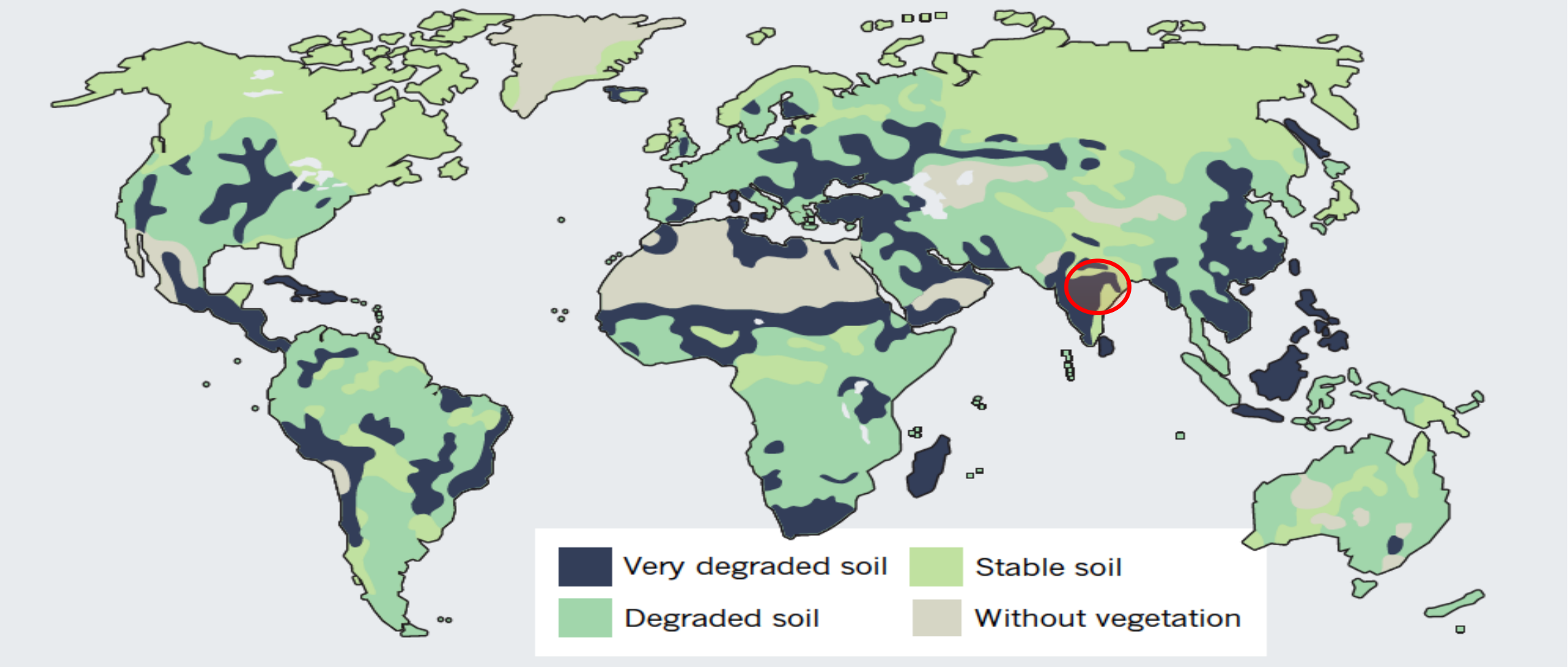
Soil Processes and Ecological Services in the Karst Critical Zone (CZ) of Southwest China

Sophie M. Green, Jenni Dungait, Xinyu Zhang, Tim Barrows, Heather Buss, Taoze Liu, Iain Hartley, Zhaoliang Song, Xuefa Wen, Hongyan Liu, Chenglong Tu, Richard P. Evershed, Penny J. Johnes, Jeroen Meersmans, Dali Guo and Tim Quine

Overview

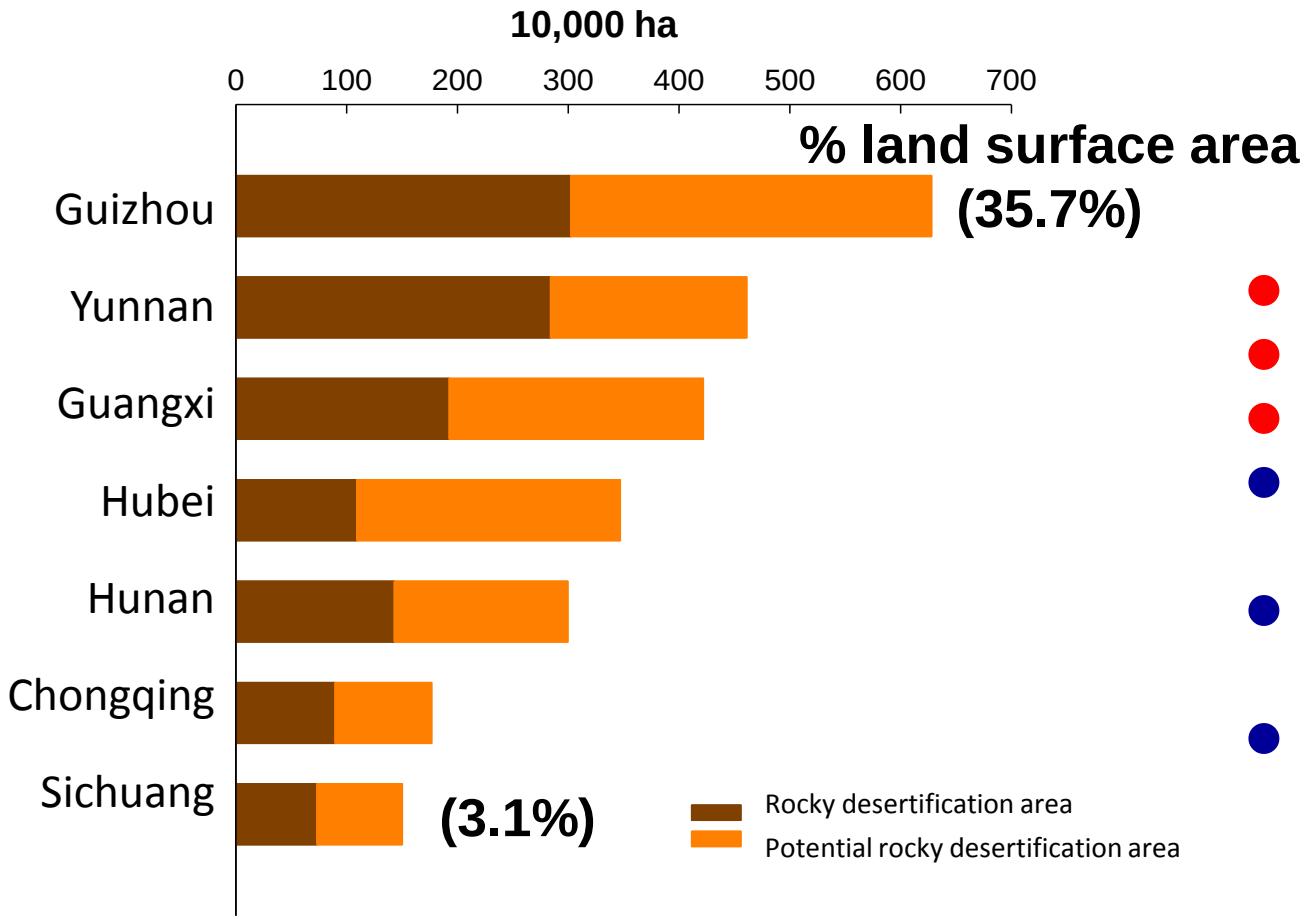
- Karst – A CZO Priority
- Scientific Questions
- Hypotheses
- Objectives
- Sampling site
- Preliminary results
- Next steps

Karst zone - severe soil degradation



Banwart (2011)

Current status of the Karst areas in China



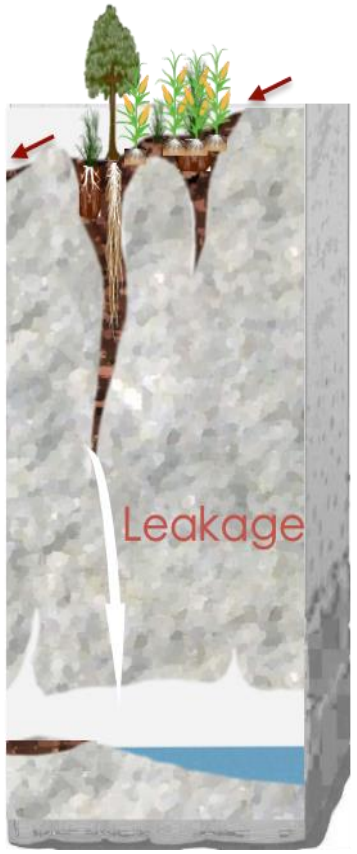
- Soil desertification
- Shallow soil layer
- Rare and scattered arable land
- Uneven distribution of water resources
- Surface water leakage and underground water
- Difficult to utilize water resources

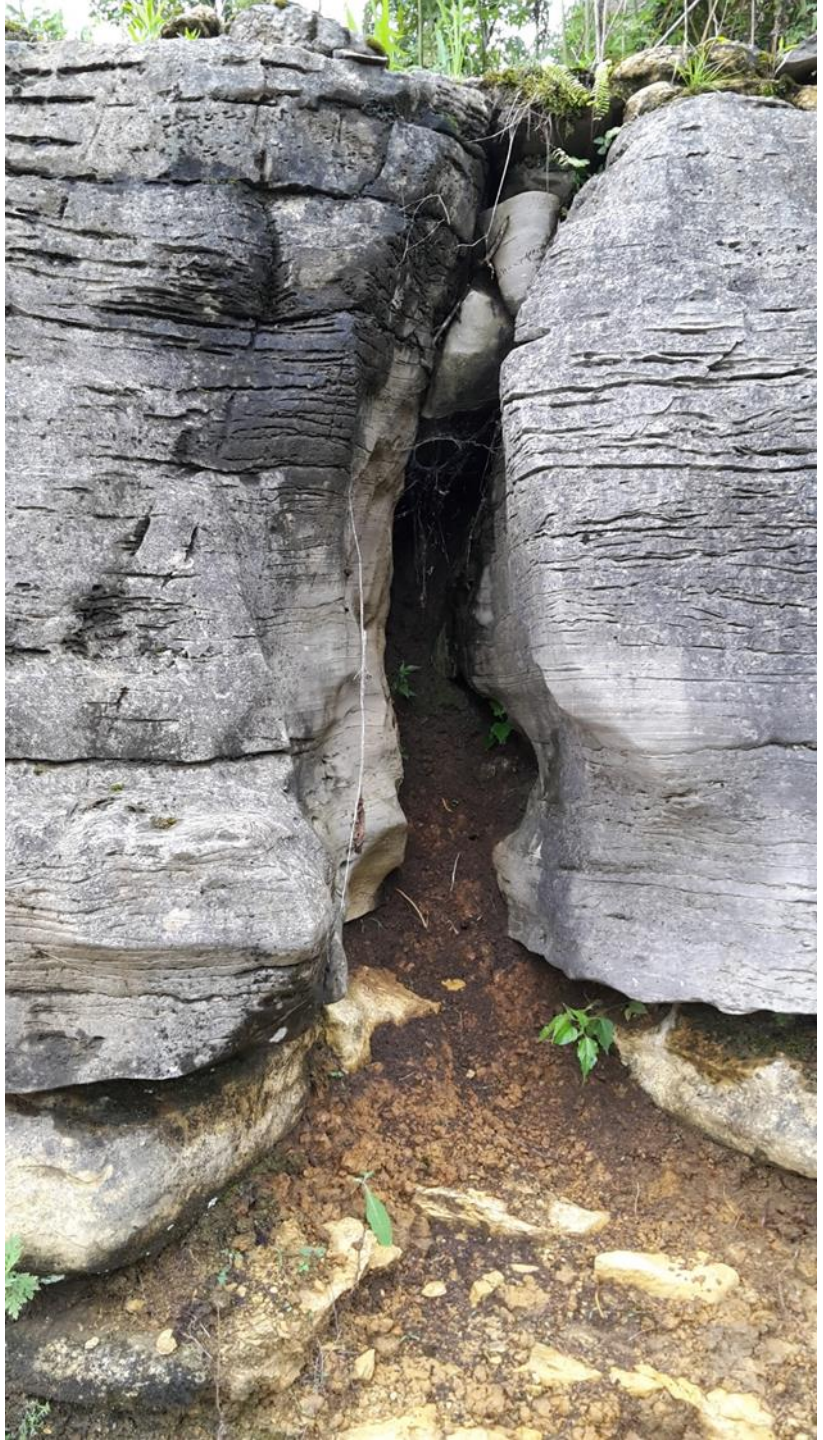
More than 50,000 people live in karst region

State Forestry Administration (2012)

Karst soil

- Highly heterogeneity
- Strong human activity
- Limited soil quantity
- Unique channel structure
- Multi-erosion process
- Complex lithology structure





CZO Scientific questions

- What controls the **resilience**, **response** and **recovery** of the CZ and its integrated geophysical-geochemical-ecological functions to perturbations?
- How can understanding of **interactions** between CZ processes from **molecular** to **catchment scale** be integrated in sustainable watershed management plans?

Giardino & Houser (2015)

Scientific objectives

- Quantification of soil formation, erosion and deposition budgets along the degradation gradient.
- Mechanistic understanding of spatial variation in carbon, nitrogen and phosphorus cycling, and soil function along and within the degradation gradient.
- Improved representation of degraded / transient states in soil and ecosystem models.
- Analysis of the control exercised on ecosystem service delivery and resilience by spatial structure of land use.

Using cutting-edge approaches we will integrate measurements of:

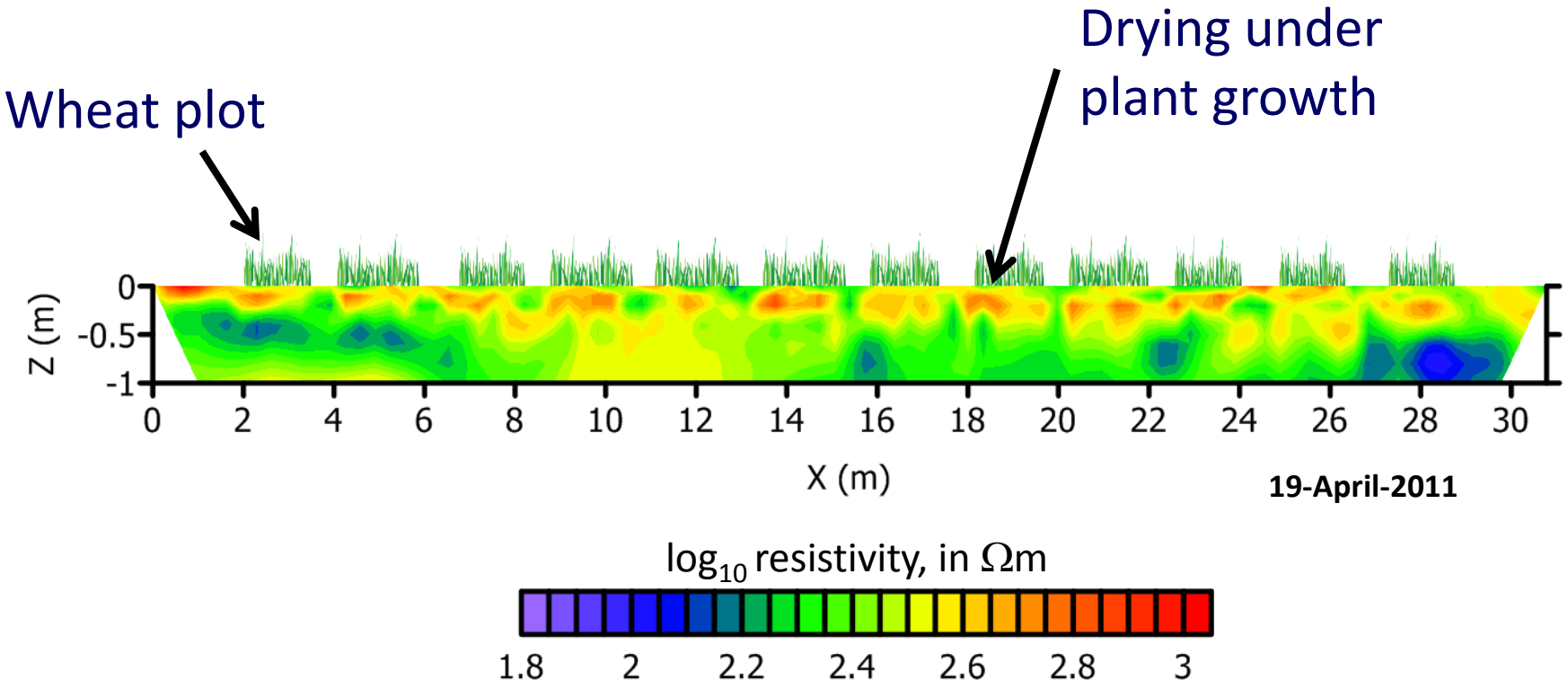
(1) **the three-dimensional distribution of plants (including roots), soil, fungi, and microbes;**

(2) **rates of rock weathering, elemental release and soil formation processes;**

(3) **rates of erosion and soil redistribution; and,**

(4) **pools and fluxes of soil organic C (SOC), nitrogen (N) and phosphorus (P).**

Through explicit consideration of plant-microbe-soil- rock interactions, we will identify the biological controls on nutrient availability, soil formation and loss in the CZ.



Andy Binley, Lancaster Environment Centre, UK

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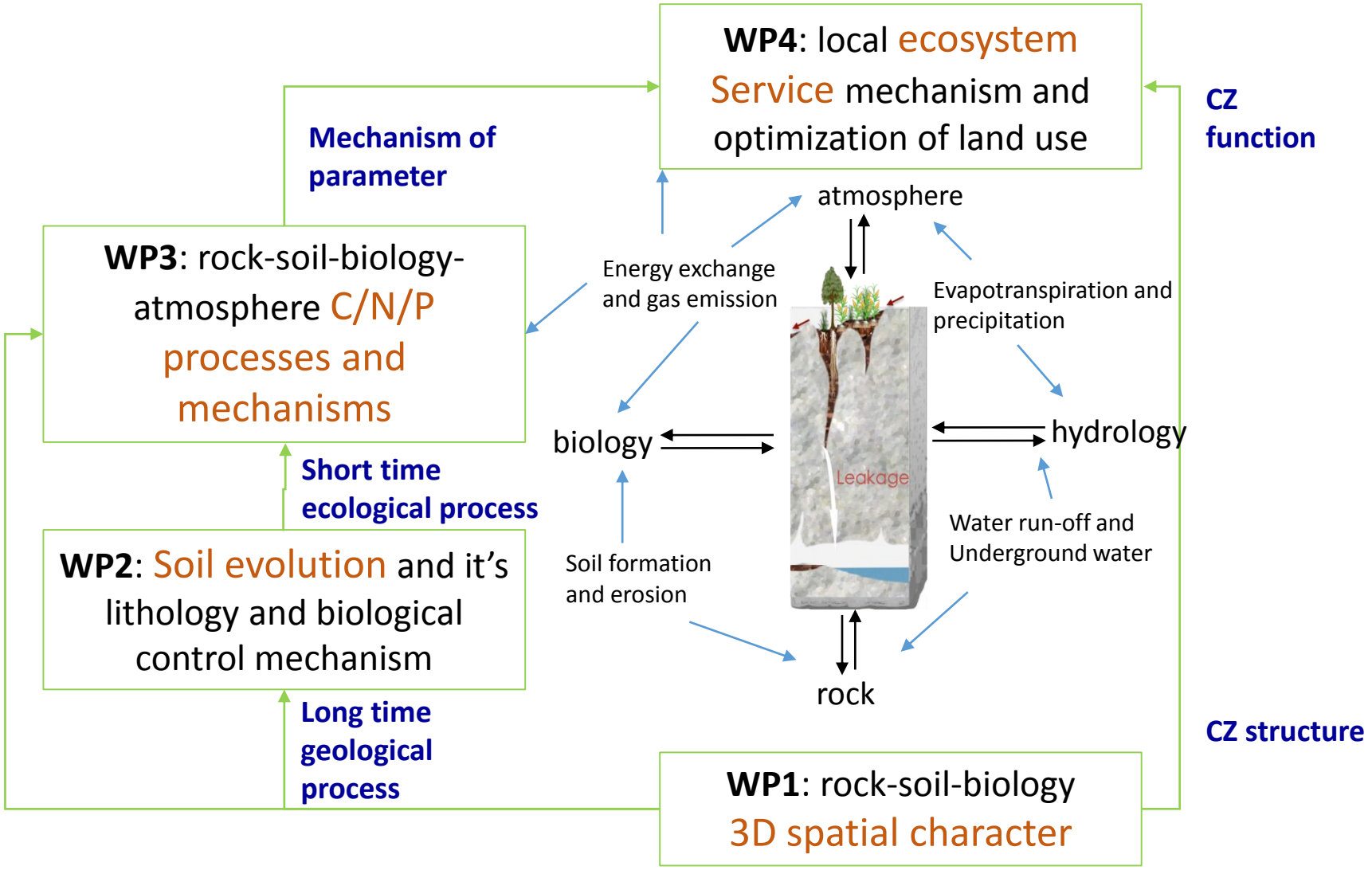
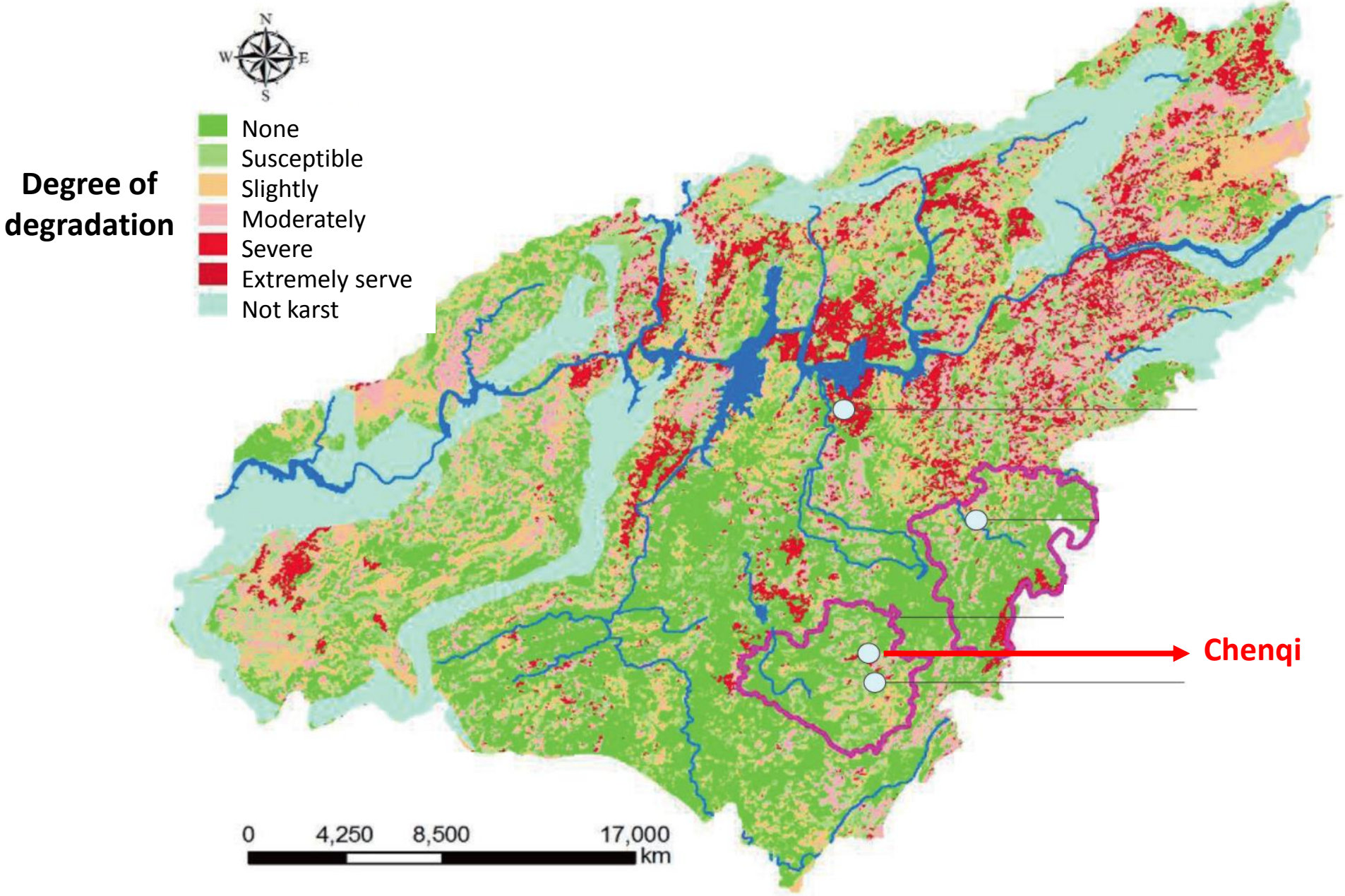
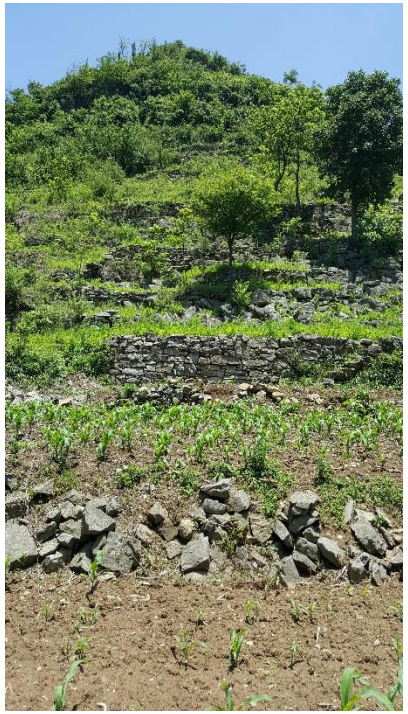
Work packages (WP)

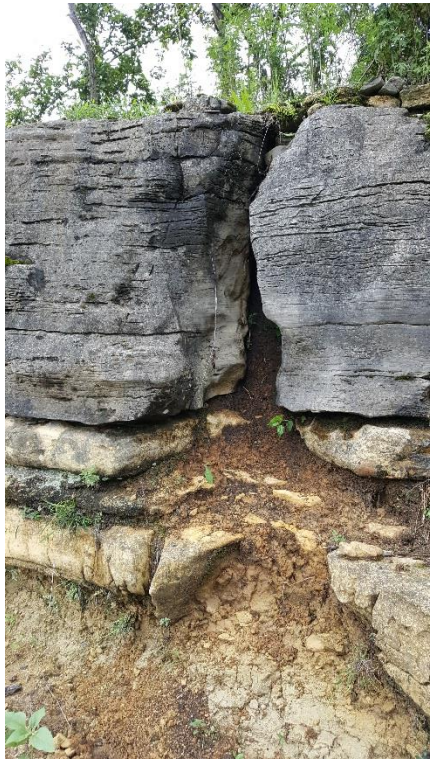


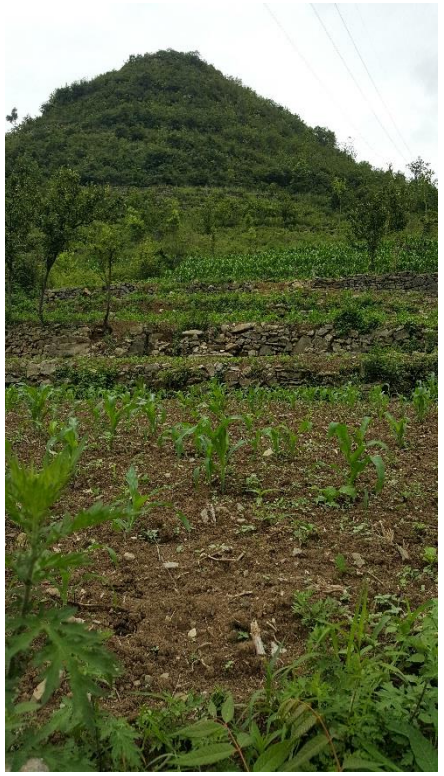
Chenqi catchment

- Located within Puding County (26°15’36”N, 26°15’36”E) in Guizhou Province, Southwest China;
- Catchment area of 1.29 km^2 with a maximum elevation of 1500 m above sea level;
- Dominant geology in this catchment is limestone of the Guanling Formation of the Middle Triassic with marl layers;
- Climate is sub-tropical-monsoonal;
- Agriculture fields are mainly located in the base of the valley as well as on the lower slopes;
- Crops commonly grown are rice, maize, soybeans, peanuts, and rape oil seed in rotation.


Degree of degradation
N
W
E
S
None
Susceptible
Slightly
Moderately
Severe
Extremely serve
Not karst
0
4,250
8,500
17,000
km
Chenqi







What has been done so far?

- The CZO was established in June 2016.
- It spans a perturbation gradient from undisturbed natural vegetation through to intensive human activity (agriculture), classified as 3 levels of perturbation: (A) sloping farmland; (B) recovery phase 1 (recently abandoned < 5 years); and, (C) recovery phase 2 (secondary forest abandoned > 5 years).
- 27 soil pits were dug in June 2016 (three per level of perturbation, at three different elevations).
- 15 rock samples collected;
- Documented land use history of the catchment.

Analyses - 2016

Soil physical and chemical properties:

Bulk density, pH, soil water content, total organic carbon, total inorganic carbon, total nitrogen, total phosphorus, dissolved organic carbon, available inorganic phosphorus, microbial P, available ammonium, available nitrate, ^{137}Cs, ^{210}Pb and ^{10}Be.

Soil enzyme activity:

Peroxidase, Phenol oxidase, β-1,4-glucosidase, α-1,4-glucosidase, cellobiohydrolase, β-1,4-N-acetylglucosaminidase, acid phosphatase.

Soil nitrogen Functional genes:

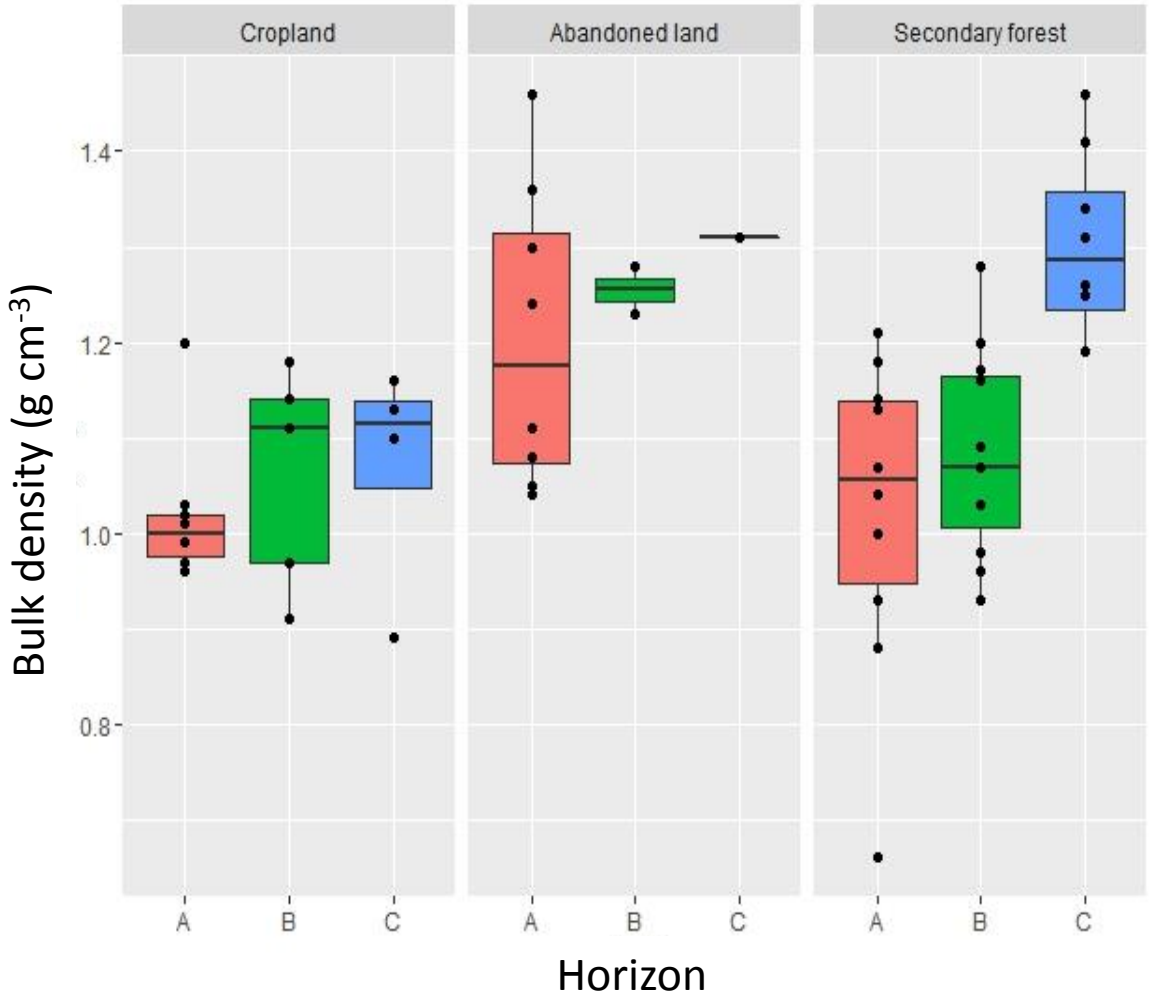
Nitrogen mineralization genes (chiA), nitrogen fixation genes (nifH), ammonium oxidization genes (AOA and AOB amoA), nitrate denitrification genes (nirK and nirS).

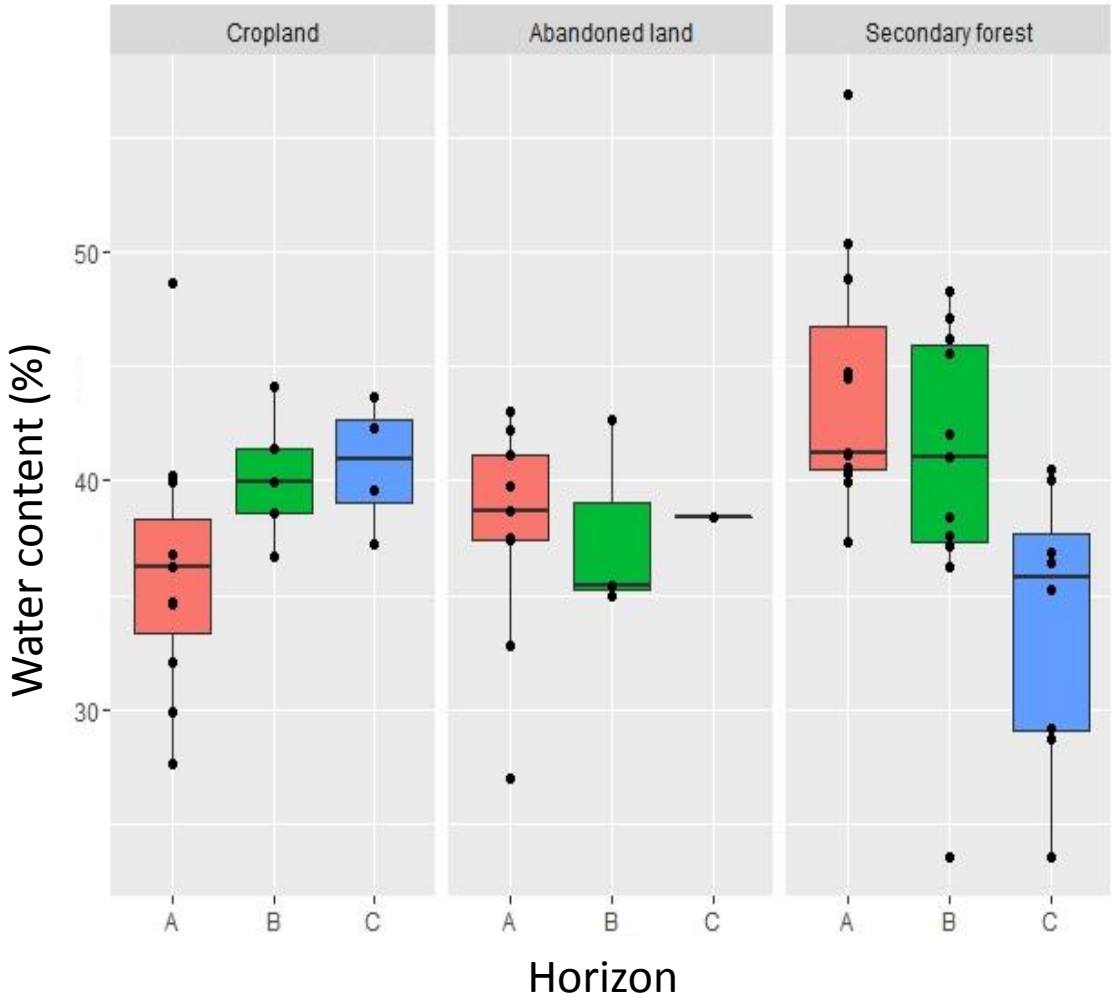
Soil microbial community:

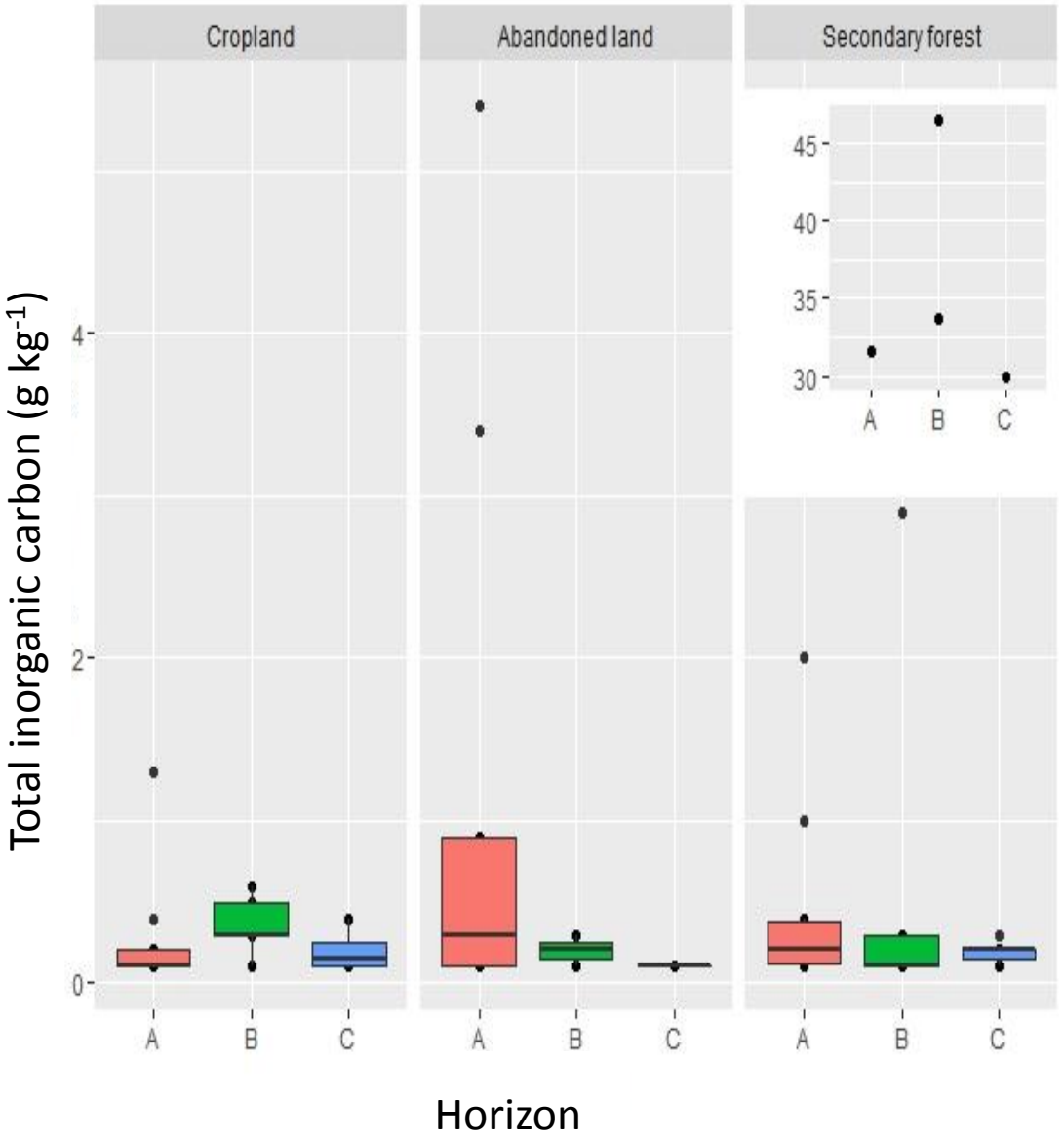
PLFA's, GDGT's and amino sugars.

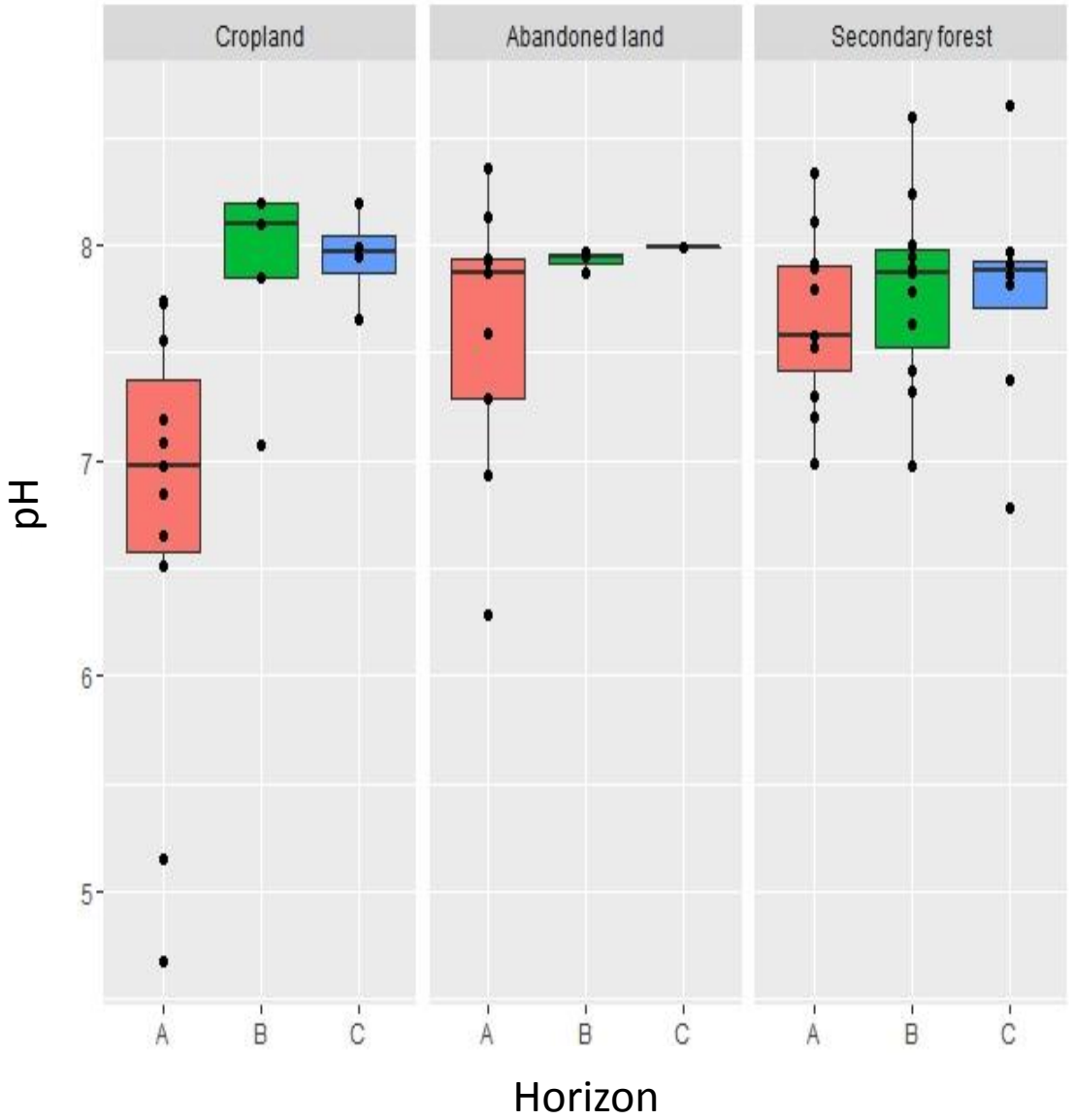
Rock samples:

^{10}Be and ^{36}Cl, scanning electron microscopy and electron probe micro-analysis.


Cropland
Abandoned land
Secondary forest
Bulk density (g cm-3)
1.4
1.2
1.0
0.8
A
B
C
Horizon


Cropland
Abandoned land
Secondary forest
Water content (%)
50
40
30
A
B
C
Horizon


Cropland
Abandoned land
Secondary forest
Total inorganic carbon (g kg-1)
0
2
4
30
35
40
45
A
B
C
Horizon


Cropland
Abandoned land
Secondary forest
pH
5
6
7
8
A
B
C
Horizon

Next steps - 2017

Field

- Geophysical survey (ERT – 3D models);
- Lysimeter installation (weathering fluxes);
- Installation of different-sized mesh columns containing two varieties of carbonate rock with differing proportions of silicate mineral and associated respiration collars (investigation into whether roots and mycorrhizal fungi can selectively mine carbonate rocks to access nutrient-rich zones);
- Coupled soil and vegetation sampling.

Laboratory

- Quantifying biological N-fixation in soils using a new ^{15}N stable isotope probing technique;
- Assessing P sources, mobilisation and availability in karst soils (a sequence of replicated laboratory microcosm experiments will be set up to investigate the rates of P dissolution in rock, gravel, and soil samples in response to water residence time, N fixation rate and temperature).

Socio-economic benefit objectives

- Scientific basis for land management decisions;
- Development of sustainable land management for karst landscapes;
- Karst CZO assessment and prediction;
- Knowledge basis for soil management, ecosystem service delivery, and regional planning;
- Improved ecological service delivery from the agro-ecosystem;
- Societal, economic and industrial engagement.

NERC-NEWTON-NSFC Programme

- **Quine/Guo** - SPECTRA: Soil Processes and Ecological Services in the Karst Critical Zone of Southwest China.
- **Waldron/Chen** - The transmissive critical zone: understanding the karst hydrology-biogeochemical interface for sustainable management.
- **Wu/Shao** - Modelling and managing critical zone relationships between soil, water and ecosystem processes across the Loess Plateau.
- **Banwart/Zhu** - Using Critical Zone Science to Enhance Soil Fertility and Improve Ecosystem Services for Peri- Urban Agriculture in China.
- **Hallett/Zhang** - Red Soil CZ: From natural to anthropogenic evolution of Red Soil and its impact on ecosystem function in the Critical Zone.