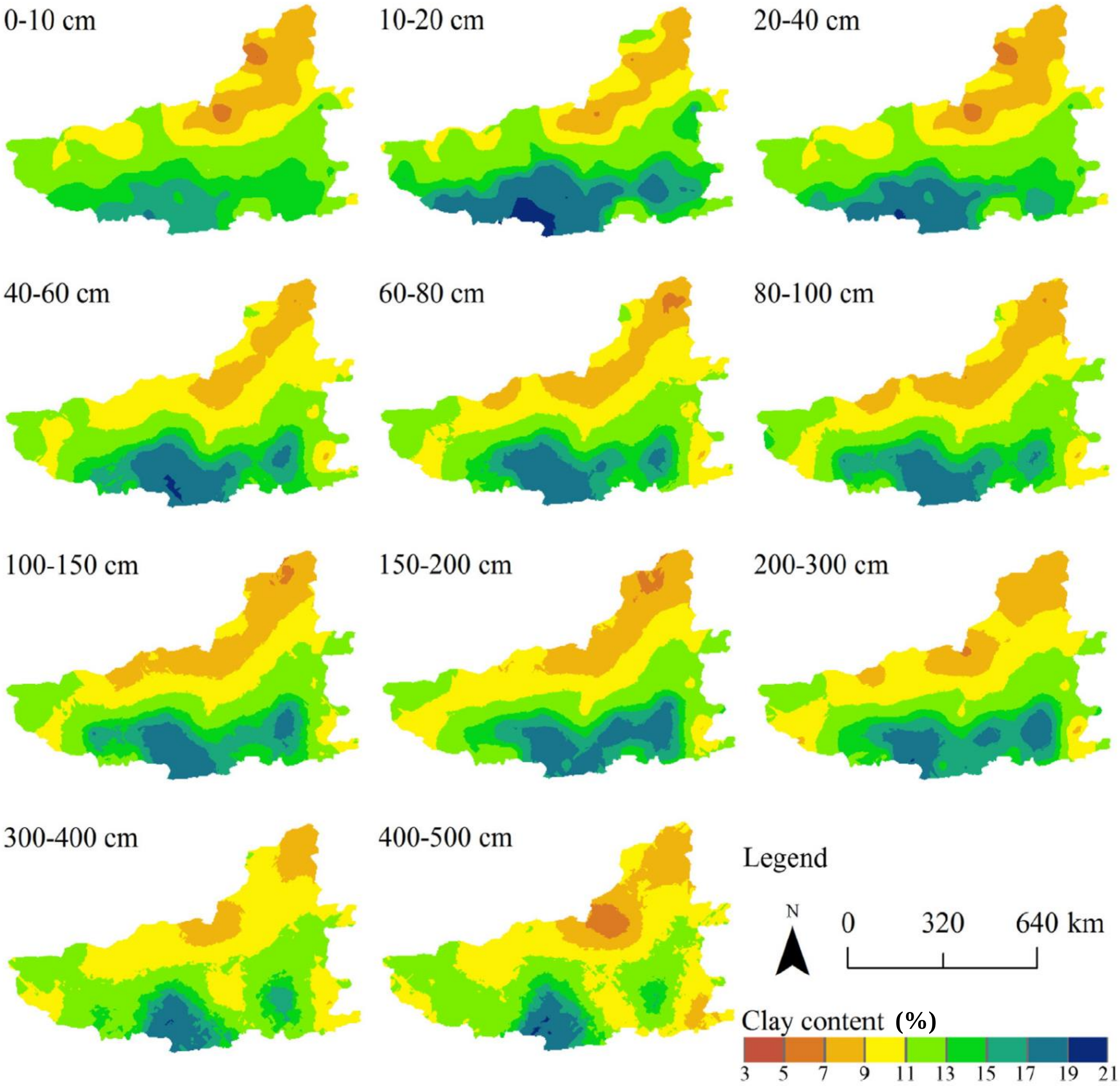
BD: bulk density



FC: field capacity

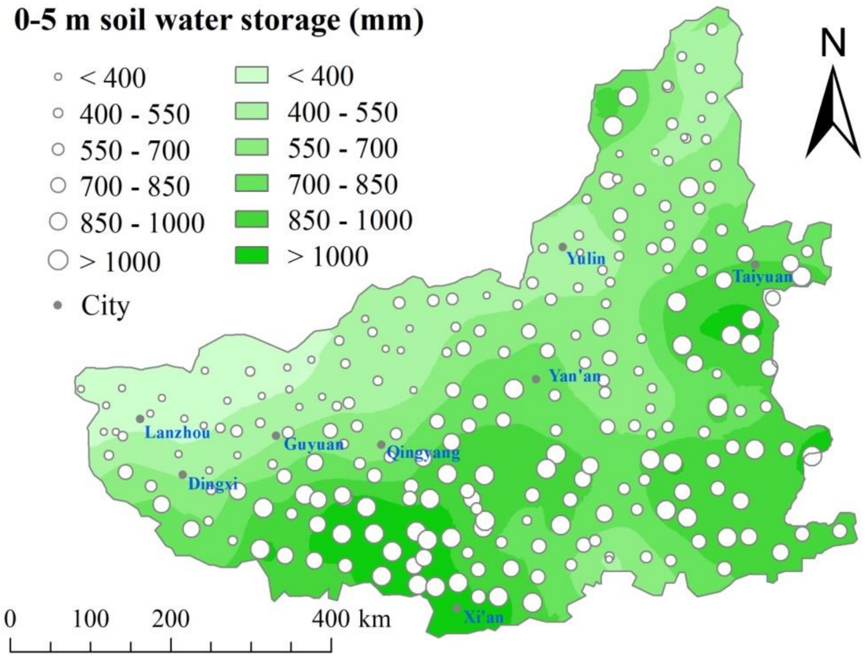


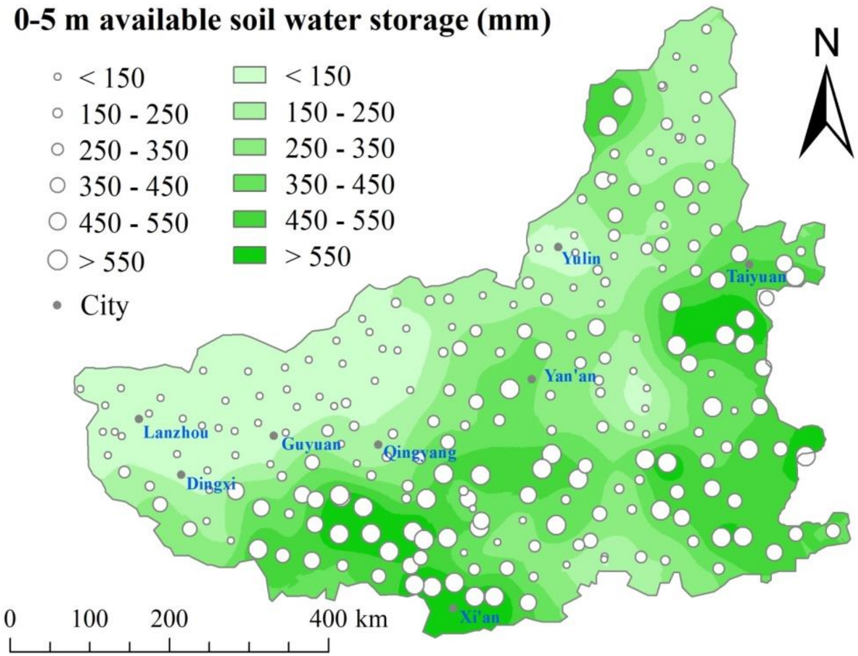
Particle size distribution of soils (0-500 cm) in the Loess Plateau



Zhao et al., 2016, Geoderma Reg.

Regional scale: The entire loess area (37×10⁴ km²)



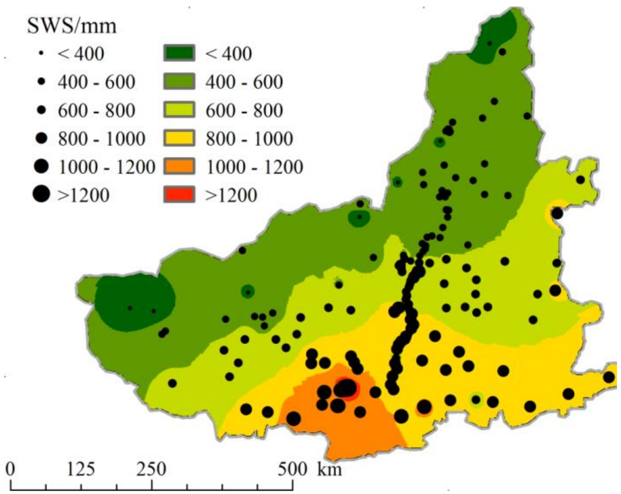


Available soil water is defined as soil water that can be absorbed and utilized directly by plants between wilting point and field capacity

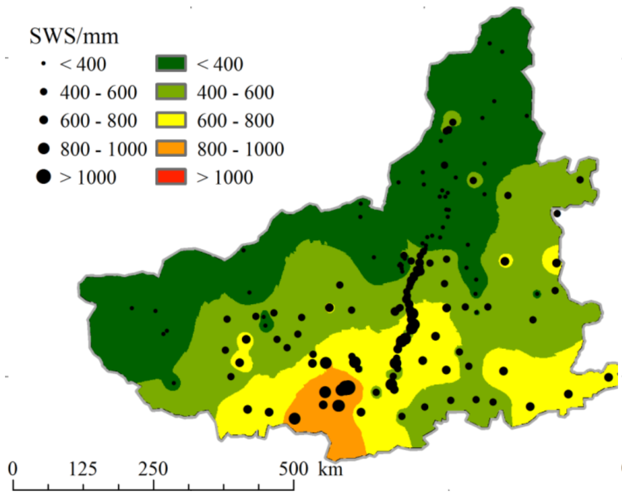
- *Total soil water in the 0-5 m soil layer reaches up to* ***270 billion m³*** *across the LP, and available soil water accounting for 42% of the total soil water;*
- *Regional-scale spatial variation of soil water was dominantly controlled by* ***precipitation and soil texture.***

Cao et al., 2018, Sci. Rep.

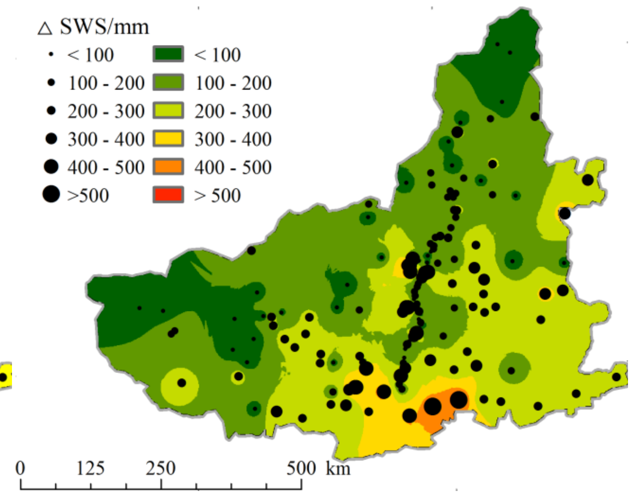
Regional losses of deep soil water due to the conversion of cropland to forest



Estimated pre-afforestation SWS within the 1-5 m profile (n = 169)

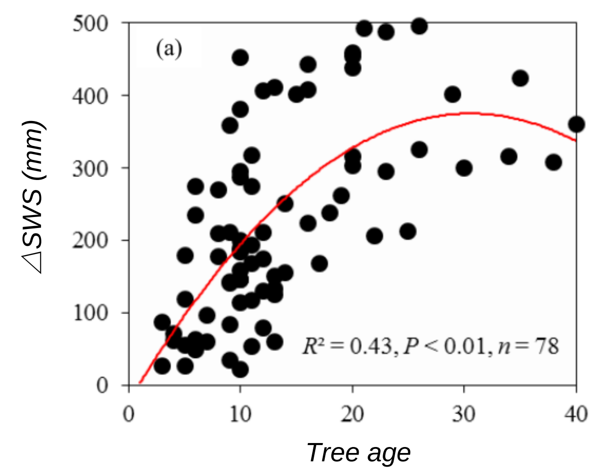


Measured post-afforestation SWS within the 1-5 m profile (n = 169)



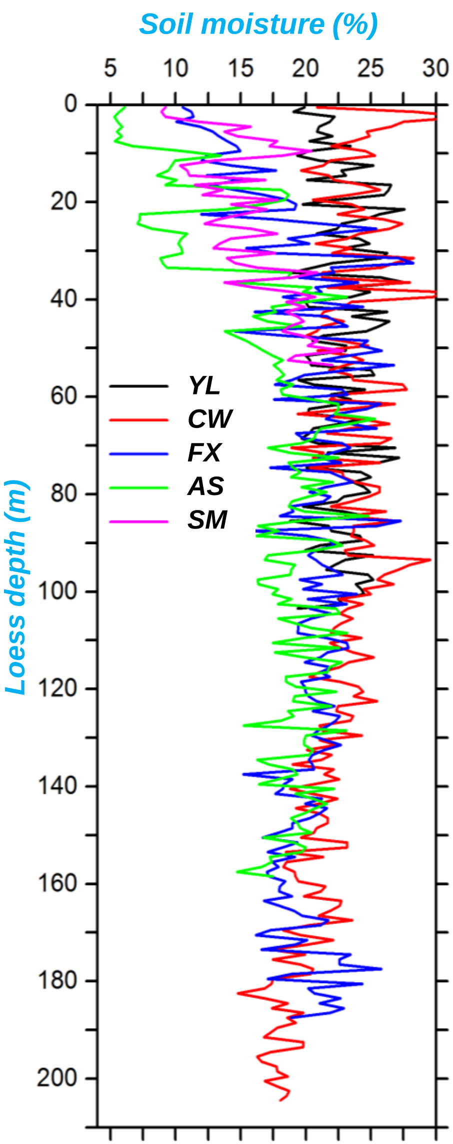
Soil-water losses (△SWS) within the 1-5 m profile (n = 169)

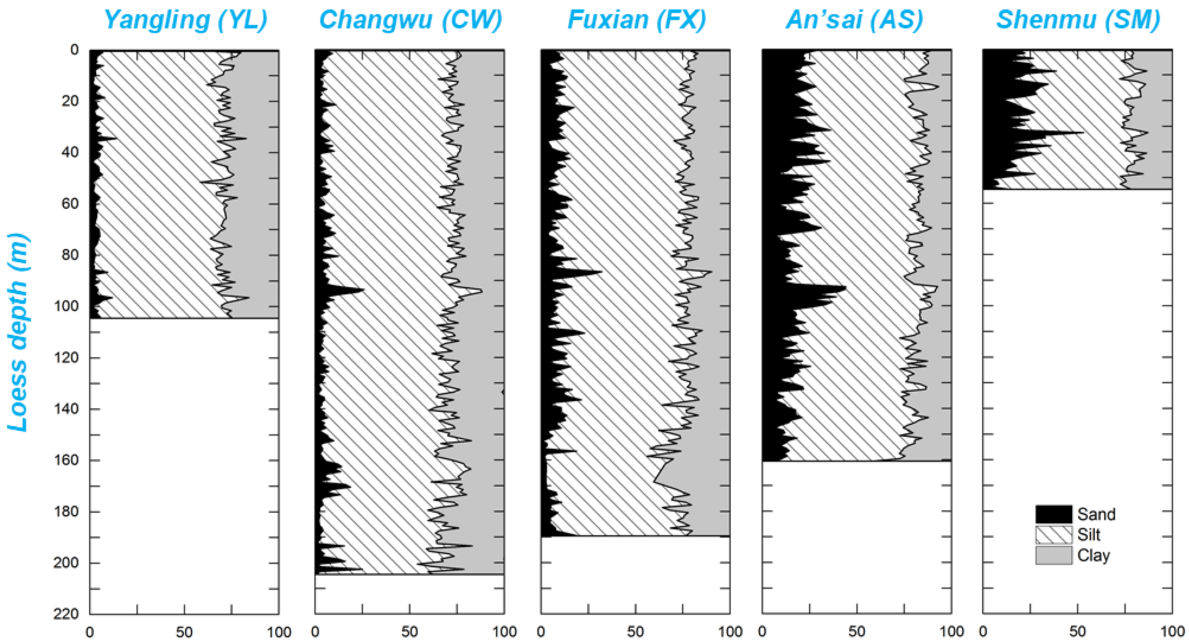
- *The mean ΔSWS in the 1-5 m profile across the study area was 203.7 mm, with an estimated annual average ΔSWS rate of 16.2 mm/year;*
- *ΔSWS depended primarily on mean annual precipitation and tree age (ΔSWS gradually increased with tree age in the first 25 years but then tended to decrease).*



Jia et al., 2017, Ecohydrology

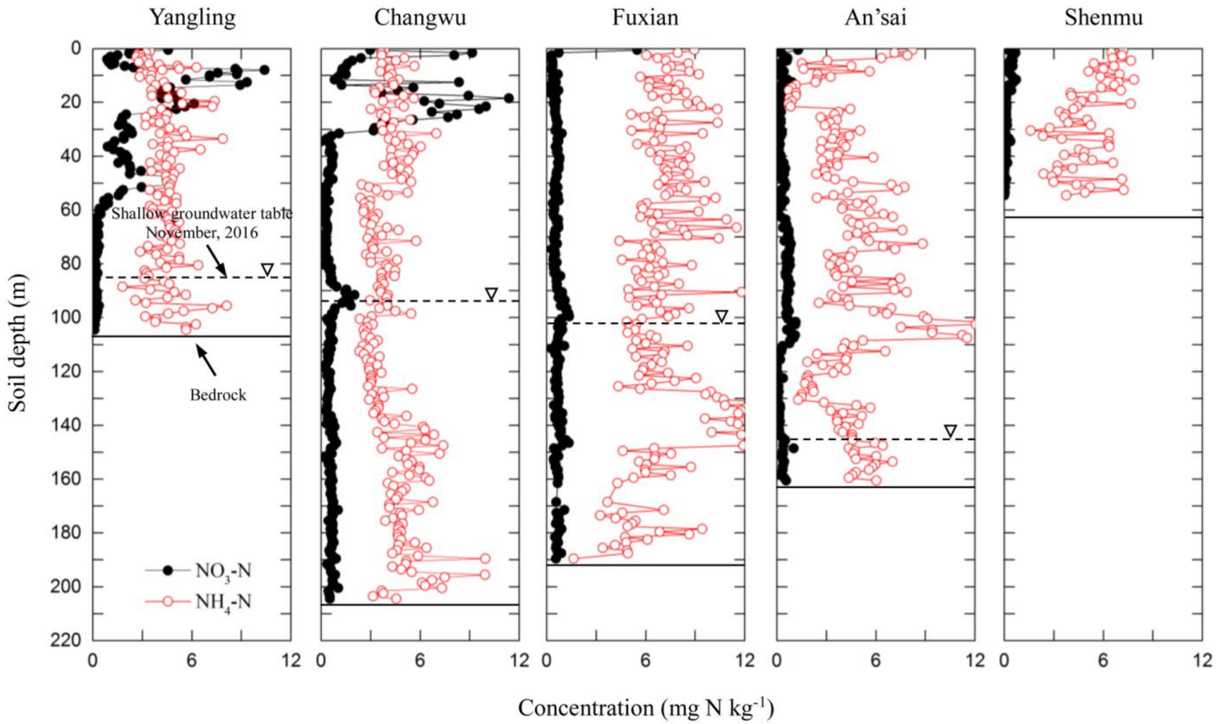
Vertical variations of soil moisture content from surface to bedrock

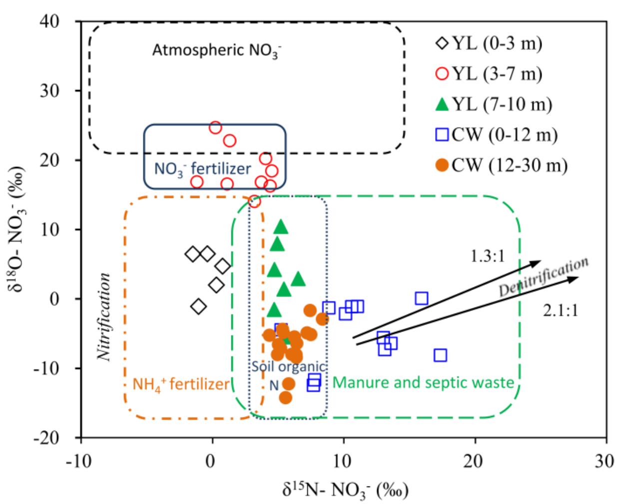




Connectivity between surface water, deep soil water and groundwater?

Vertical distributions of mineral N from surface to bedrock





Nitrate may have accumulated in the upper 50 m layer in the irrigated agricultural area Yangling, which has experienced long-term and intensive agricultural activities; while in the rain-fed agricultural area, e.g., Changwu, nitrate may have accumulated at shallow depths (30 m in the loess profile analyzed here).

Nitrate transport through the deep vadose zone?

Jia et al., 2018, Sci. Total Environ.


Thanks