FAO/IAEA International Symposium, 23 – 27 July 2012, Vienna, Austria

Quantify agricultural land degradation processes related to soil carbon and nitrogen redistribution in China by using FRN and δ^{13}C techniques

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Study Landscapes in China

- **Accelerated soil erosion by intensive tillage, over grazing and irrational tillage practices on steep slopes**

Why important is erosion-induced C and N redistribution?

- Carbon stored in soils represents globally significant carbon pool, which has the potential to influence global climate.
- Soil erosion involves preferential removal of soil organic carbon (SOC) and available nutrients that is concentrated in soil surface horizon.
- Soil erosion is one of the most important driving forces declining soil quality and disturbing the terrestrial C cycle.

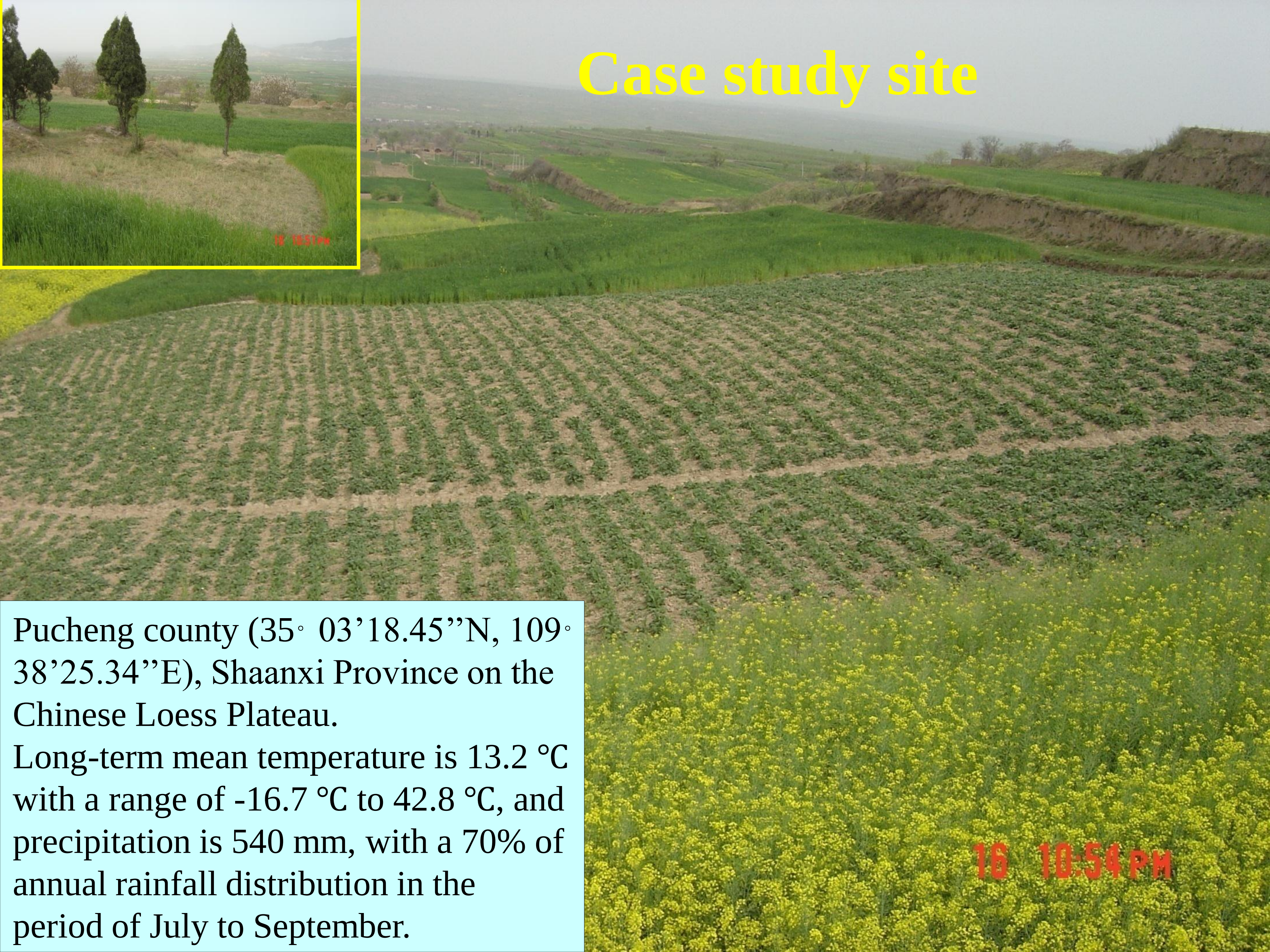
Therefore, there is a need for quantifying land/soil degradation processes related to erosion-induced C and N redistribution.

Objectives

Combinative use of fallout ^{137}Cs and $^{210}Pb_{ex}$ and $\delta^{13}C$ for quantification of land degradation processes through

- Understanding the magnitude and mechanisms of soil C and nutrients changes, and
- Reconstructing evolution of SOC sources in cultivated slope.
- developing the empircal models to quantify soil C and N distribution in cultivated landscapes.

Case study site

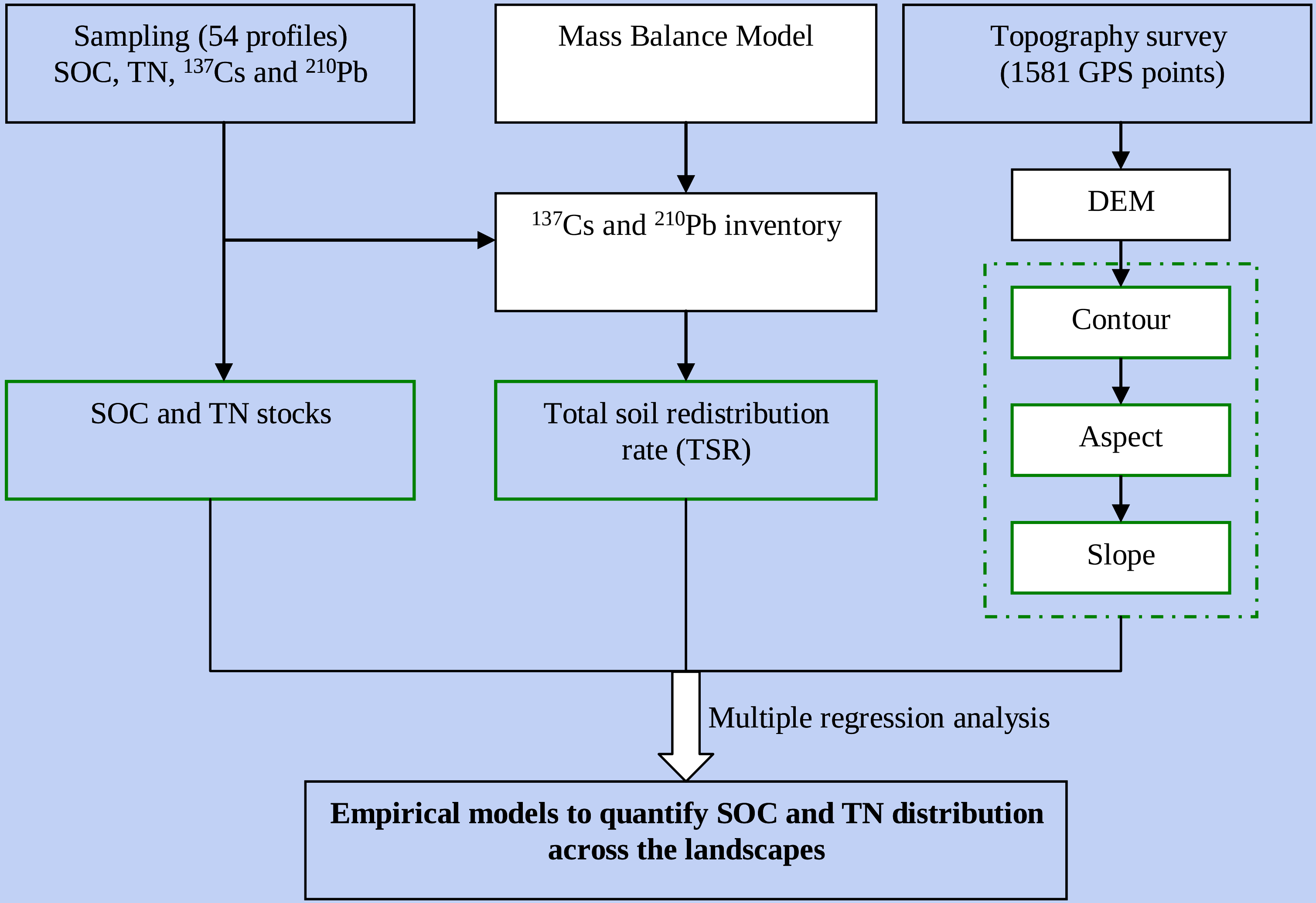


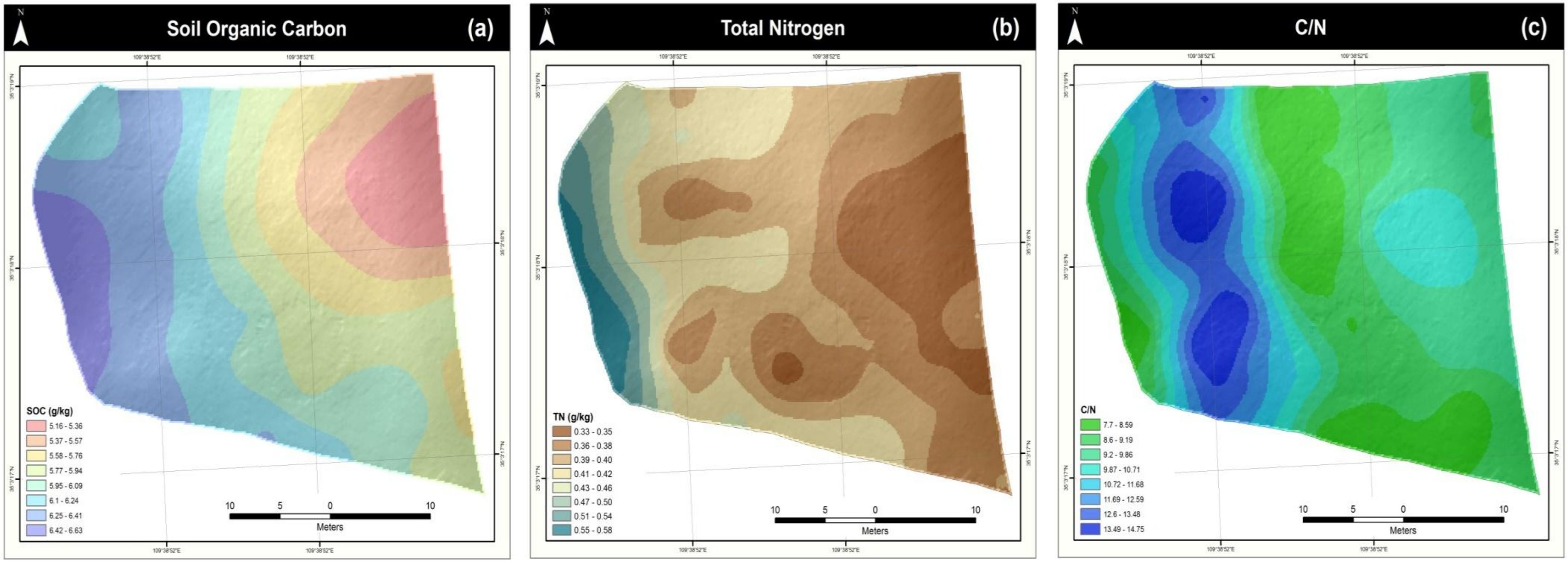
Pucheng county (35° 03’18.45’’N, 109° 38’25.34’’E), Shaanxi Province on the Chinese Loess Plateau.

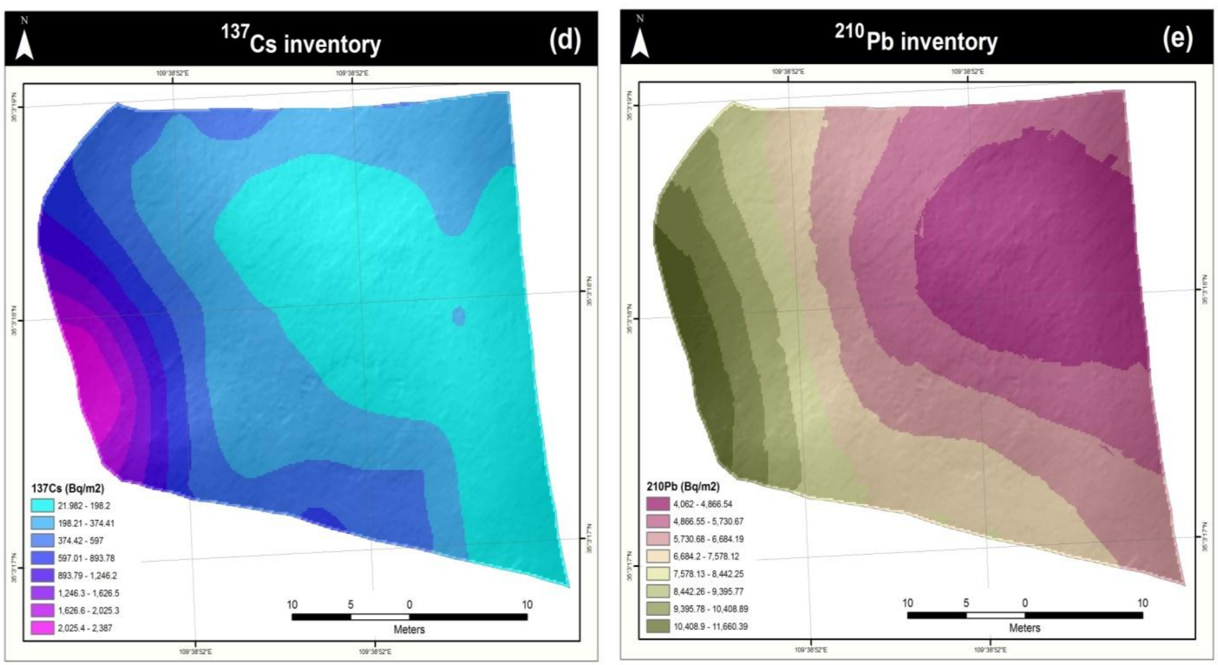
Long-term mean temperature is 13.2 ℃ with a range of -16.7 ℃ to 42.8 ℃, and precipitation is 540 mm, with a 70% of annual rainfall distribution in the period of July to September.

Objective I: Quantifying spatial patterns in soil C and N on the slope

Methods







- High C:N ratios at lower slope indicate high input of crop carbon to soil.
- Very low C:N ratios suggest severe land degradation.

Summary of SOC and TN stocks and inventories of ^{137}Cs and ^{210}Pbex at different slopes positions

Statistics		SOC, t C ha^{-1}			TN, t C ha^{-1}			^{137}Cs, Bq m^{-2}			^{210}Pb$_{ex}$, Bq m^{-2}		
		Upper	Middle	Lower	Upper	Middle	Lower	Upper	Middle	Lower	Upper	Middle	Lower
Down slope	Mean	19.00	22.68	29.70	2.05	2.28	2.78	160.86	285.28	1065.21	5202.64	5980.11	9786.24
	Stdev	1.16	4.96	0.75	0.17	0.22	0.57	155.01	189.53	828.87	1573.58	2524.25	3686.18
	CV, %	6.10	21.88	2.52	8.24	9.63	20.57	96.36	66.44	77.81	30.25	42.21	37.67
	N	21	21	12	21	21	12	21	21	12	21	21	12
Cross slope	Mean	23.02	22.30	22.99	2.29	2.24	2.38	469.98	309.30	415.50	6376.29	6650.74	6632.04
	Stdev	5.40	5.27	4.90	0.49	0.40	0.31	753.96	353.21	184.78	3709.31	2718.02	2332.81
	CV, %	23.46	23.65	21.30	21.26	17.66	12.93	160.42	114.20	44.47	58.17	40.87	35.17
	N	24	15	15	24	15	15	24	15	15	24	15	15

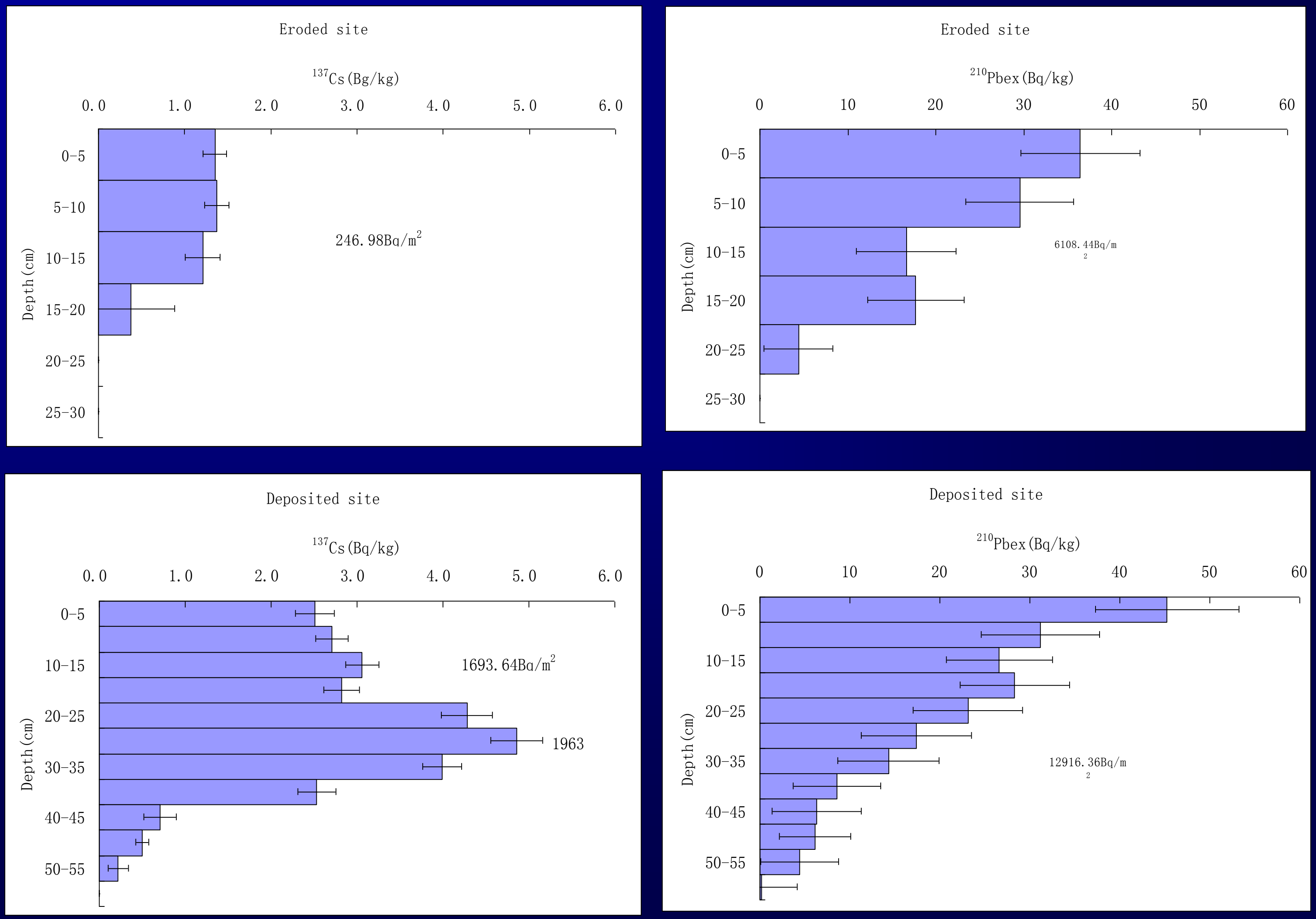
Relations between slope relative elevation (E, m), slope degree (S, in degree) and slope aspect (A) and SOC (t ha^{-1} and TN (t ha^{-1})

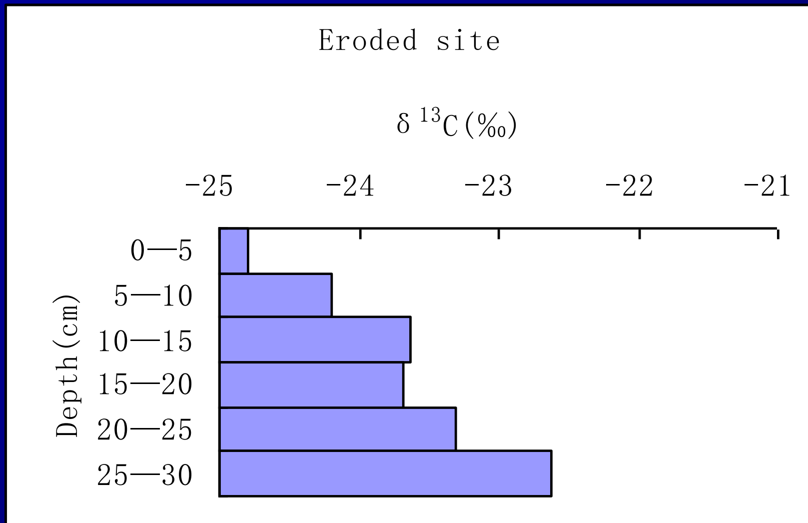
Linear regression	R^2	***n***	**P**
SOC_{stock}=-1.71E + 29.42	0.661	54	<0.001
SOC_{stock}= -0.07A+ 42.02	0.135	54	<0.01
SOC_{stock} = -0.26S+ 25.60	0.028	54	n.s.*
TN_{stock} = -0.11E + 2.72	0.412	54	<0.001
TN_{stock} = -0.01A+ 3.64	0.101	54	<0.05
TN_{stock} = -0.041S + 2.74	0.104	54	<0.05

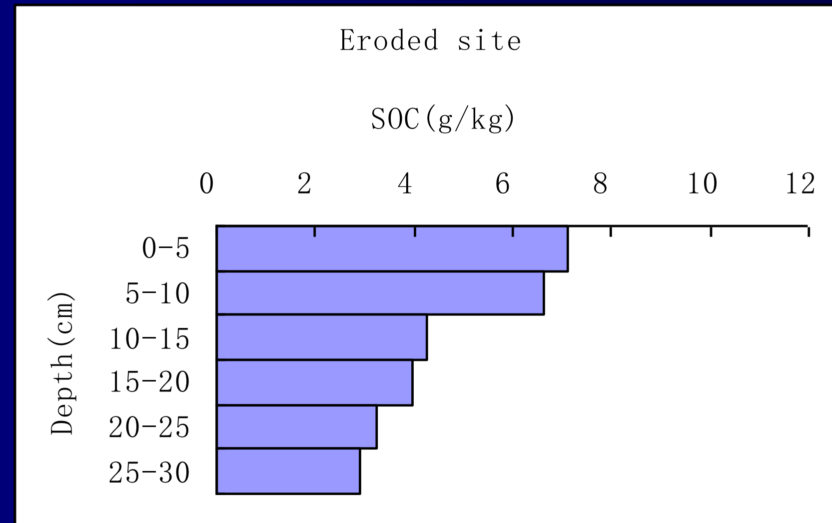
Models for predicting SOC and TN stocks on the slope land by using terrain attributes of relative elevation (E, m), slope gradients (S, degree), slope aspect (A, degree) and total soil erosion (TSR)

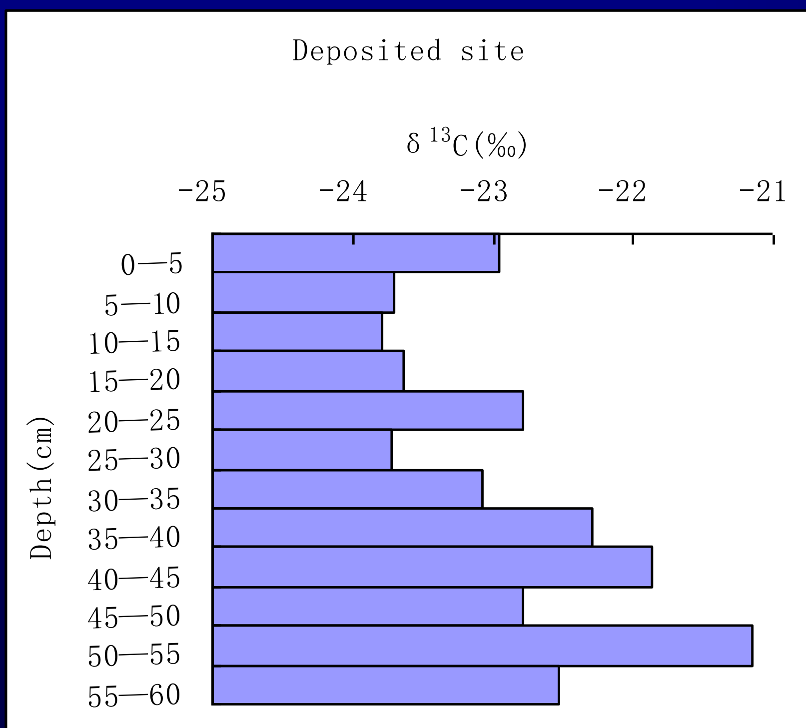
Period	**Multiple regression model**	**R**	**P-value**	**deviation from observed value**
1954-2007	SOC_{stock}=44.34-1.49E-0.04A-0.38S+0.006TSR	0.8613	$P<0.0001$	9.4%
1907-2007	SOC_{stock}=45.14-1.53E-0.04A-0.39S+0.016TSR	0.8603	$P<0.0001$	9.6%
1954-2007	TN_{stock}=3.81-0.065E-0.0024A-0.041S+0.0024TSR	0.8135	$P<0.0001$	8.6%
1907-2007	TN_{stock}=3.75-0.071E-0.002A-0.036S+0.012TSR	0.8351	$P<0.0001$	8.0%

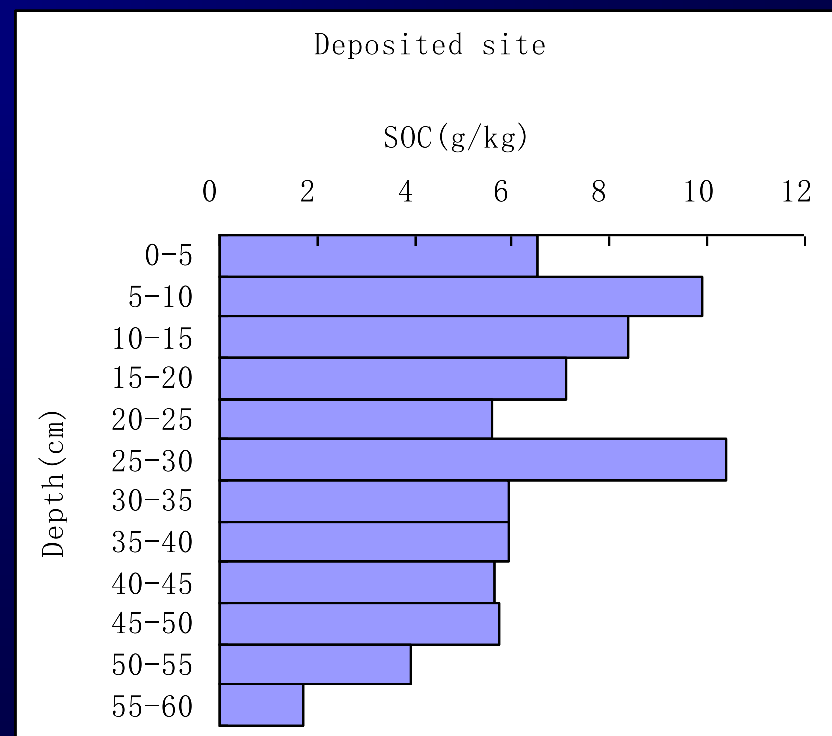
Objective II: Reconstructing evolution of SOC sources in cultivated slope

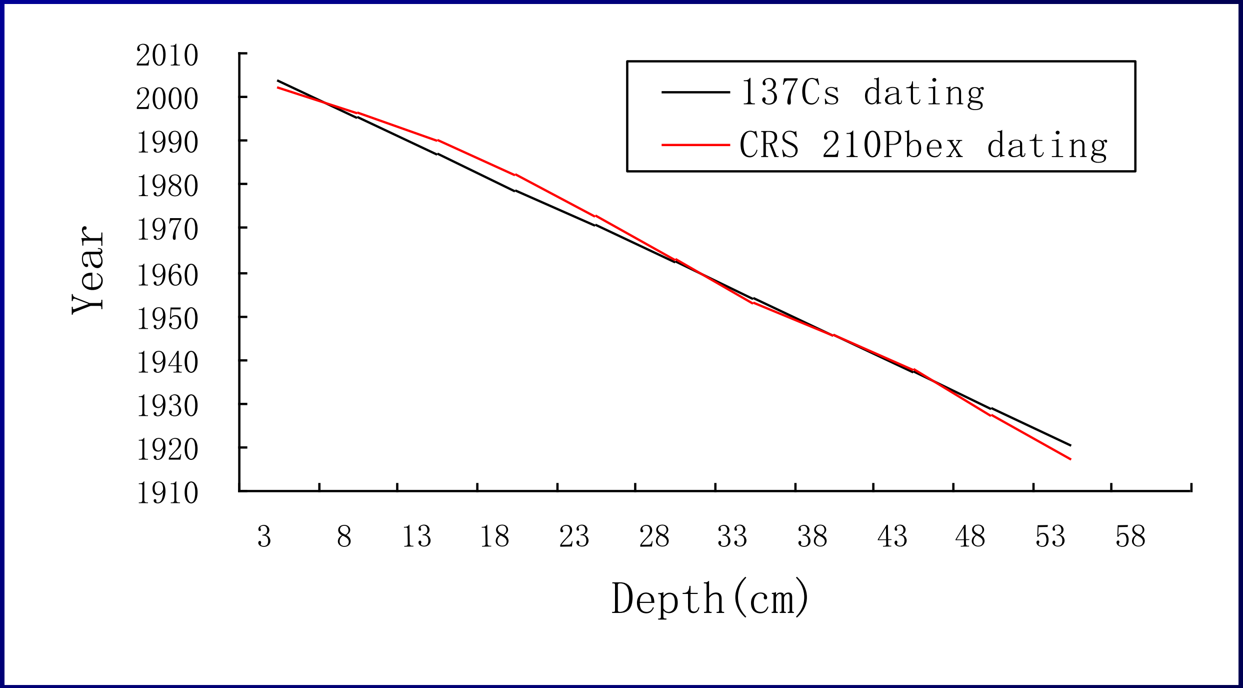



Eroded site
δ 13C (‰)
-25 -24 -23 -22 -21
Depth (cm)
0—5
5—10
10—15
15—20
20—25
25—30


Eroded site
SOC (g/kg)
0 2 4 6 8 10 12
Depth (cm)
0-5
5-10
10-15
15-20
20-25
25-30


Deposited site
δ 13C (‰)
-25 -24 -23 -22 -21
Depth (cm)
0—5
5—10
10—15
15—20
20—25
25—30
30—35
35—40
40—45
45—50
50—55
55—60


Deposited site
SOC (g/kg)
0 2 4 6 8 10 12
Depth (cm)
0-5
5-10
10-15
15-20
20-25
25-30
30-35
35-40
40-45
45-50
50-55
55-60

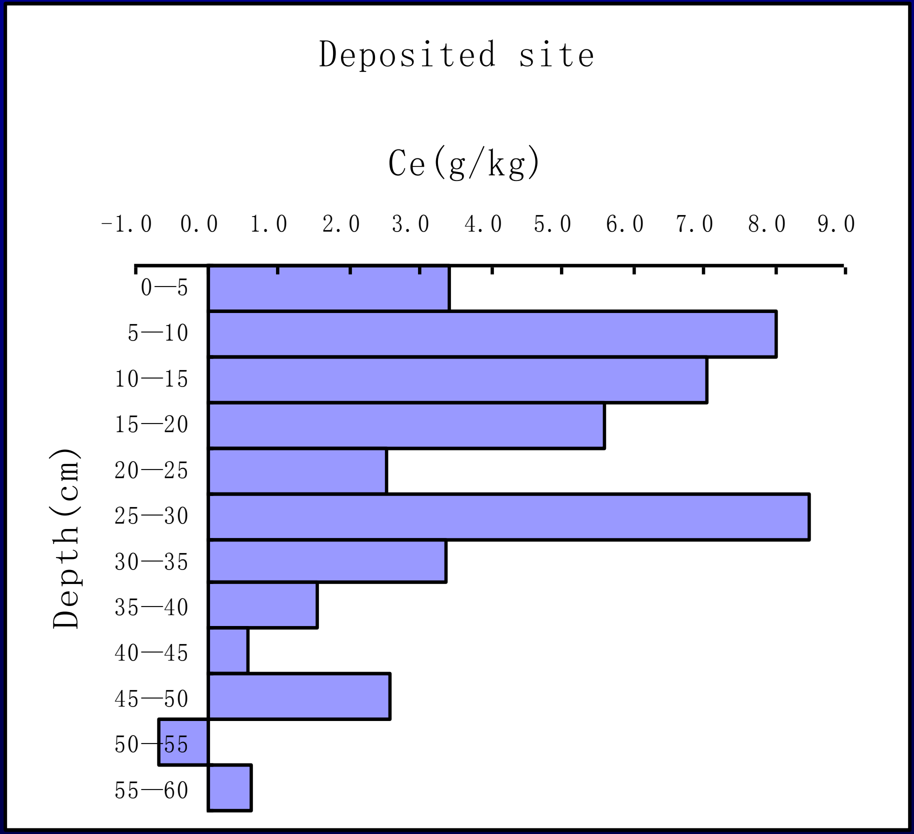


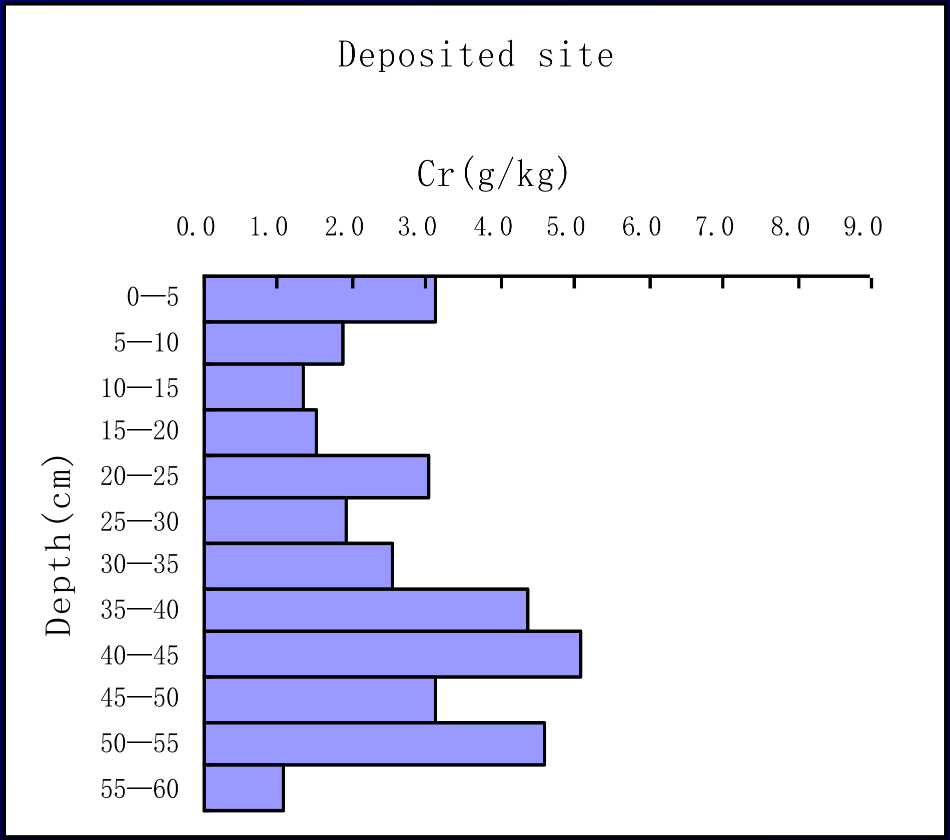
Ce+Cr=Ct (1)

δ^{13}Ce*Ce+δ^{13}Cr*Cr=δ^{13}Ct*Ct (2)

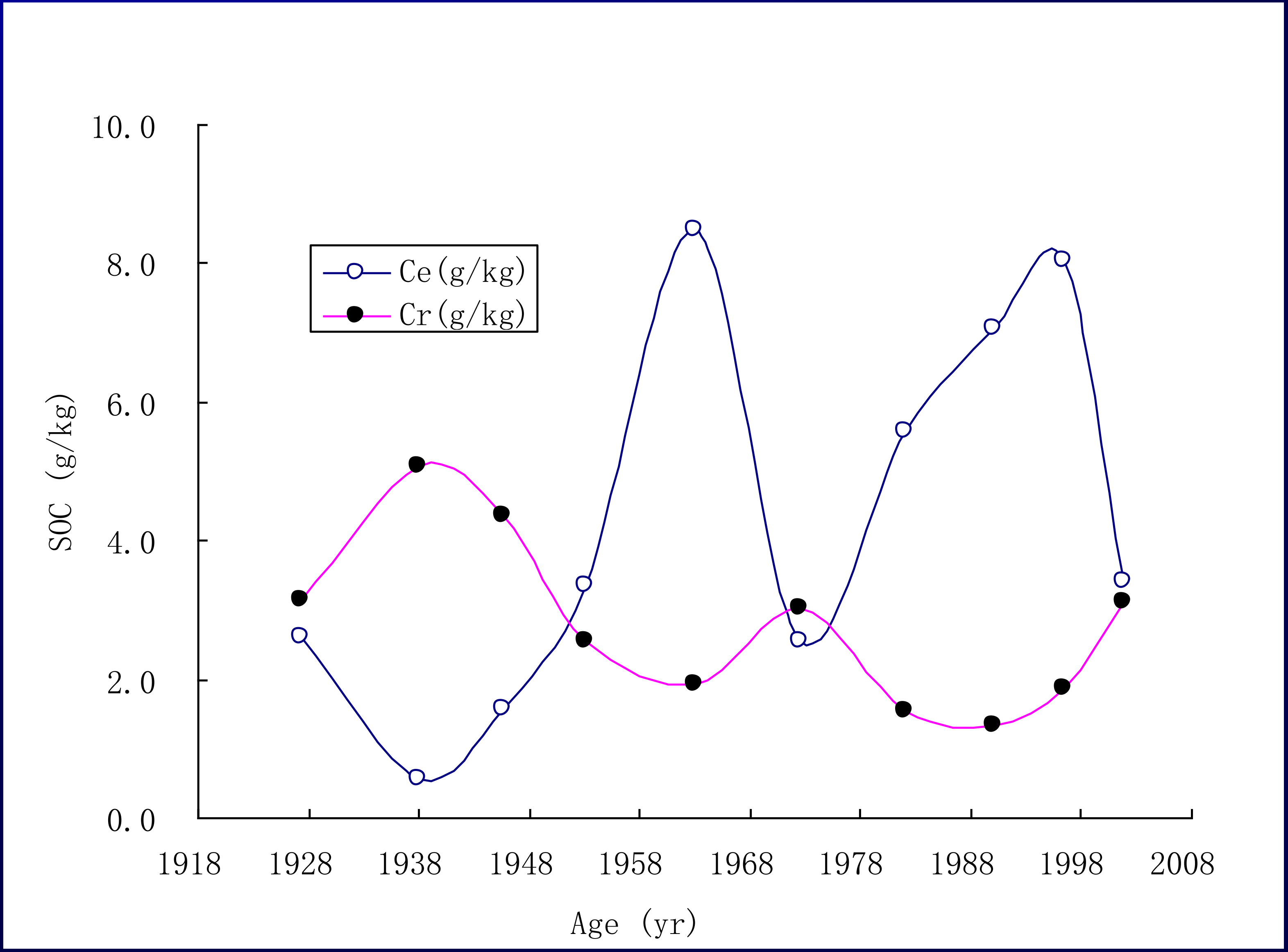
Where: Ce (g kg^{-1}) - eroded soil carbon from upland, Cr (g kg^{-1}) rpresents carbon input by crop roots, Ct (g kg^{-1}) represents total carbon in deposited soil profile.

Profile distribution of SOC sources identified by $\delta^{13}C$





Reconstructed changes in SOC sources in deposited profile at the lower filed boundary of the cultivated slope



Conclusion

- Using ^{137}Cs and ^{210}Pbex integrated with terrain attributes, we established models for slope-catchment evaluation of SOC and TN stocks covering a time of 50-100 years. These models have a very high accuracy for quantify changes in SOC and TN stocks in cultivated slope catchment.

- By using FRN profile dating in combination with natural ^{13}C tracer, it is possible to explain the role of water erosion and intensive tillage processes controlling upland degradation over the past 100 years.

- Next step: Validating and upscaling these models for entire loess Plateau will be conducted.

Thank you for your kind attention