How far away are we from controlling the global soil erosion below the soil loss tolerance?

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1. Background

Soil resources are an important material basis for human survival and development, and the most basic material conditions for agricultural production. The exploitation of resources by humans has caused serious soil degradation. Soil erosion is one of the most common and important driving factors.

Harm of soil erosion

1. **Destroy the land and reduce soil fertility**
2. **Reduce the water holding capacity of farmland**
3. **Cause water quality to deteriorate**
4. **Affect the sustainable development of economy and society**

1. Background

Soil and water conservation measures

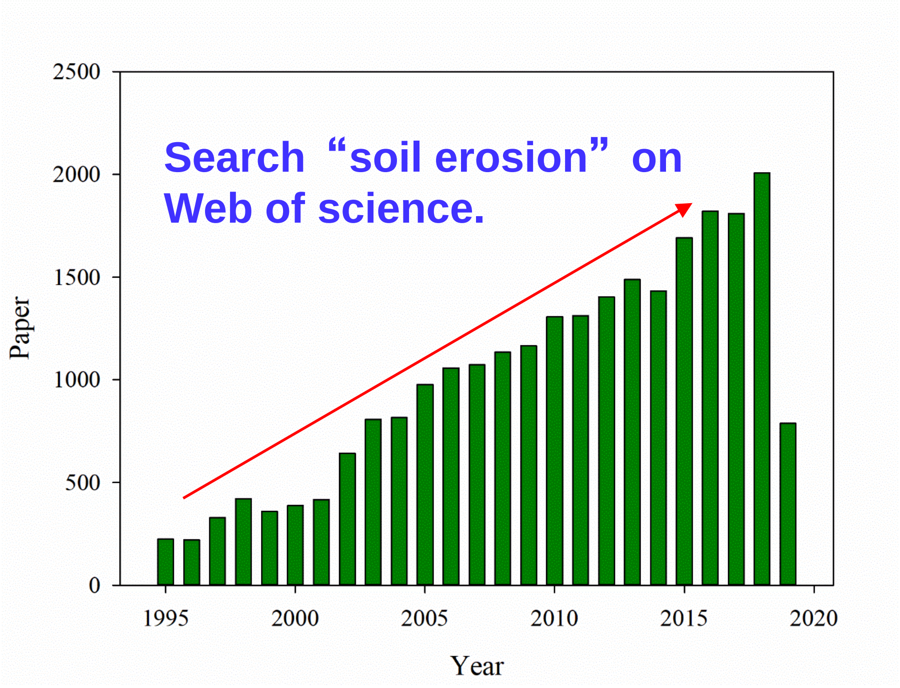
1. Background

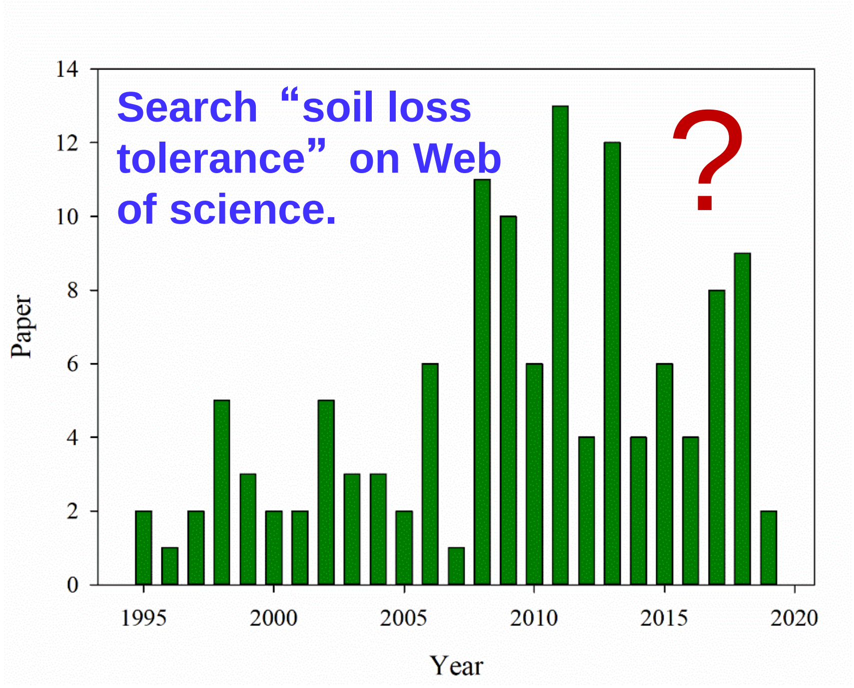
How many soil erosion be controlled is suitable?

Soil loss tolerance is defined as the amount of soil that can be lost without reducing fertility, thereby maintaining the soil with a certain crop productivity (Smith, 1941).

Maximum soil loss that does not reduce soil productivity	**Browning et al. (1947)**
Maximum level of soil erosion that allows high levels of crop productivity to sustain economically and indefinitely	**Wischmeier and Smith (1978)**
The largest surface soil erosion that can provide high productivity and fertility for a long time	**Patsukevich et al. (1997)**
Soil erosion amount when the mother rock is weathered into soil	**Roose (1996)**
Soil erosion when soil productivity is not reduced	**Roose (1996)**
Maximum soil loss not greater than the rate of soil formation	**Boardman and Poesen (2006)**
Soil fertility can maintain the maximum allowable soil erosion rate of 20-25 years	**Morgan (2005)**
Maximum average annual soil loss that allows for continuous planting and maintaining soil productivity without additional management inputs	**SSSA (2001)**

1. Background





Articles about "soil erosion" are increasing year by year, while articles about "soil loss tolerance" are few and the increasing trend is not obvious.

1. Background

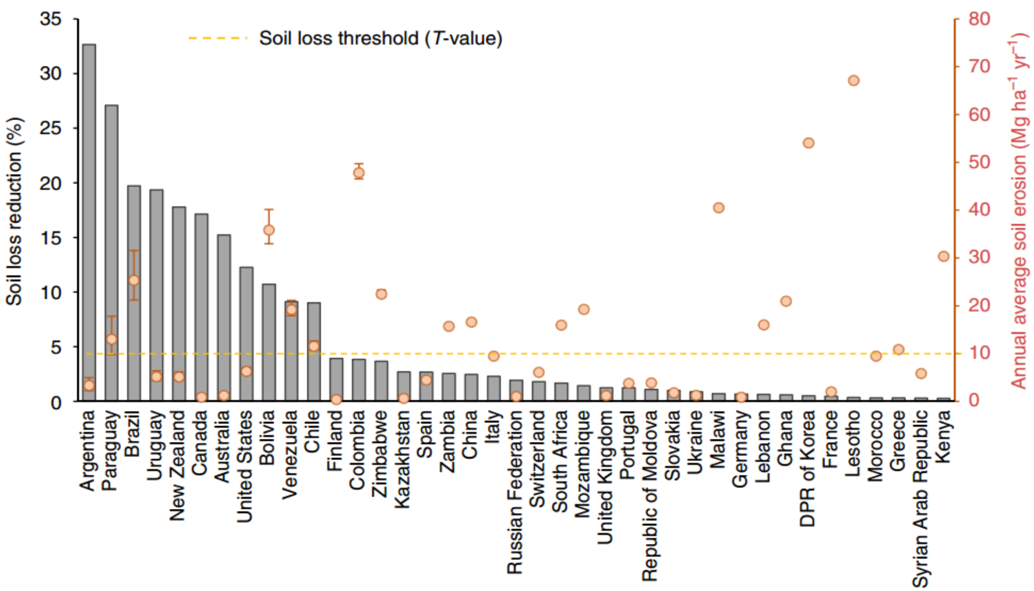
nature COMMUNICATIONS

ARTICLE

DOI: 10.1038/s41467-017-02142-7 OPEN

An assessment of the global impact of 21st century land use change on soil erosion

Pasquale Borrelli[1,2], David A. Robinson[3], Larissa R. Fleischer[4], Emanuele Lugato[2], Cristiano Ballabio[2], Christine Alewell[1], Katrin Meusburger[1], Sirio Modugno[5], Brigitta Schütt[6], Vito Ferro[7], Vincenzo Bagarello[8], Kristof Van Oost[9], Luca Montanarella[2] & Panos Panagos[2]



line 90. I am willing to bet this is re-cycled from Pimental or GLASOD.

line 91. Therefore I don't think these are 'succeeding studies'

line 100. The references are to forests

line 114. Note the emphasis is on rainfall intensity again!

Line 119. I think the basic cell size in 5 ha...rather large to be averaging across!

Line 126. Where are these 'empirical observations' they are using?

line 147. T values have been discredited as a political tool with no scientific basis

line 171. What does it mean 'Classified...'?

line 199. Average cropland erosion rate (12) is ridiculously high

line 228. Conservation agriculture covers great variety of measures...very dodgy data

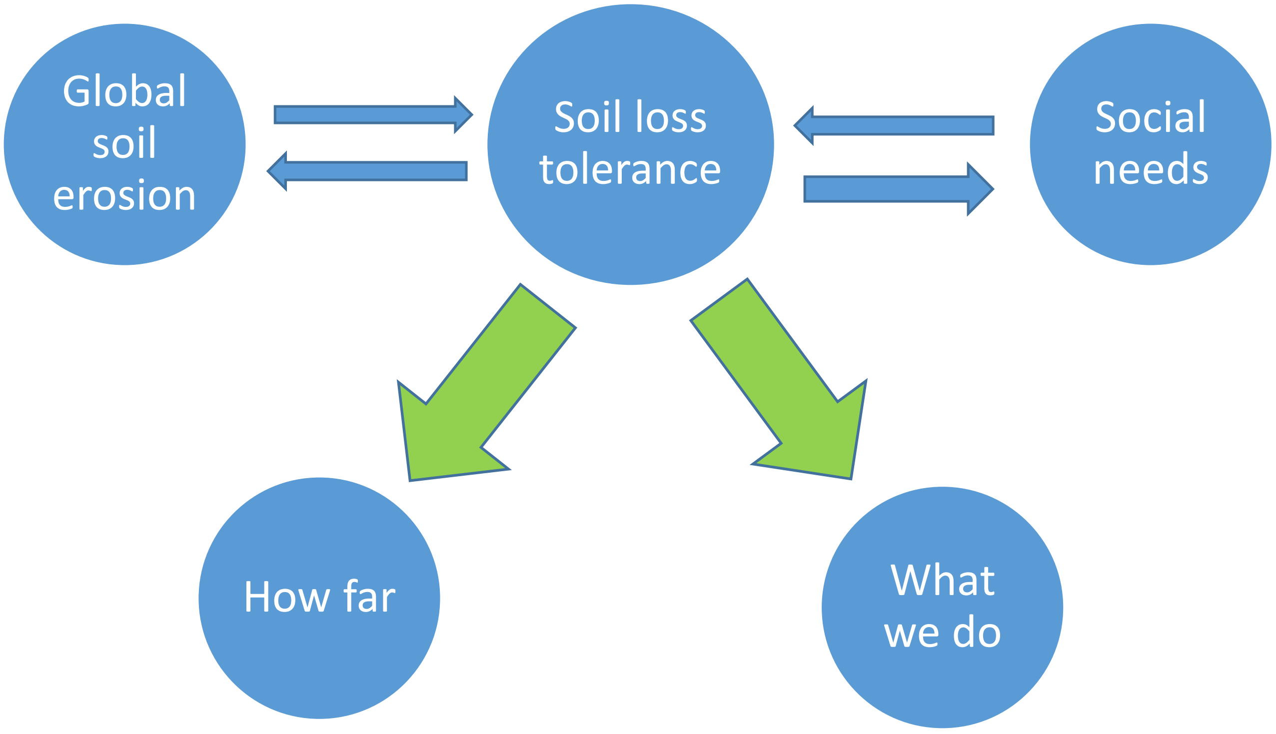
line 293. 'Most cited estimate is by Pimental et al.' This was conclusively shown to be very bad science and probably an order of magnitude too high (Boardman 1998, Journal of Soil & Water

By: John Boardman
Environmental Change Institute
University of Oxford

As the boundaries between natural science and social science become increasingly blurred, soil loss tolerance can be considered as a bridge linking soil erosion research and social demand

1. Background

Aim of this study：



2. Materials and Methods

2.1 RUSLE Model

$$A = R \times K \times L \times S \times C \times P$$

A**—— soil erosion rate (Mg ha^{-1}·yr^{-1})；**

R **——Rainfall erosivity factor (MJ·mm·ha^{-1}·h^{-1}·yr^{-1})；**

K**——Soil erodibility factor (Mg·ha·h·MJ^{-1}·ha^{-1}·mm^{-1})；**

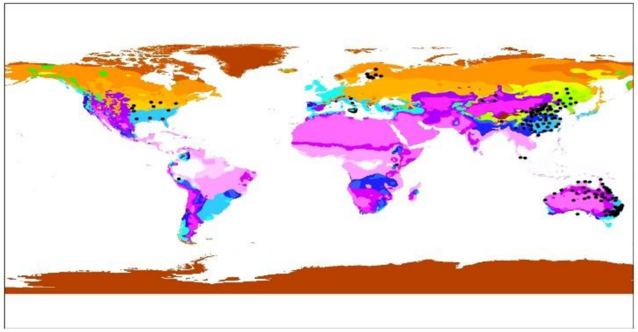
LS**——Slope length and slope gradient factor；**

C**——Crop cover and management factor,**

P**——Soil and water conservation project factor ,**

2. Materials and Methods

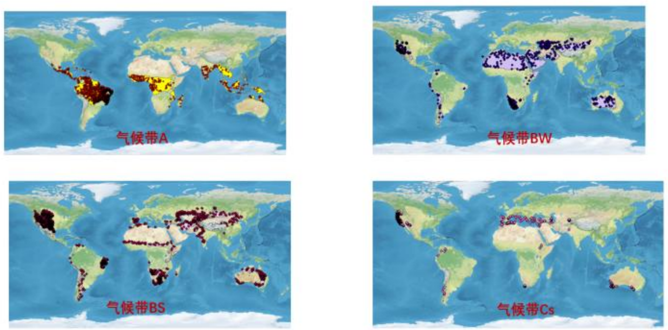
R:

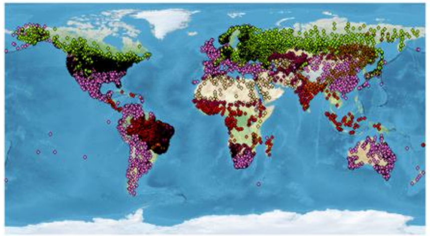


气候带	b	a	a'/a
A	b=1.694+0.013*latitude	Log a=2.363-1.561*b	1.59-0.04*latitude
BS	1.73	Log a=1.85-1.348*b	没有明显关系，最终取值0.3296
BW	1.514	Log a=1.781-1.341*b	2.123-0.04*latitude
Cs	1.563	Log a=1.669-1.428*b	没有明显关系，最终取值0.2735
Cw	1.558	Log a=2.935-1.94*b	没有明显关系，最终取值0.817
Cf	1.5	Log a=3.016-2.079*b	-0.012*longitude-0.037*latitude+3.792
Df	b=2.243-0.008*latitude	Log a=9.458-5.236*b	0.028*longitude-0.588
Dw	1.466	Log a=2.637-1.735*b	没有明显关系，最终取值1.24

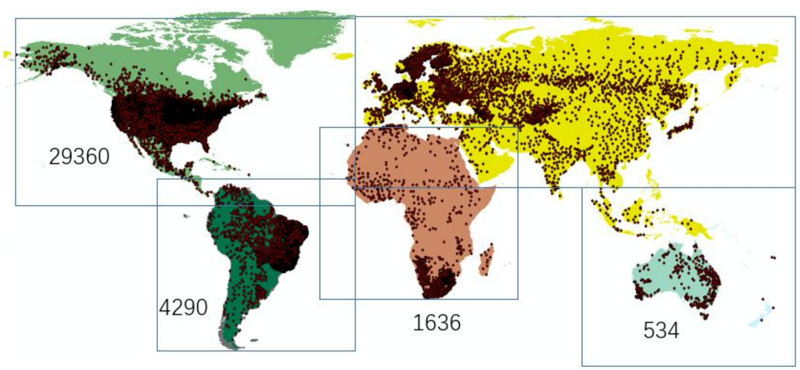
1.The relationship between R and daily rainfall :R=α*p^β. We got 253 α and β from published papers.

2. Constructed 8 climate zone formulas



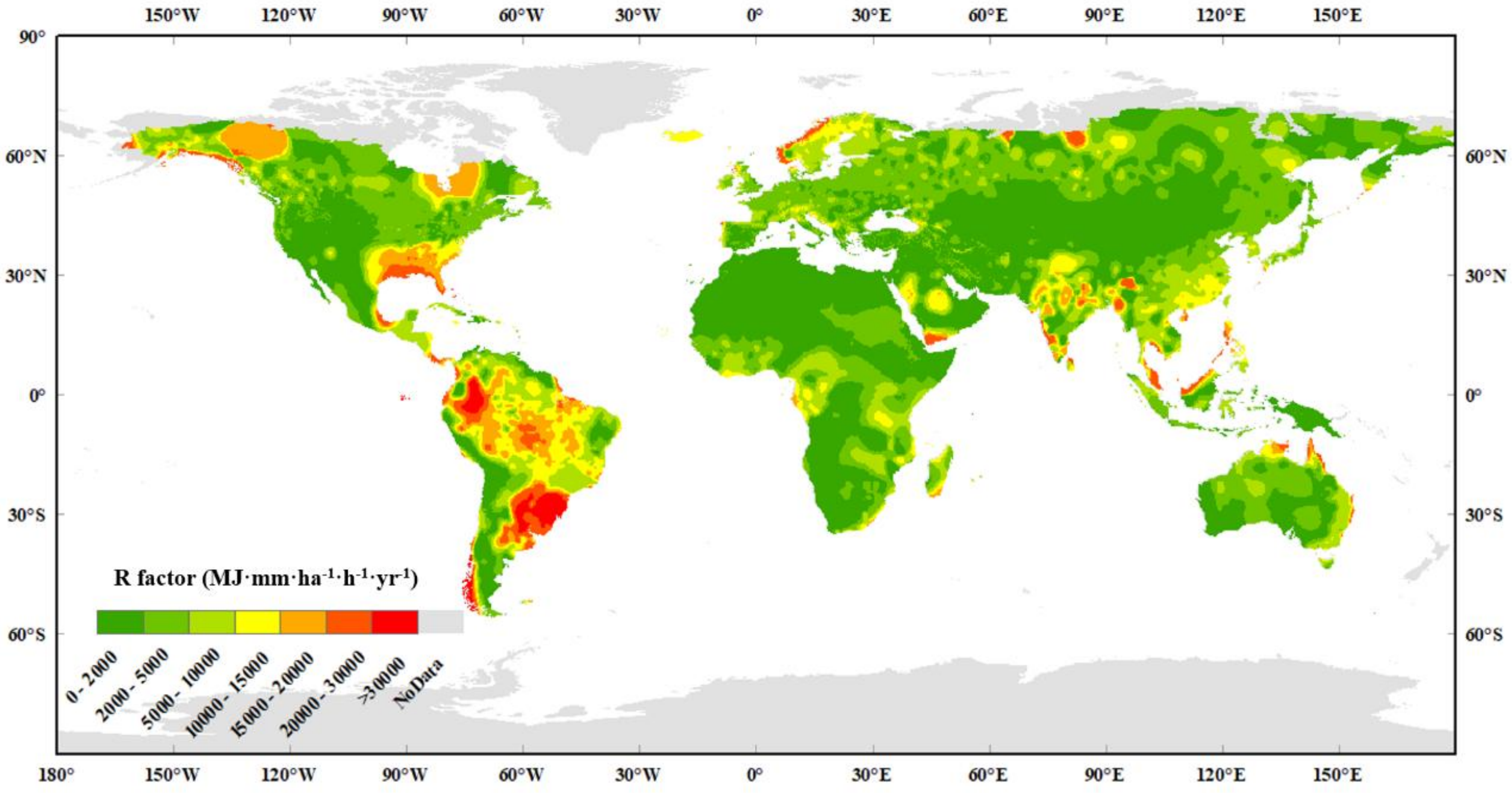


3.Calculate base on Keben climate zone



4.Interpolation to get the global R factor

2. Materials and Methods



Global 37-year average R factor（1980-2017）

2. Materials and Methods

K: EPIC Model (Sharpley and Williams, 1990)

$$K = \left\{0.2 + 0.3 * exp\left[-0.0256 * SAN\left(1 - \frac{SIL}{100}\right)\right]\right\} * \left(\frac{SIL}{CLA + SIL}\right)^{0.3} * \left(1 - \frac{0.25 * C}{C + exp(3.72 - 2.95 * C)}\right) * \left(1 - \frac{0.7 * SN1}{SN1 + exp(-5.51 + 22.9 * SN1)}\right)$$

SAN: Percentage of sand content;

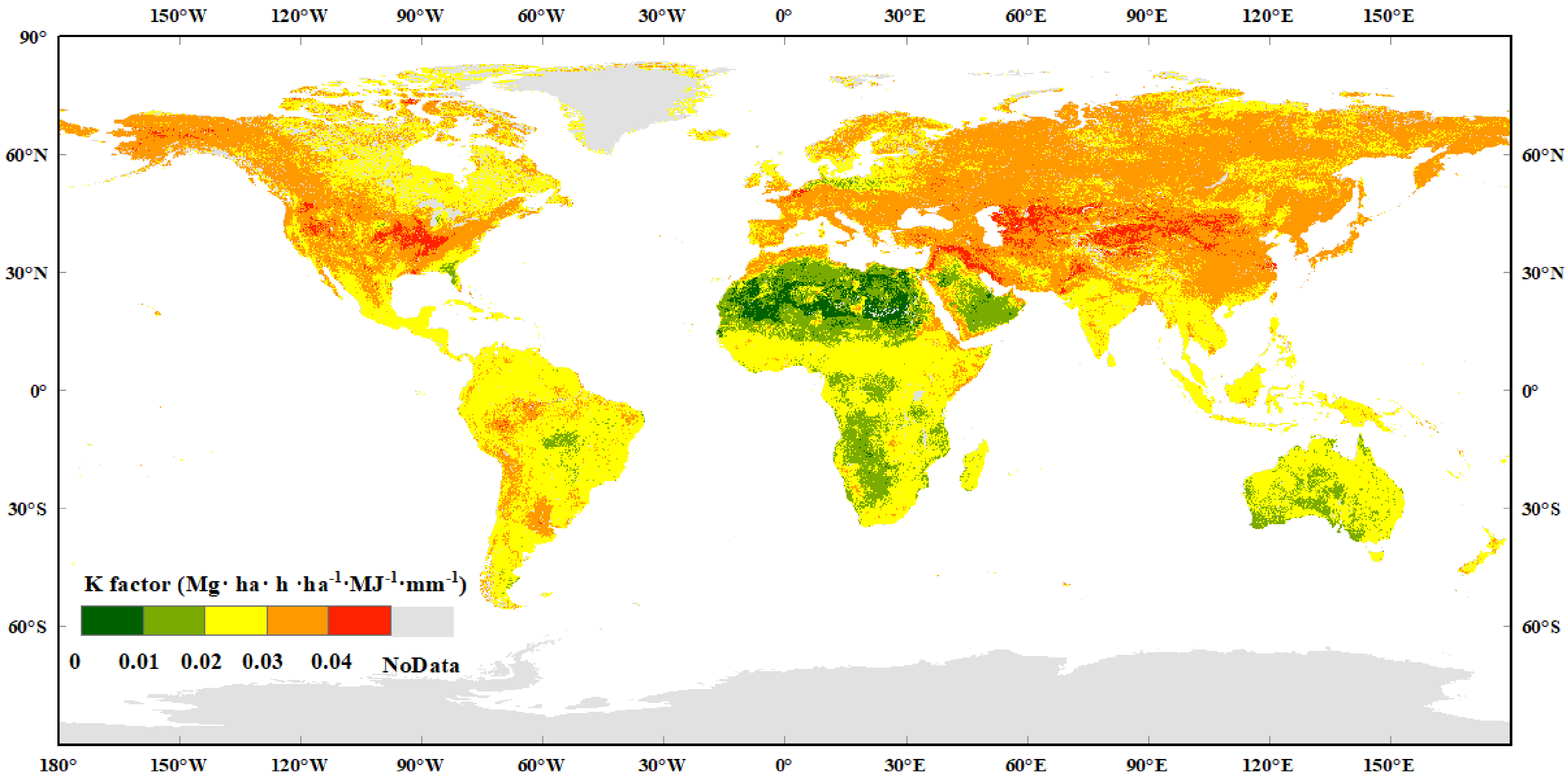
SIL: Percentage of silt content;

CLA: Percentage of clay content ;

C: percentage of organic carbon content;

SN1=1 - SAN/100。

2. Materials and Methods



Global K factor

2. Materials and Methods

LS: based on Wischmeier and Smith, 1978

$$L = (\gamma/22.3)^m$$

$$m = \beta(1+\beta)$$

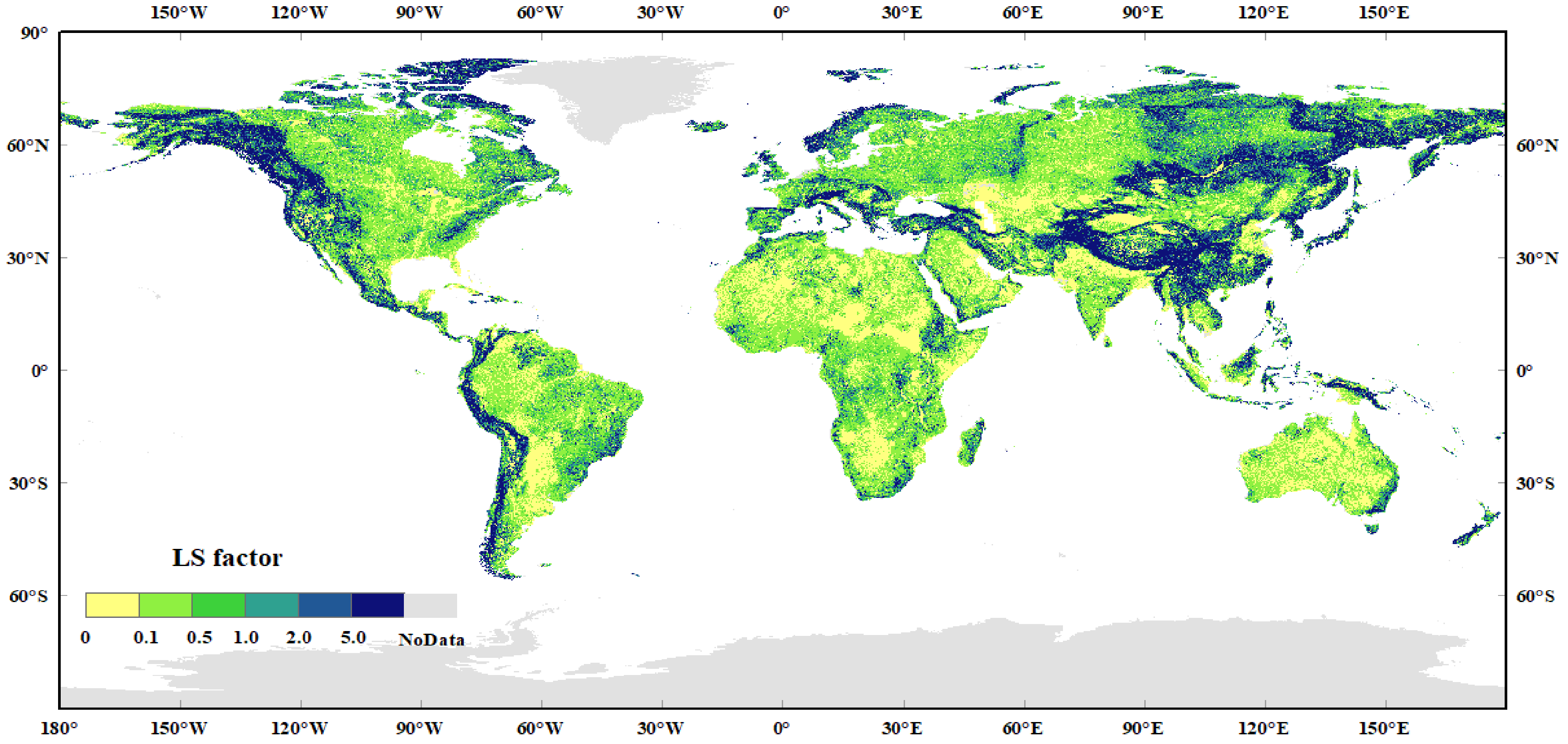
$$\beta = \left(\sin\frac{\theta}{0.0896}\right)/[3.0 * (\sin\theta)^{0.8} + 0.56]$$

$$S = 65.41 * \sin^2\theta + 4.56 * \sin\theta + 0.065$$

Λ is the grid unit horizontal projection length (m); m is slope length；

β is the ratio of rill erosion and rill erosion; θ is the slope of DEM extraction。

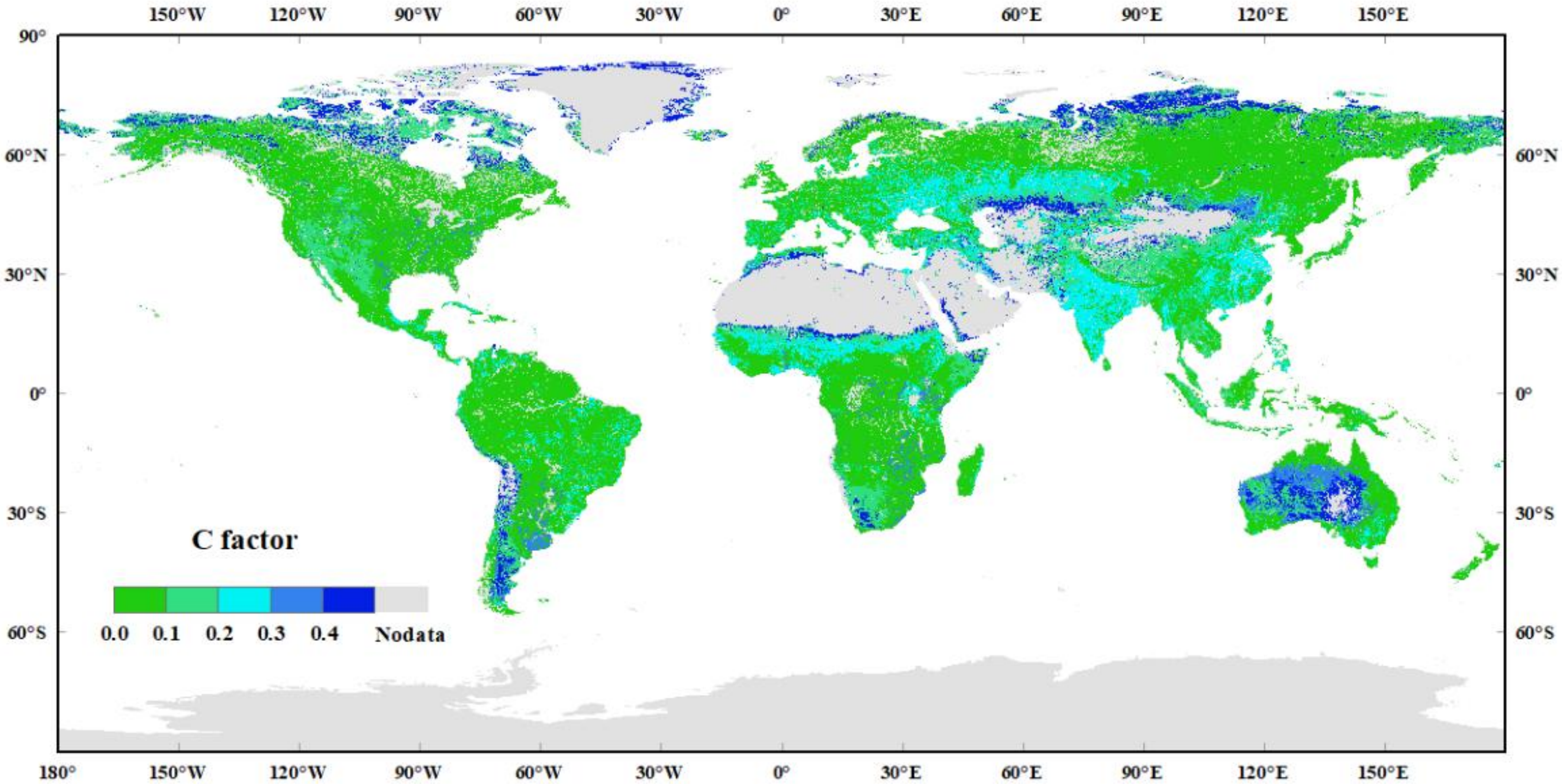
2. Materials and Methods



SRTM V4.1 (90 m) http://www.gscloud.cn

2. Materials and Methods

C: Use the method of Borrelli et al., 2017. in Nature Communications



Global C factor in 2015

2. Materials and Methods

Calculating global T value by soil productivity method

Basic idea: The productivity reduction in the next 100-500 years does not exceed 5% in line with the sustainable goal of soil productivity (Benson et al., 1998)。

$$T = \frac{\Delta\, MPI\%}{t} \times \frac{MPI_0 \times W}{V} \qquad V = \frac{MPI_d - MPI_0}{d}$$

T: Soil loss tolerance (t/km^2×a);

ΔMPI/t: The reduction in the productivity index that can be accepted during the planning period, this study takes 5%;

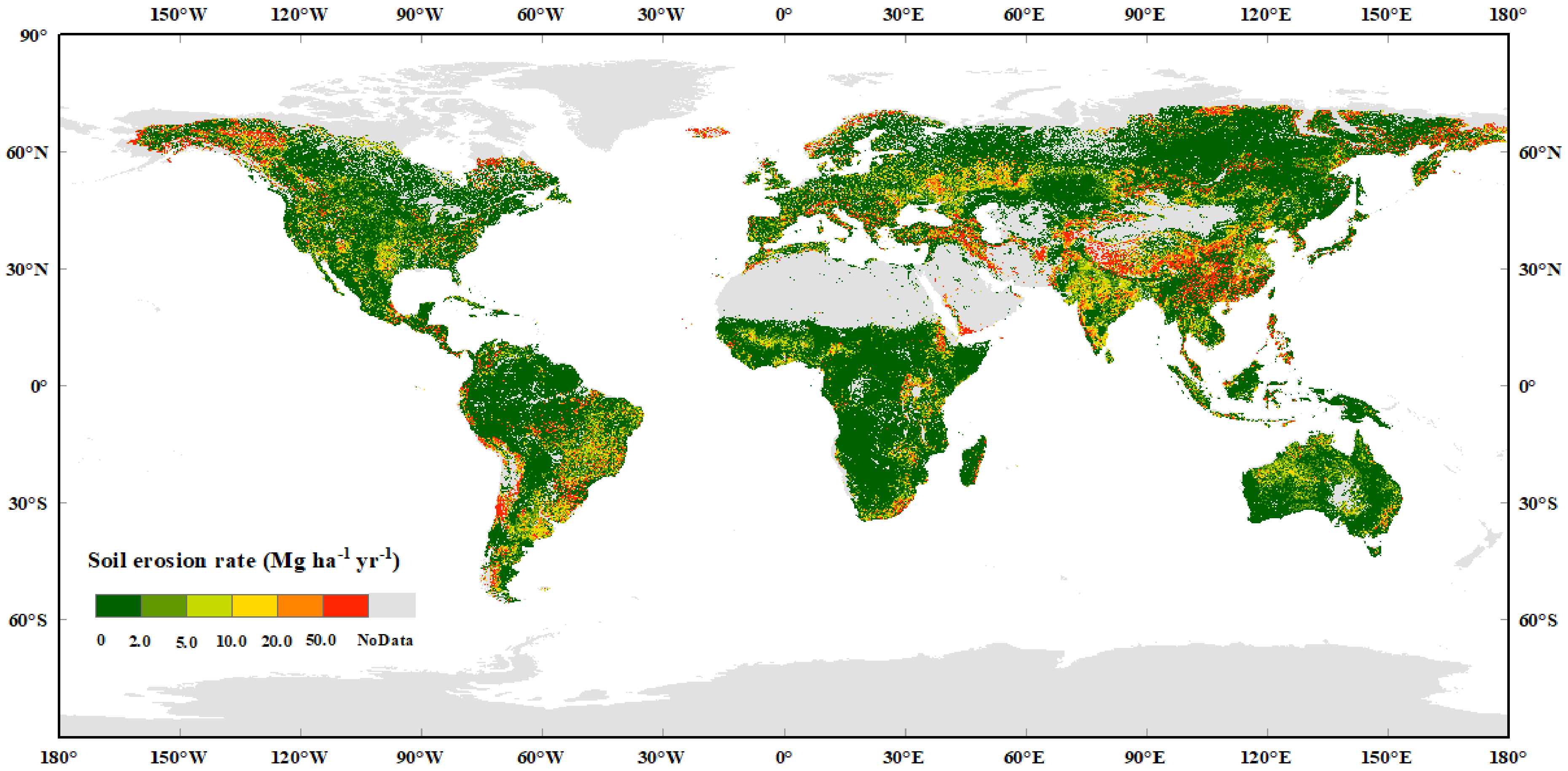
W: Soil weight unit area unit thickness

MPI_0: Current productivity index (0-1);

V: Soil erosion vulnerability index (cm^{-1});

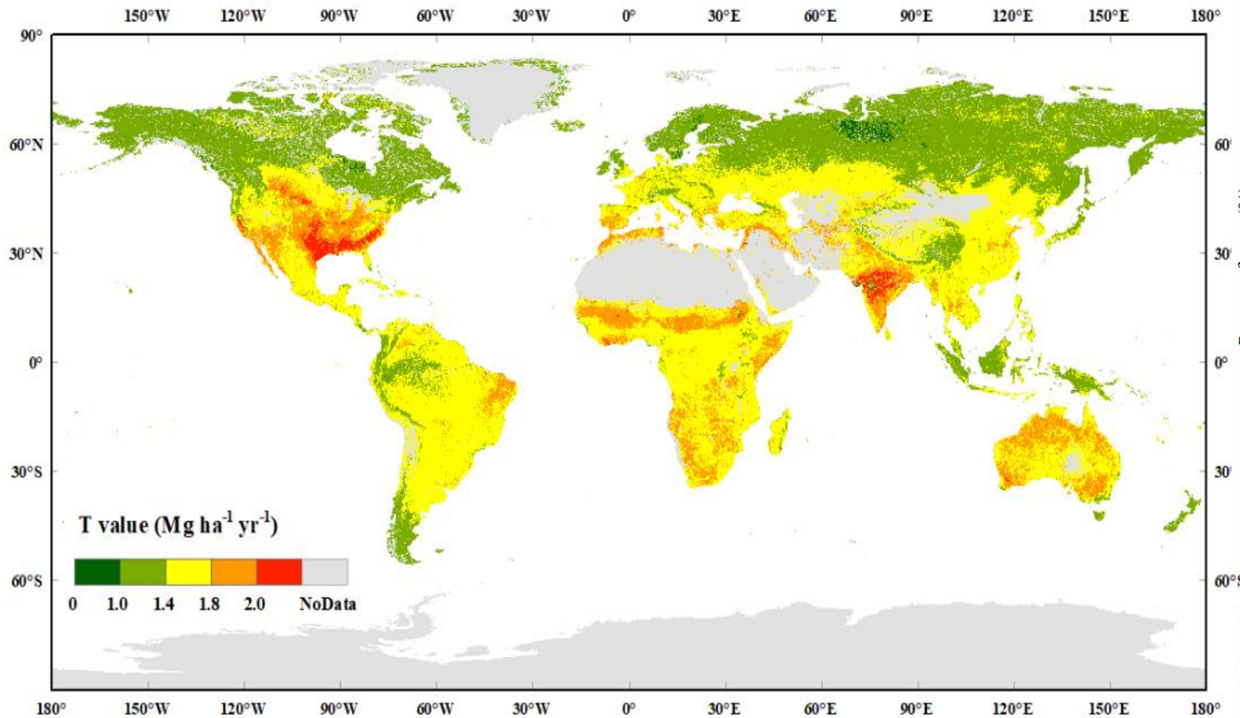
MPI_d: Productivity index after erosion of d cm surface soil.

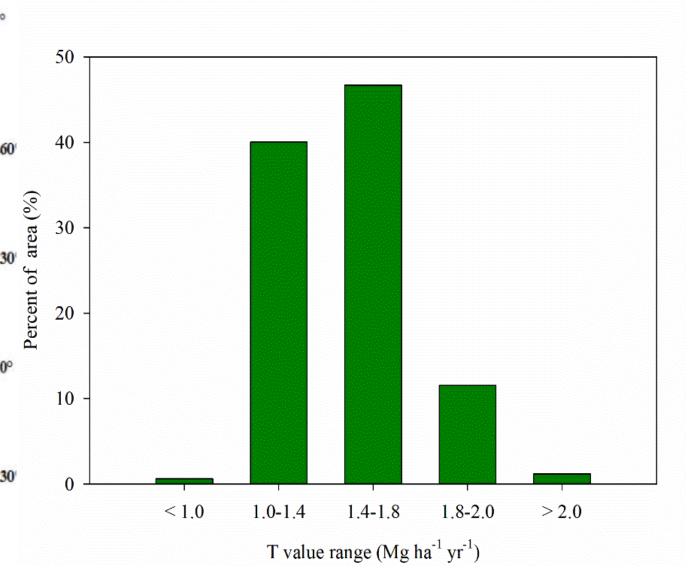
3. Results



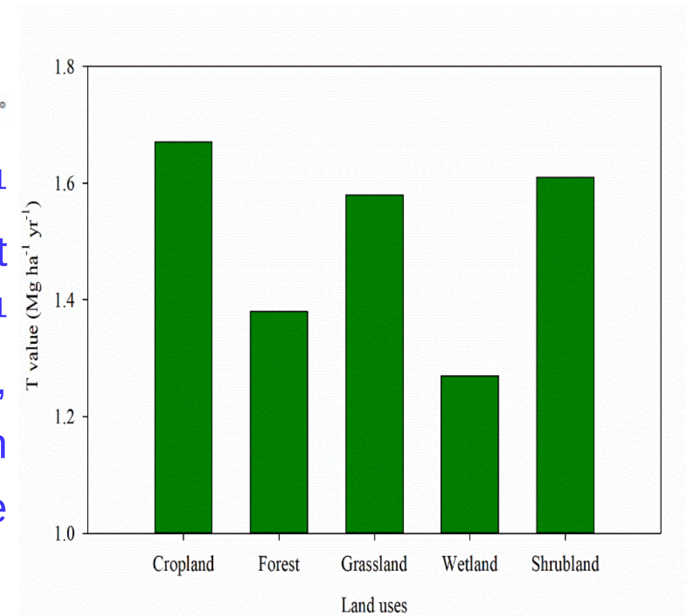
The global average soil erosion rate in 2015 was 21.15 Mg ha $^{-1}$yr^{-1}. Areas with severe soil erosion are mainly distributed in eastern and southern Asia, southern Europe, northern North America and southern South America.

3. Results

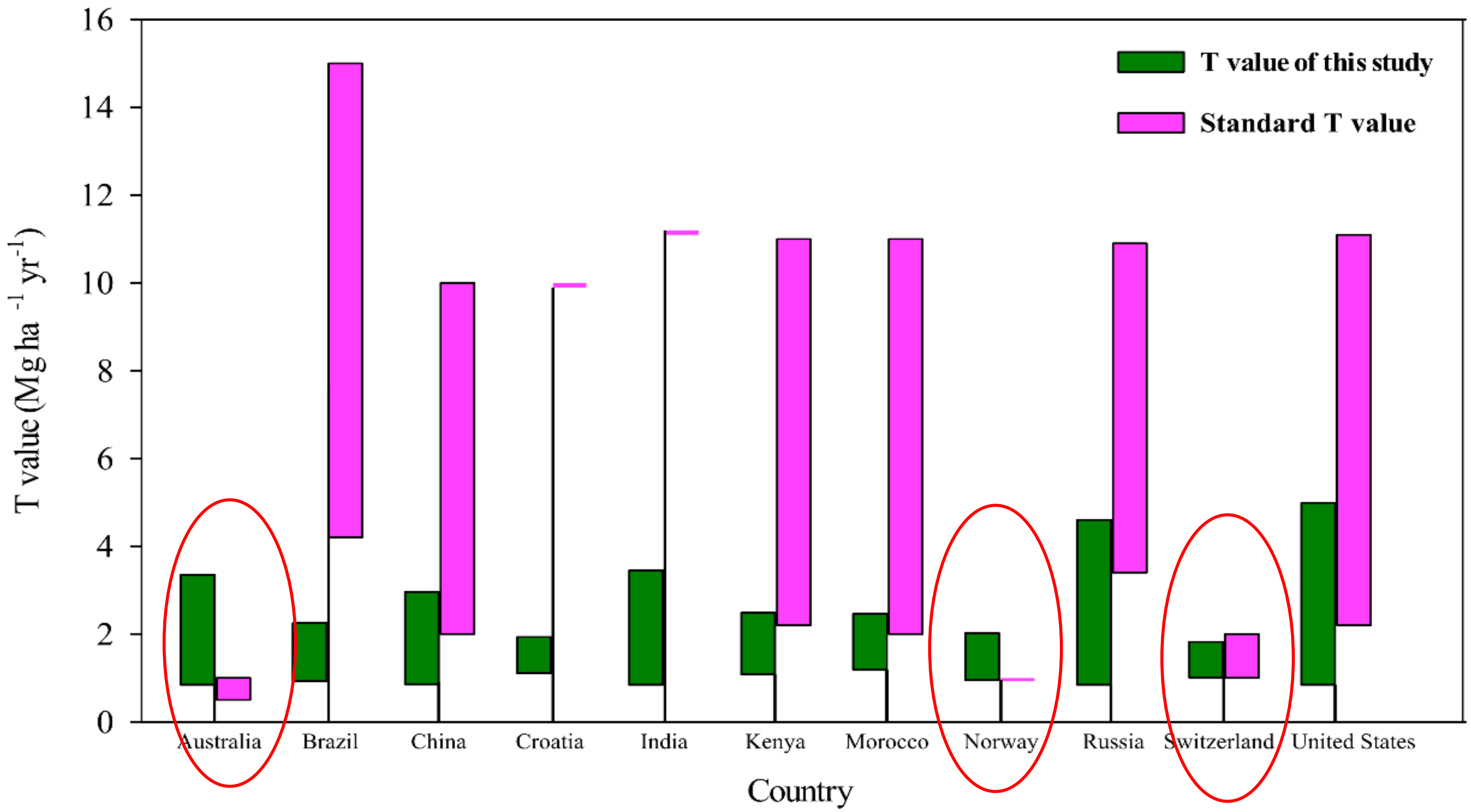




The global T value is between 0.84 and 4.99 Mg ha^{-1} yr^{-1} with an average of 1.49 Mg ha^{-1} yr^{-1}. The T values in most regions of the world are distributed between 1.0 and 2.0 Mg ha^{-1} yr^{-1}. The T values of different land use types are quite different, and the average T value of agricultural land is the highest, which is 1.67 Mg ha^{-1} yr^{-1}. The T value of woodland and wetland is the smallest, about 1.30 Mg ha^{-1} yr^{-1}.

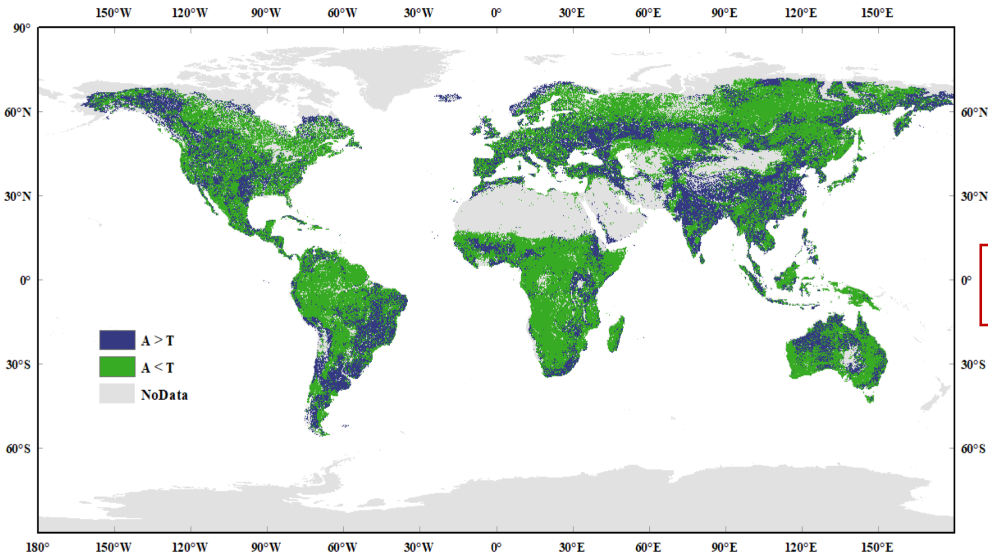


3. Results

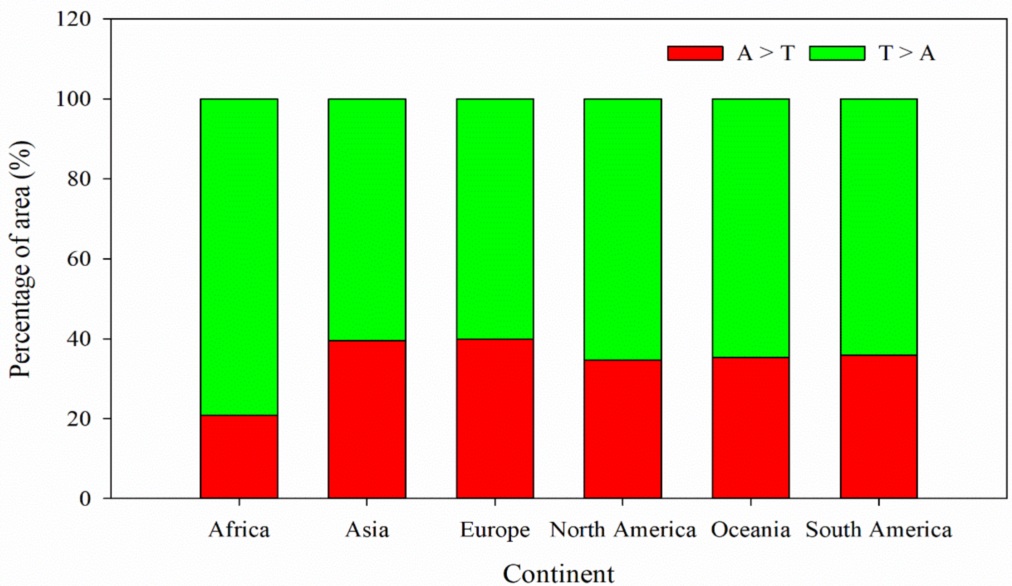


The T value standards of various countries are obtained by combining the soil rate method with expert experience. However, the soil formed by the weathering of the rock is less productive than the surface soil. Therefore, although the existing T value standard can ensure that the soil depth is not reduced, the soil productivity is still decreasing. Therefore, the existing T value standard should be properly revised based on this study.

3. Results



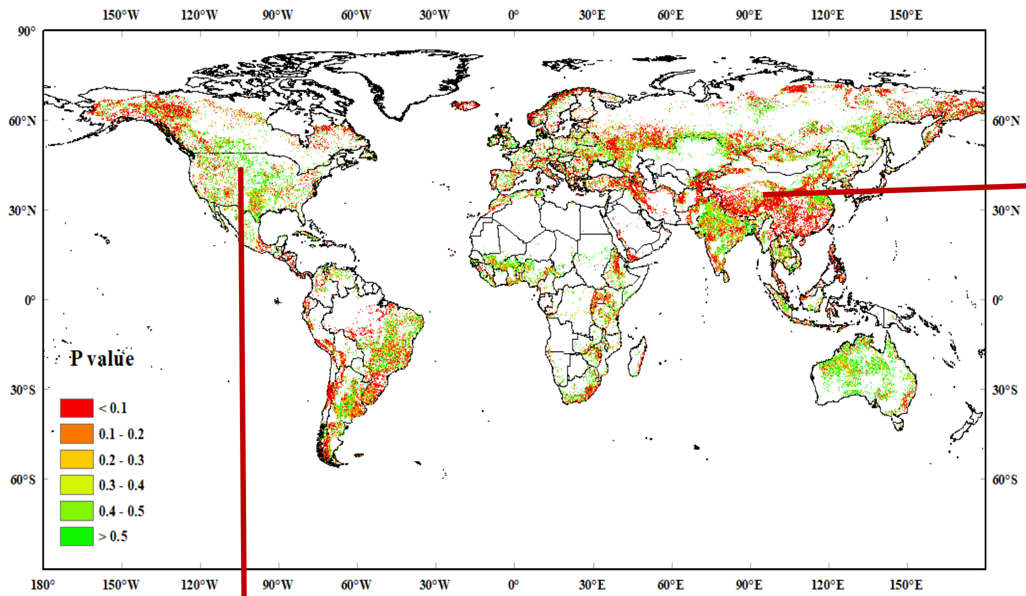
If no soil and water conservation measures were taken (P = 1), soil erosion rate (A) larger than T value occupied about 35% of the total area. This area located in Eastern and Southern Asia, Eastern Europe, Northern Australia, Southern South America and Northern North America.



The percentage of A > T between continents did not differ obviously, except for Africa, which is significantly lower than other regions.

3. Results

When $P = \frac{T}{RKLSC}$, the distribution of P value, with an average of 0.3.



Soil and water conservation measures	P Value
Contour tillage	0.55
Ridges	0.18
Hedgerows	0.49
Terrace	0.03

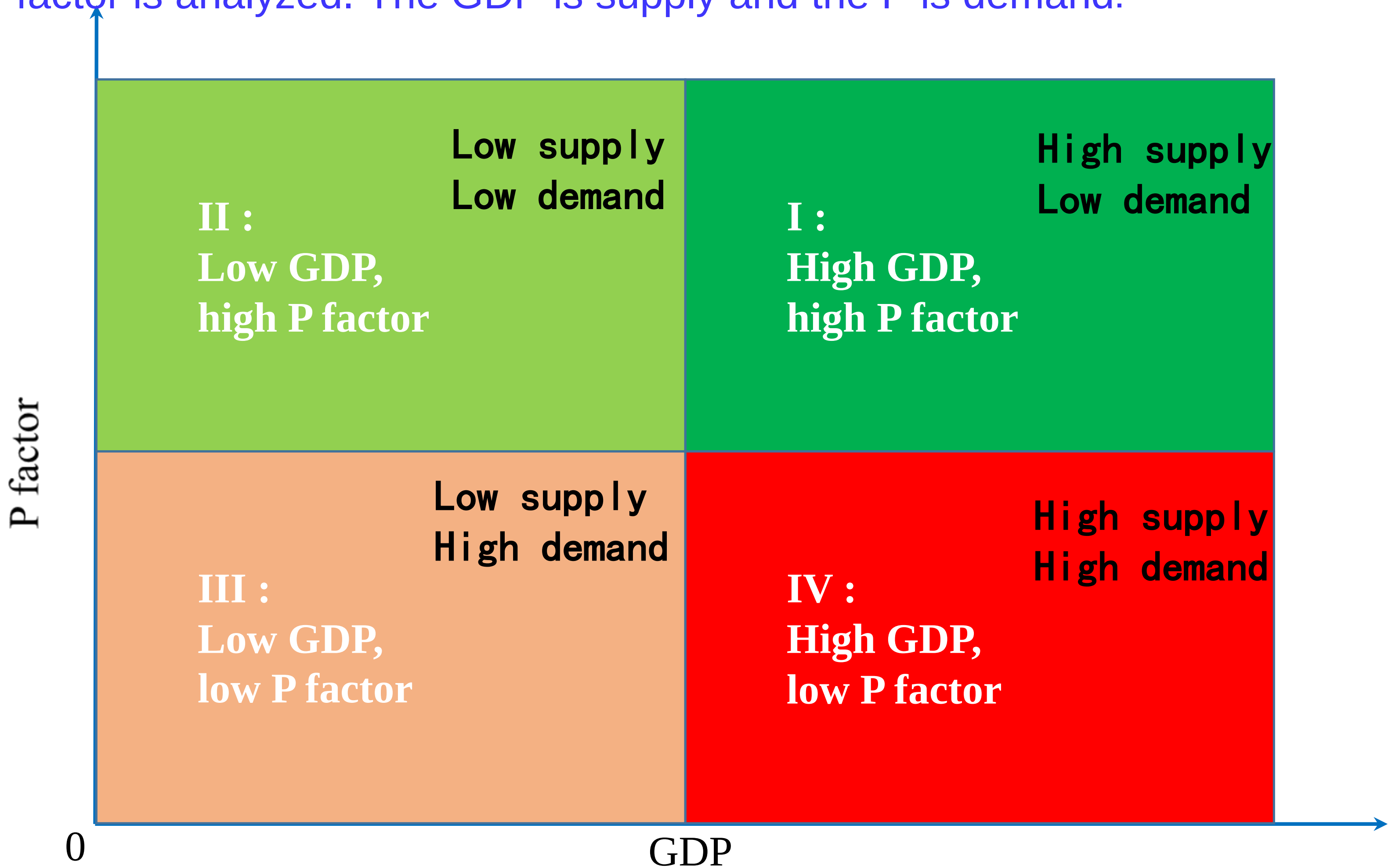
In southern China, terraces should be considered for areas where the P < 0.1. For areas where the P value is required to be 0.1-0.2, ridges should be considered.

Soil and water conservation measures	P Value
Contour tillage	0.6-0.9
Terrace	0.12-0.18
Contour tillage + hedgerow	0.3-0.45

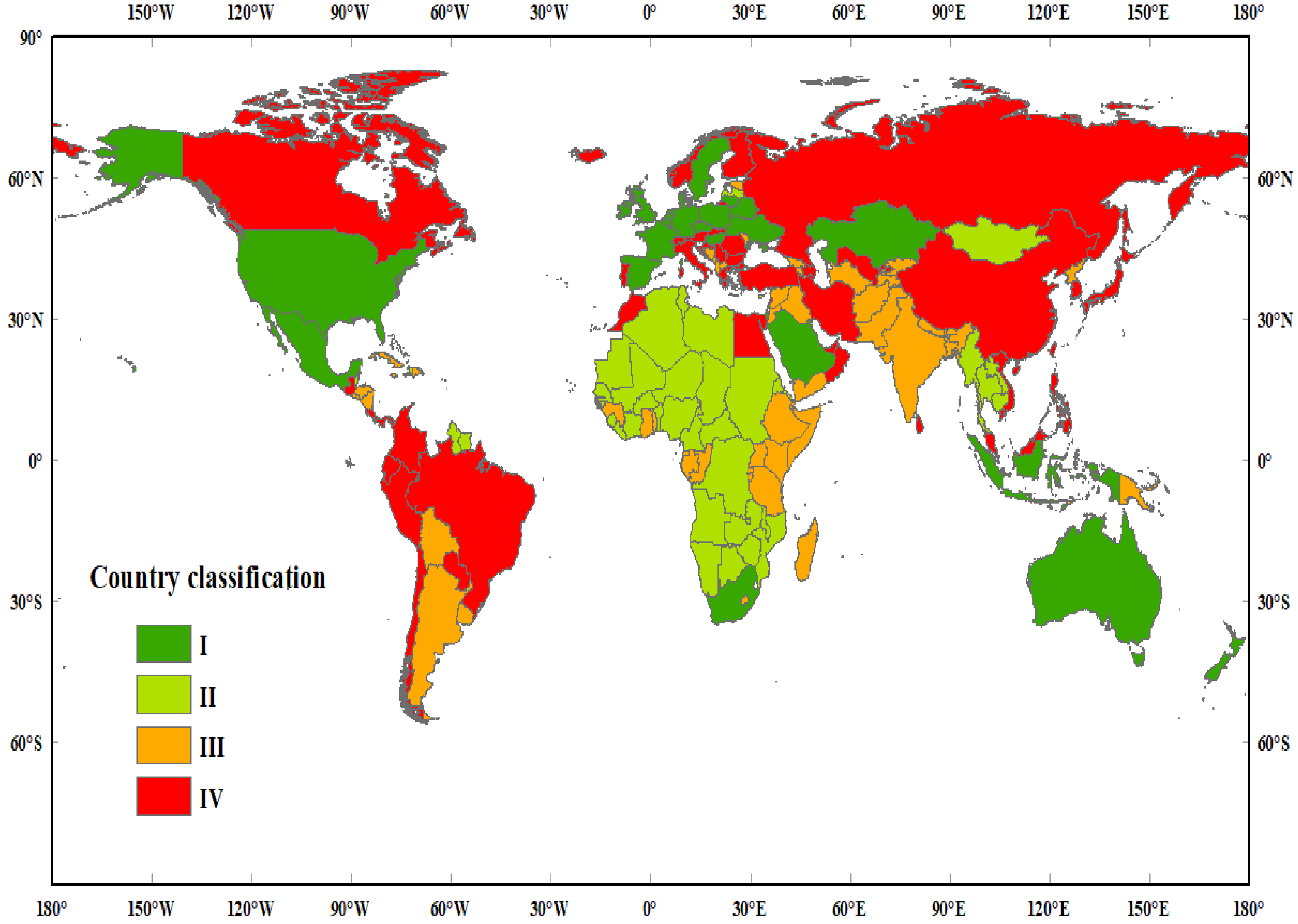
In the United States, P values in most regions are between 0.4-0.5, so the choice of contour tillage + hedgerow is the best option.

3. Results

The construction of soil and water conservation measures requires a certain economic foundation as a support. The smaller the P value is, the higher the cost will be. According to the analysis of supply and demand, the relationship between GDP and P factor is analyzed. The GDP is supply and the P is demand.

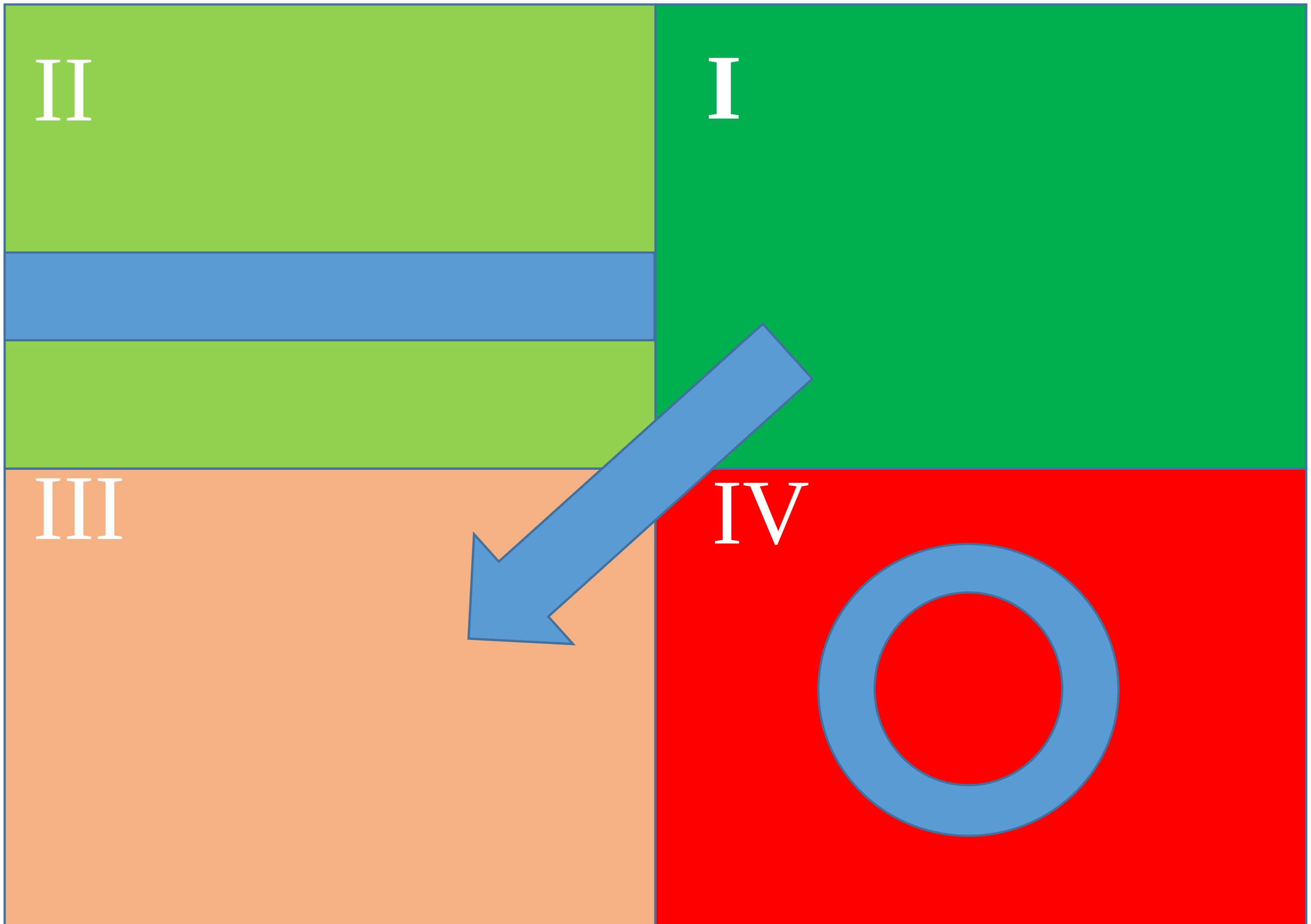


3. Results


150°W
120°W
90°W
60°W
30°W
0°
30°E
60°E
90°E
120°E
150°E
180°
90°
60°N
30°N
0°
30°S
60°S
Country classification
I
II
III
IV

3. Results

Strategies for different countries



4 Conclusions

1. The global average soil erosion rate in 2015 is 21.15 Mg ha^{-1} yr^{-1}, and the global average soil loss tolerance is 1.49 Mg ha^{-1} yr^{-1}, so if the global average soil erosion rate is controlled to be less than T values, the global soil erosion rate should be reduced by 93%.
2. Soil erosion rate larger than T value occupied about 35% of the total area, if global soil erosion is controlled under T values, the P factor should be less than 0.3.

Thank you for your attention!