辽宁师范大学
Liaoning Normal University

EGU General Assembly 2022

Simulating soil loss on farmland hillslope cultivated in centennial periods using magnetic susceptibility in Northeast China

Yue Yu[1], Keli Zhang[2], and Liang Liu[3]

1 Liaoning Normal University, Dalian, China
2 Beijing Normal University, Beijing, China
3 Nanjing Forestry University, Nanjing, China

May 25, 2022

1 Background

- Soil erosion is one of the most important global environmental issues
- Soil erosion leads to the land degradation and crop yield reduction

Fig. 1 Soil erosion （September, 2021）

1 Background

- Northeastern region supplies more than half of the total grain market in China
- Increasingly serious soil loss in northeastern China is threatening grain production
- It is very urgent to control soil loss for food security in China

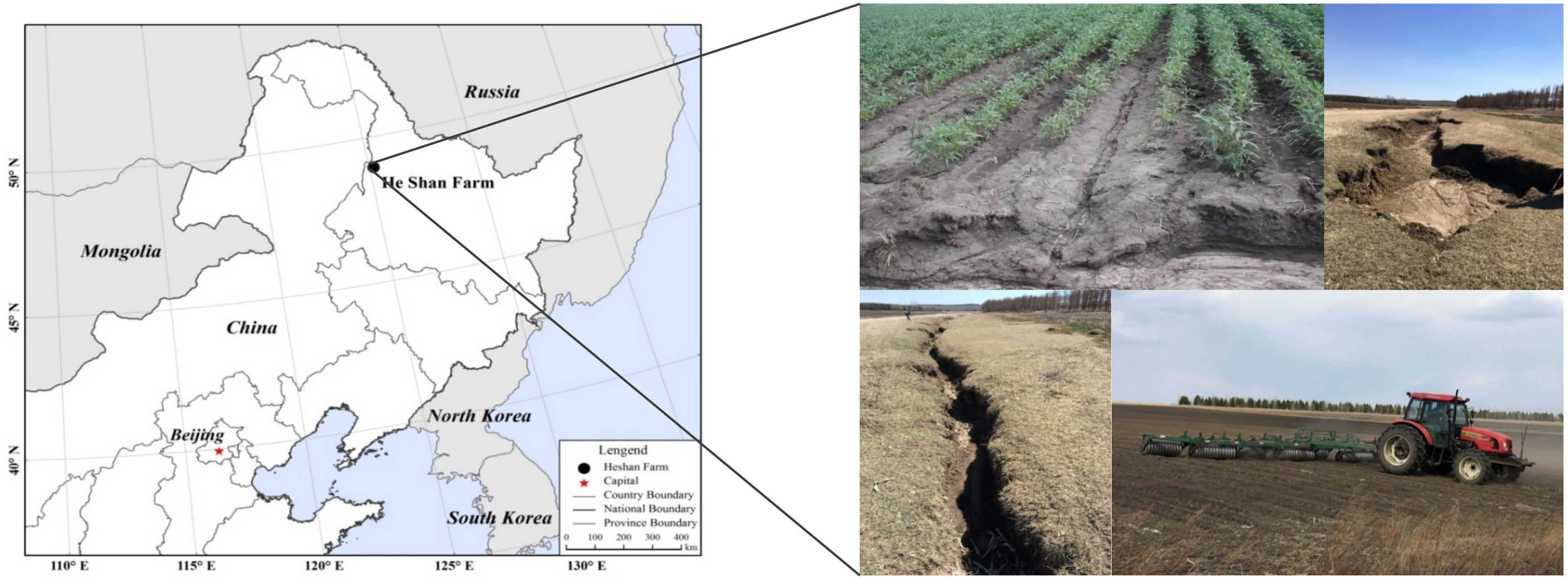

Fig. 2 Soil erosion in northeastern China

2 Magnetic Susceptibility (MS) Technique

- In the nature, all materials are with magnetic in different magnitudes
- Magnetic susceptibility (MS) of materials (*Thompson and Oldfield, 1986; Evans and Heller, 2003*)

$$\chi_{total} = \chi_{ferro} + \chi_{ferri} + \chi_{antiferro} + \chi_{para} + \chi_{dia}$$

	ferromagnetic	ferrimagnetic	antiferromagnetic	paramagnetic	diamagnetic
χ_{total}	χ_{ferro}	χ_{ferri}	$\chi_{antiferro}$	χ_{para}	χ_{dia}
	Strong magnetic	•10^3	•10^1	•10^1	•-10^{-3}
χ_{soil}	**Almost none**	**Low content**	**Low content**	**High content**	**Rare**
	Iron, cobalt, nickel and their allies	Iron-cobalt-nickel oxides and sulfides	Iron (manganese) oxides and other ferruginous oxides	Most rocks and many minerals	Most metal, most organics, pure silica and water

2 Magnetic Susceptibility (MS) Technique

◆ **Magnetic susceptibility technique (MS technique)**

✓ Simple, rapid and economic

✓ Non-destructive

✓ High time and spatial resolution

• Lack of quantitative models

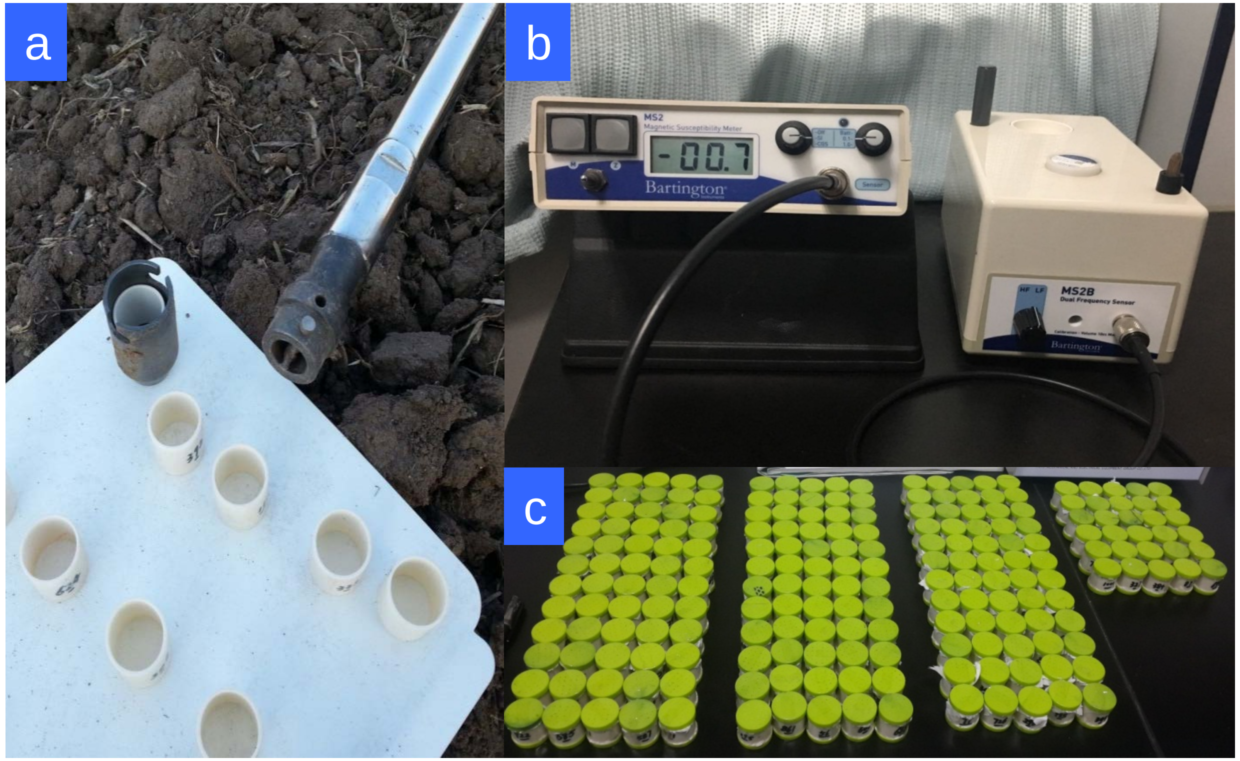

Fig. 3 Magnetic technique (a. An improved core sampler; b. Bartington magnetic meter ; c. Soil samples in PVC boxes)

2 Magnetic Susceptibility (MS) Technique

◆ Formulas using in MS calculation

- Volume magnetic susceptibility (κ)

$$\kappa = \frac{M}{H} \qquad (1)$$

Measured values

- Mass magnetic susceptibility (χ_{lf} or χ_{hf})

$$\chi = \frac{\kappa}{\rho} \qquad (2)$$

Calculated values

- Frequency –dependent magnetic susceptibility (χ_{fd})

$$\chi_{fd} = \frac{\chi_{lf} - \chi_{hf}}{\chi_{lf}} \times 100 \qquad (3)$$

Calculated values

2 Magnetic Susceptibility (MS) Technique

◆ Theories and Hypothesis

- Soil MS is closely relative to **pedogenic processes** and **pedogenic environment**
- **Enhancement** of MS on **topsoil** for a given soil

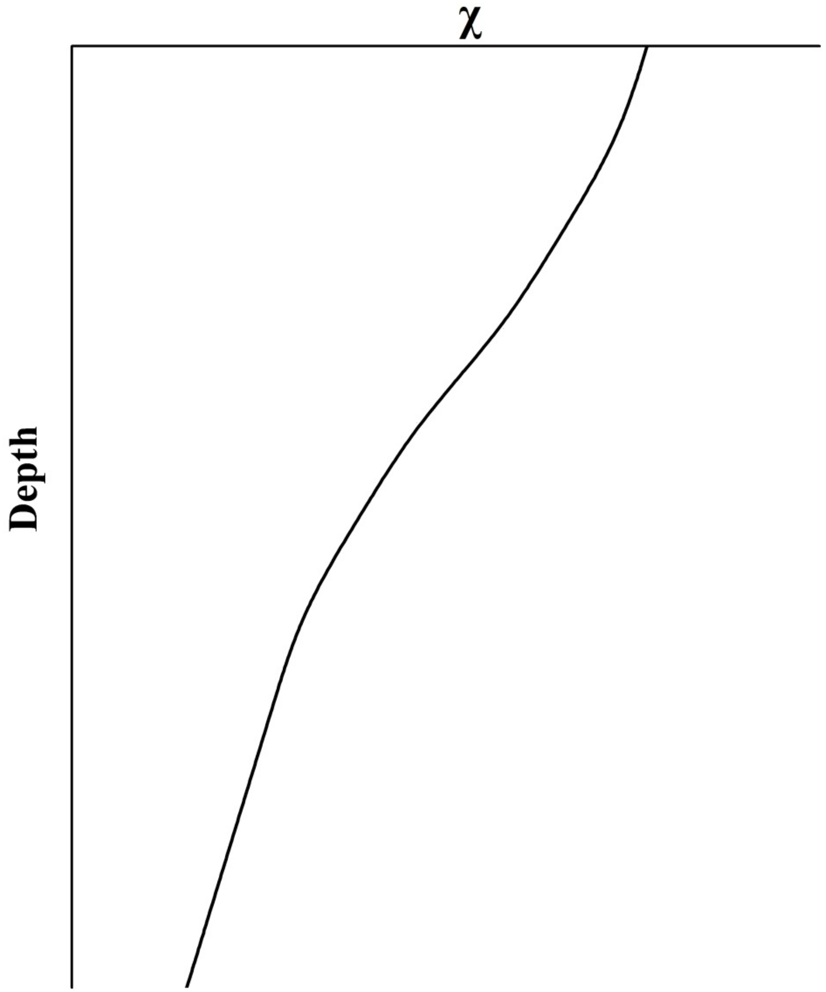

Fig. 4 Enhancement of soil MS on topsoil

2 Magnetic Susceptibility (MS) Technique

◆ Theories and Hypotheses

- **Short-term geographic condition** leads soil material to transform from its own position
- We use soil MS to reconstitute soil transforming process and quantify soil loss

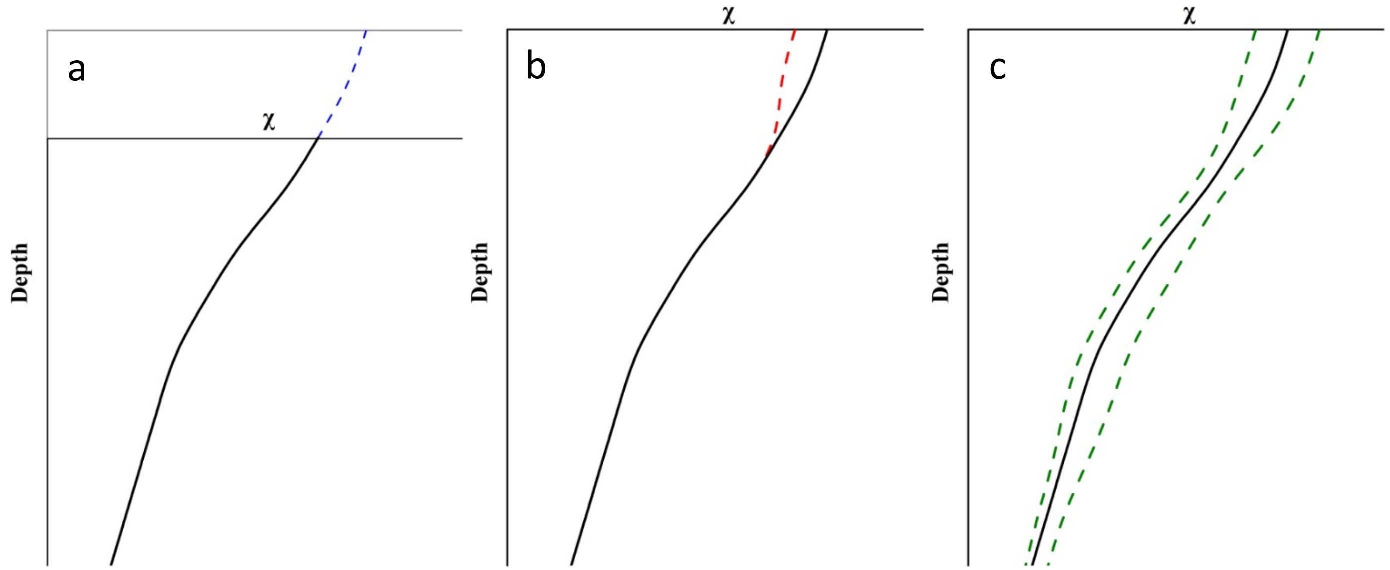

Fig. 5 Changes of MS in profile
(a. loss of top soil; b. movement of clay grains; c. different pedogenic environment)

3 Our Works

- **Qualitative research in different cultivated periods:** Evaluation of the influence of cultivation period on soil redistribution in northeastern China using magnetic susceptibility (Yu, et al., 2017)
- **Quantitative research on a single slope:** Estimating long-term erosion and sedimentation rate on farmland using magnetic susceptibility in northeast China (Yu, et al., 2019)
- **Quantitative research on several slopes in different cultivated periods:** Simulating soil loss on farmland hillslope cultivated in centennial periods using magnetic susceptibility in Northeast China (Previous)

3 Our Works

◆ **Qualitative research in different cultivated periods:** Evaluation of the influence of cultivation period on soil redistribution in northeastern China using magnetic susceptibility (Yu, et al., 2017)

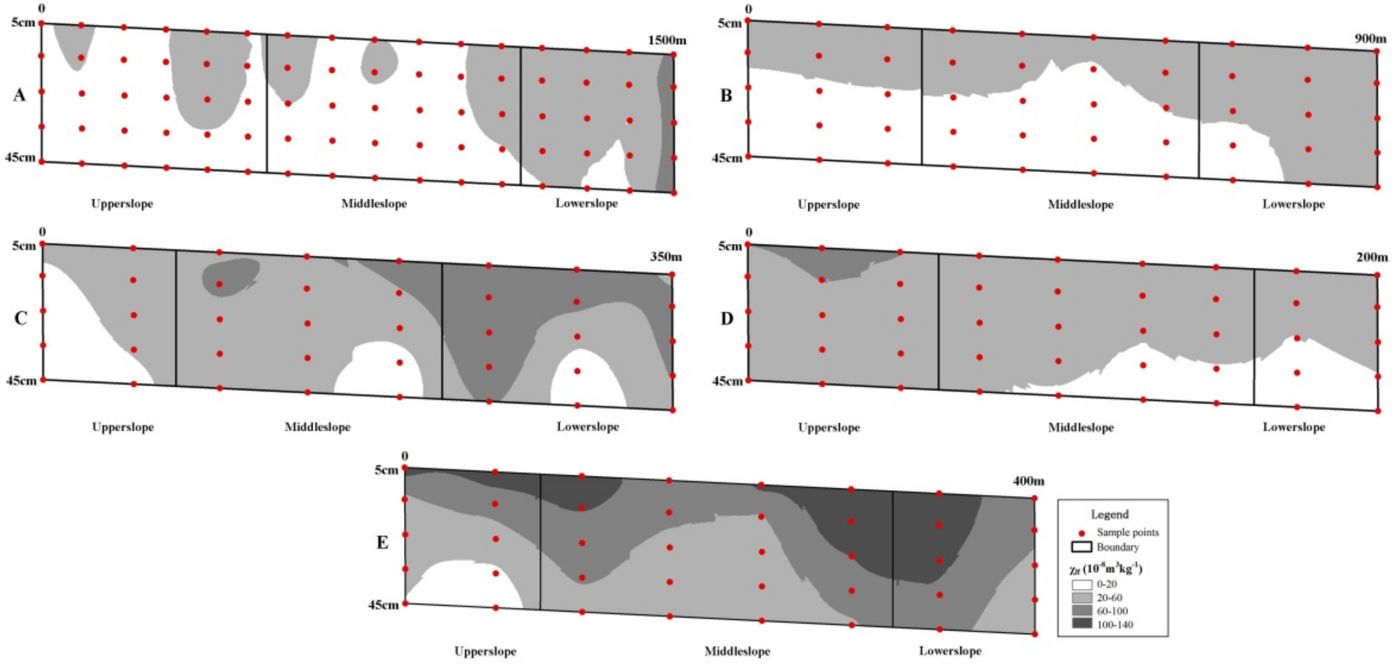

Fig. 6 Soil distribution patterns of χ_{lf} profile (0 to 50 cm) deep in different cultivation period (A. 110 years; B. 50-60 years; C. 30 years; D. 20 years; E. 0 year).

3 Our Works

- **Quantitative research on a single slope:** Estimating long-term erosion and sedimentation rate on farmland using magnetic susceptibility in northeast China (Yu, et al., 2019)

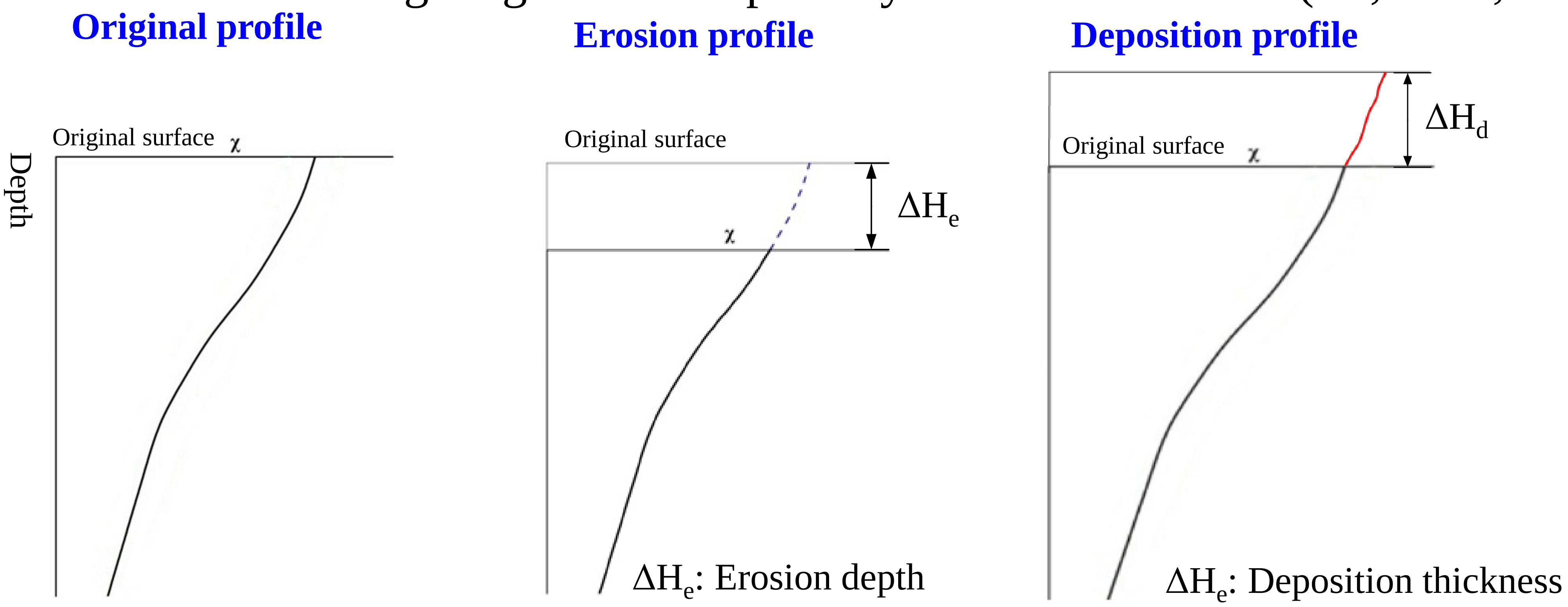

Fig. 7 Processes of soil erosion

3 Our Works

◆ **Quantitative research on a single slope:** Estimating long-term erosion and sedimentation rate on farmland using magnetic susceptibility in northeast China (Yu, et al., 2019)

Tillage-Homogenization Model

$$\chi_d = \frac{\sum_{i=1}^{20} \chi_i}{20} \quad (3)$$

when d = 0, otherwise,

$$\chi_d = \frac{19(\chi_{d-1}) + (\chi_{d+20})}{20} \quad (4)$$

where χ_d is the predicted MS ($10^{-8}\cdot m^3\cdot kg^{-1}$), *d* is the total erosion depth (cm), *i* is the depth increment below the surface (cm), χ_{d-1} is the MS value within the plow layer for the erosion stage prior to the current one ($10^{-8}\cdot m^3\cdot kg^{-1}$), χ_{d+20} is the 1-depth-unit soil layer immediately below the plow depth, regardless of the erosion stage ($10^{-8}\cdot m^3\cdot kg^{-1}$).

3 Our Works

◆ **Quantitative research on a single slope:** Estimating long-term erosion and sedimentation rate on farmland using magnetic susceptibility in northeast China (Yu, et al., 2019)

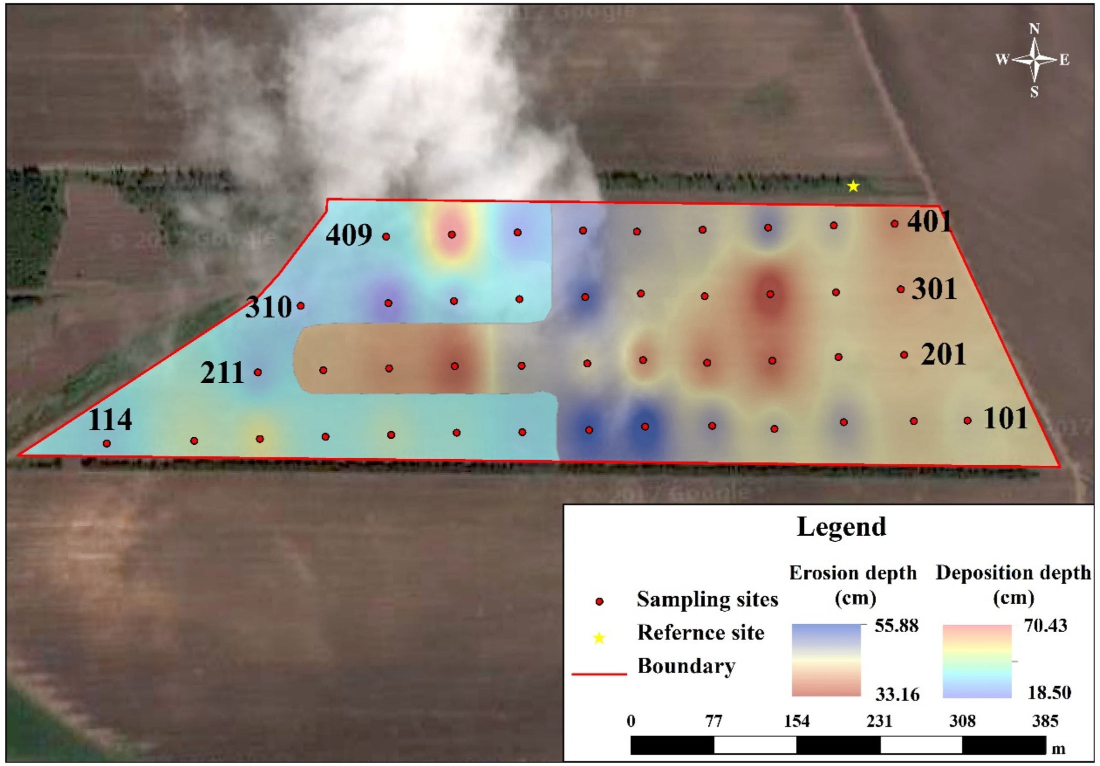

Fig. 8 The spatial pattern of soil erosion depth across the sampling slope.

3 Our Works

◆ **Quantitative research on several slopes in different cultivated periods:** Simulating soil loss on farmland hillslope cultivated in centennial periods using magnetic susceptibility in Northeast China (Previous)

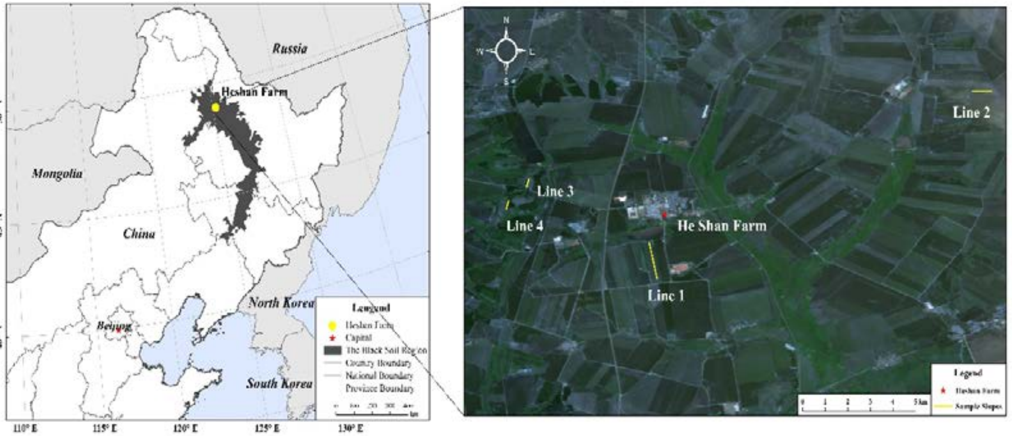

Fig. 9 Location of the sampling sites.

Table 1 Sampling information of the selected slope.

Transect code	Cultivation period (yr)	Slope (°)	Length (m)	Aspect	Number of sampling sites	Land use
Line 1	110	2.2	1500	North	16	Cropland
Line 2	60	2.4	900	West	10	Cropland
Line 3	30	5.1	350	North	8	Cropland
Line 4	20	2.2	200	South	9	Grassland
Reference Line(RL)	0	3.8	400	North	8	Forestland

3 Our Works

The reduction rate (R) was calculated by the ratio of the subtraction of cropland χ (χ_c) from forestland χ (χ_f) and forestland χ (χ_f). The relative difference value of MS among cultivation periods ($\Delta\chi$, e.g. $\Delta\chi_{lf}$, $\Delta\chi_{hf}$, or $\Delta\chi_{fd\%}$) may express the soil loss in a certain period, which is defined as the ratio of the difference between MS of the slopes cultivated in i years (χ_i) and j years (χ_j) and the period of these years (j-i).

$$R = \frac{\chi_f - \chi_c}{\chi_f} \times 100 \qquad (5)$$

$$\Delta\chi = \frac{\chi_i - \chi_j}{j - i} \quad (j > i) \qquad (6)$$

3 Our Works

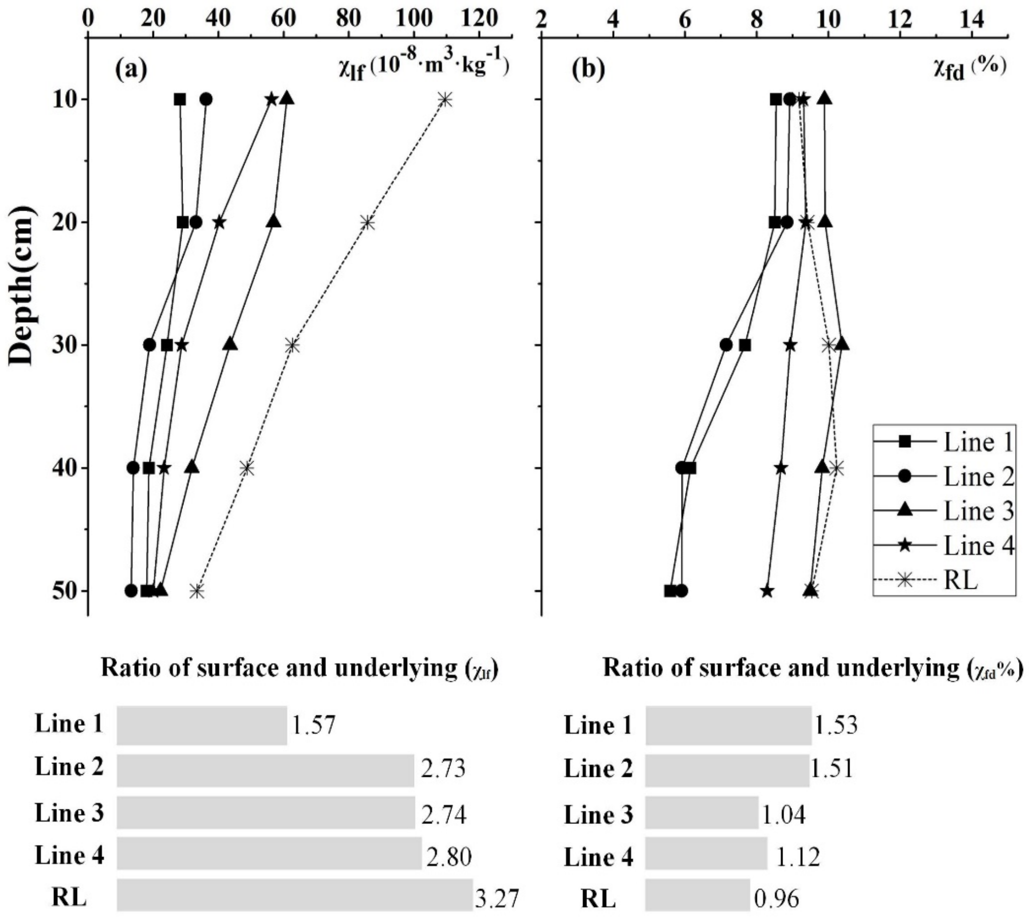

Fig. 10 The (a) χ_{lf} and (b) χ_{fd}% profile (0~50 cm) of different slopes.

3 Our Works

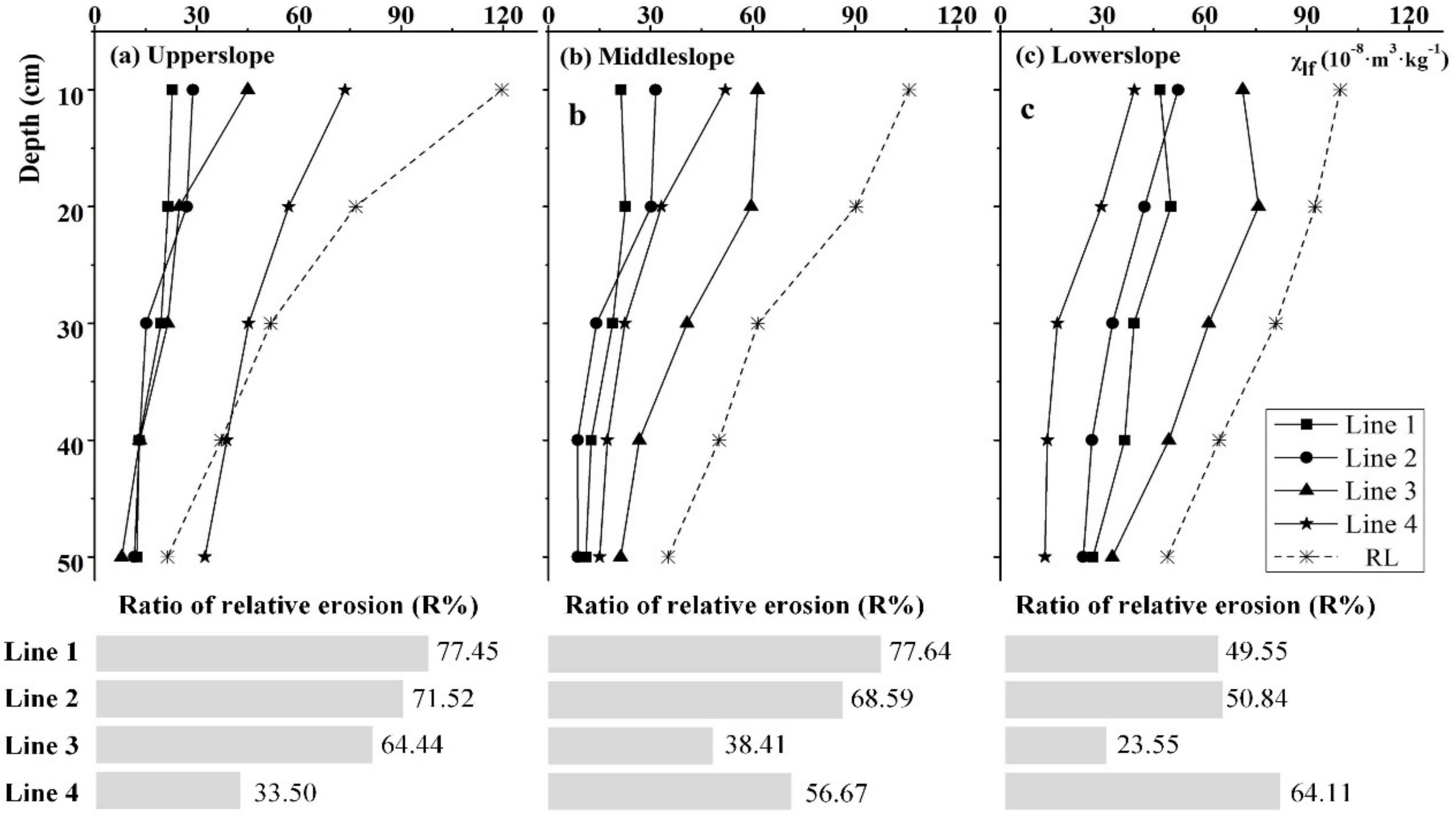

Fig. 11 The χ_{lf} profile at different slopes position.

3 Our Works

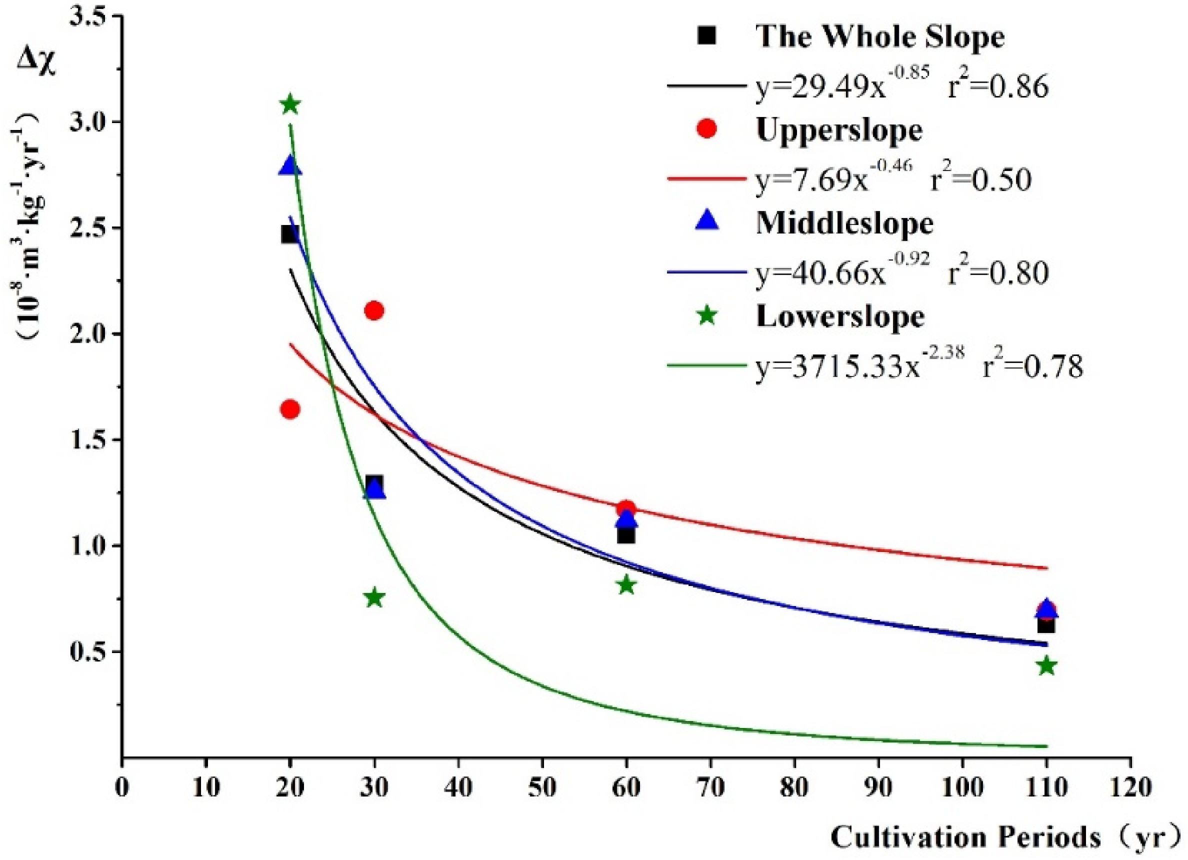

Fig. 12 The relationship of Δχ and cultivation periods.

3 Our Works

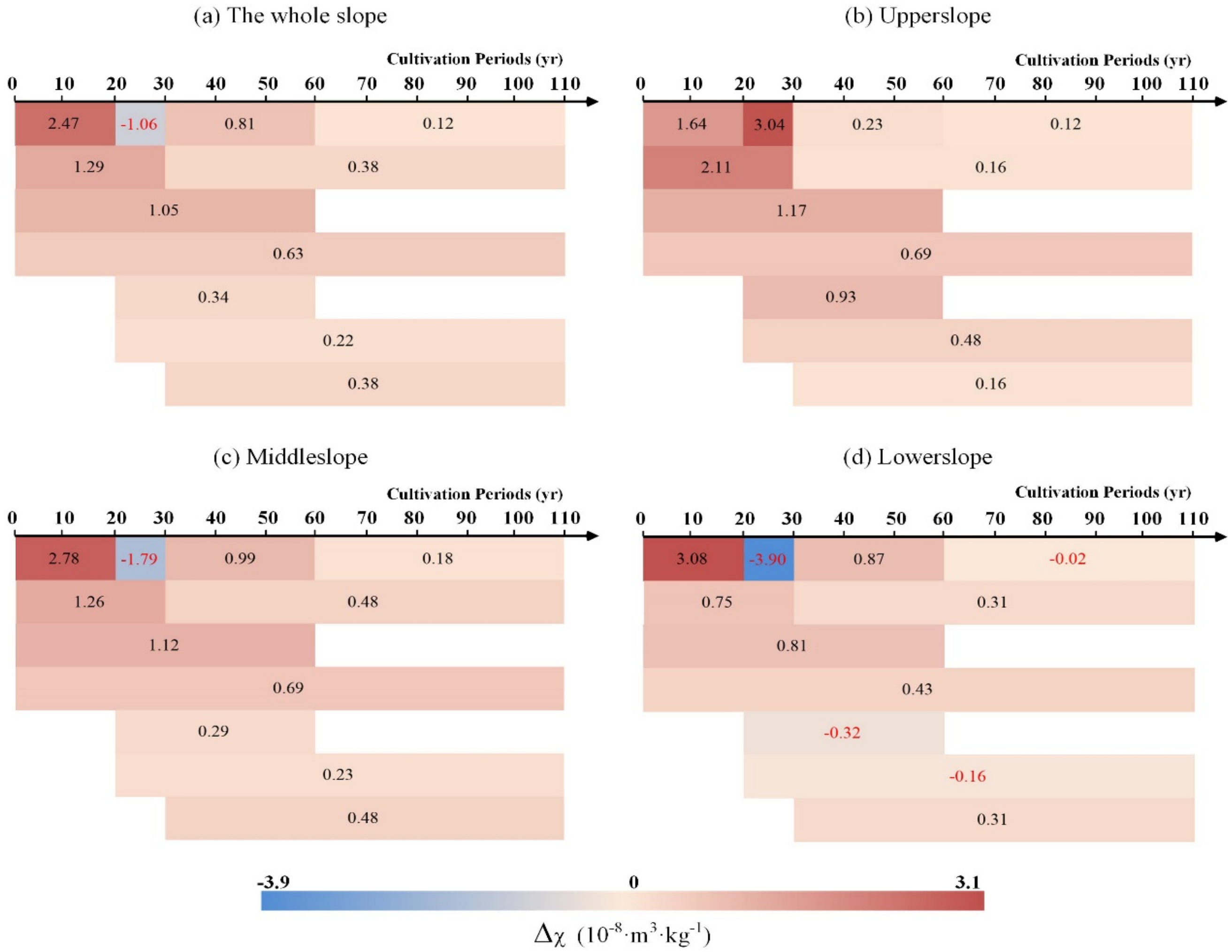

Fig. 13 Magnetic susceptibility Ration ($\Delta\chi_{lf}$) values of plough layer (0~20 cm) across the sampling slope.

3 Our Works

Conclusions

- MS **enhanced** markedly on the **topsoil**, whereas the difference between the topsoil and subsoil became increasingly **slight** with the **increase in cultivation period.**
- The values **increased** gradually from the upperslopes to lowerslopes, and the **longer** the cultivation time, the **larger** the difference between upperslopes and lowerslopes.
- Soil loss has exponent relation to the cultivation periods.
- Farmland in longer cultivation periods was associated with greater soil loss, but soil erosion and deposition tend to be stable for slopes in longer cultivation periods.

4 Prospect

- Quantitative farmland soil loss in different cultivated periods by T-H Model
- Evaluate the accuracy of T-H Model
- Calculate soil erosion in mechanism model

Thanks for Your Attention！