

# Supplementary Materials

## 1. Estimating Regional Nutrient Surpluses

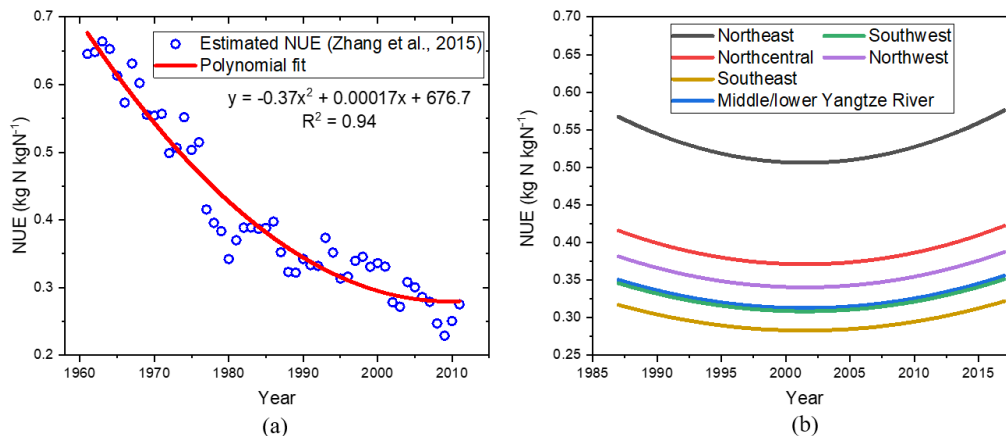
In agricultural soils, the total N inputs generally include N from fertilisers (mineral and organic), biologically fixed N and N deposition [1], whereas the total P inputs mainly refer to P from fertilisers. To derive regional N and P surpluses due to the application of mineral fertilisers, an estimation can be established as presented in equation (1), assuming the differences among NUEs and PUEs of various sources of N and P are negligible.

$$NP_{sur(ij)} = N_{fert(ij)} (1 - NUE_{ij}) + P_{fert(ij)} (1 - PUE_{ij}) \quad (1)$$

where  $NP_{sur(ij)}$  is the sum of N and P surpluses from mineral fertiliser of  $j$ -province on  $i$ -th year,  $N_{fert}$  and  $P_{fert}$  refer to N and P inputs from mineral fertilisers (measured as the effective components), and  $NUE_{ij}$  and  $PUE_{ij}$  are the regional N and P use efficiency of year  $i$ . According to fertilisation data from National Bureau of Statistics of China,  $N_{fert}$  and  $P_{fert}$  have two further sources, respectively N or P from nitrogenous or phosphate fertilisers, and N or P from compound fertilisers. N and P from compound fertilisers were estimated based on the N: P<sub>2</sub>O<sub>5</sub>: K<sub>2</sub>O ratio in different regions of China: 1:2.0:0.2 in the northeast region, 1:1.5:0.4 in the northcentral and northwest regions and 1:1:0.8 in the middle and lower reaches of Yangtze River, southwest and southeast regions [2].

### 1.1 The estimation of regional NUEs

We estimated regional NUEs of China based on published data of Zhang et al. [1] and Li et al. [2]. We firstly obtained a polynomial fit of the time-series NUE of China based on published data of Zhang et al. (**Figure S1a**). Then, to reflect regional variations of NUEs over different regions, we derived a variation factor based on Li et al.'s published data regarding regional NUEs of China in 2008. We assumed that the regional variation of NUEs over China in 2008 can represent that of the time period 1993 to 2018, and the variation factor is therefore attained as the ratio of the regional NUE and China's average NUE of the year 2008. Estimated NUEs of different regions in China for the time period needed are presented in **Figure S1b**.



**Figure S1.** (a). Estimated NUE of China from 1961 to 2011 based on Zhang et al. [1], and (b) the estimation of regional-corrected NUEs of six zones in China. The regional variation factors were derived by dividing the regional NUE by the mean NUE of China in the year 2008, based on published data of Li et al. [2].

### 1.2 The Estimation of Regional PUEs

Regional PUEs used in the study were estimated from a 10-year panel dataset generated by field surveys of Zhang et al. [3]. Zhang et al. measured total field P inputs (mineral fertiliser input, manure and human excreta) and total harvested P within crops and straw fields of 30 provinces in mainland China, with 186 collected samples during 2004 to 2009 and 155 collected samples during 2010 to 2014. As the calculated PUEs of most of the provinces in China have rather small variations, the arithmetic mean of the 10-year PUEs of each province was adopted in the study (**Table S1**).

**Table S1.** Estimated PUEs of 30 provinces in mainland China. Source of data: Zhang et al. [3].

<b>Northeast</b>	Liaoning	0.35	<b>Southeast</b>	Fujian	0.18
	Jilin	0.57		Guangdong	0.16
	Heilongjiang	0.61		Zhejiang	0.28
<b>Northcentral</b>	Beijing	0.19	<b>Southwest</b>	Guangxi	0.20
	Tianjin	0.22		Hainan	0.12
	Hebei	0.34		Sichuan (incl. Chongqing)	0.27
	Shanxi	0.32		Guizhou	0.33
	Shandong	0.31		Yunnan	0.27
	Henan	0.31		Tibet	0.05
<b>Yangtze River</b>	Shanghai	0.27	<b>Northwest</b>	Inner Mongolia	0.35
	Jiangsu	0.35		Shaanxi	0.32
	Anhui	0.36		Gansu	0.26
	Jiangxi	0.33		Qinghai	0.16
	Hubei	0.27		Ningxia	0.32
	Hunan	0.36		Xinjiang	0.41

## 2. Performances of Each Province in Responding to the Annual Target

In the Implementation Plan following the Zero Growth Action Plan of fertiliser use by 2020, detailed annual targets in fertiliser use reduction were given, specifying the aim of having an annual growth rate of fertiliser use less than 1%, 0.8%, 0.6% and 0.4% for 2015, 2016, 2017 and 2018 [4]. **Table S2** illustrates the growth rates of fertiliser use per hectare of 30 provinces in China from 2015 to 2018. Provinces with a growth rate exceeding the annual targets are marked with \*.

**Table S2.** Growth rate of per hectare fertilizer use of 30 provinces in China from 2015 to 2018. Provinces with the growth rate exceeding the annual targets are marked with \*.

		2015	2016	2017	2018
<b>Northeast</b>	Liaoning	-2.32%	-0.52%	-0.09%	-1.13%
	Jilin	0.19%	-0.06%	-1.48%	-1.09%
	Heilongjiang	-0.81%	-1.12%	-0.20%	-1.59%
<b>Northcentral</b>	Beijing	2.29% *	8.38% *	6.63% *	-0.65%
	Tianjin	-4.30%	-2.34%	-16.53%	-3.64%
	Hebei	-0.07%	-1.22%	-1.96%	-0.80%
	Shanxi	0.54%	-0.67%	-3.96%	-1.52%
	Shandong	-1.54%	-0.62%	-2.13%	-4.19%
	Henan	0.45%	-0.30%	-0.02%	-2.31%
<b>Middle &amp; Lower reaches of Yangtze River</b>	Shanghai	3.11% *	6.23% *	3.92% *	-5.06%
	Jiangsu	-2.12%	-1.65%	-1.70%	-3.29%
	Anhui	-1.80%	5.43% *	-1.83%	-2.67%
	Jiangxi	0.12%	-0.78%	-4.42%	-7.36%
	Hubei	-6.44%	-0.84%	-3.64%	-6.92%
	Hunan	0.01%	0.12%	-0.25%	1.49% *
<b>Southeast</b>	Fujian	4.28% *	4.45% *	-6.11%	-6.49%

	Guangdong	3.51%	2.09%	-2.12%	-11.53%
	Zhejiang	-1.90%	-1.92%	-3.90%	-5.78%
	Guangxi	-3.24%	2.77% *	0.59%	-3.37%
	Hainan	6.39% *	2.45% *	4.67%	-6.28%
<b>Southwest</b>	Sichuan (incl. Chongqing)	-0.72%	-1.20%	-2.90%	-3.05%
	Guizhou	1.95% *	-1.30%	-8.63%	-3.34%
	Yunnan	2.57% *	2.08% *	-1.61%	-7.64%
	Tibet	11.65% *	-14.45%	-3.08%	-11.82%
<b>Northwest</b>	Inner Mongolia	-1.21%	-3.79%	-0.46%	-3.22%
	Shaanxi	0.86%	-2.19%	1.97% *	-1.74%
	Gansu	0.53%	-4.11%	-9.63%	-2.12%
	Qinghai	3.13%	-13.42%	-0.59%	-4.37%
	Ningxia	0.55%	2.80% *	-1.02%	-8.54%
	Xinjiang	2.64% *	-11.86%	0.80% *	-1.35%

\* Provinces with a growth rate exceeding the annual targets.

## References

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4. MoA. Notice of the General Office of the Ministry of Agriculture on Issuing the “<Action Plan for Zero Growth in Fertilizer Use by 2020> Promotion Plan” MoA: Beijing, China, 2015.