Science of the Total Environment 627 (2018) 361–372

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Analyzing and modelling the effect of long-term fertilizer management on crop yield and soil organic carbon in China

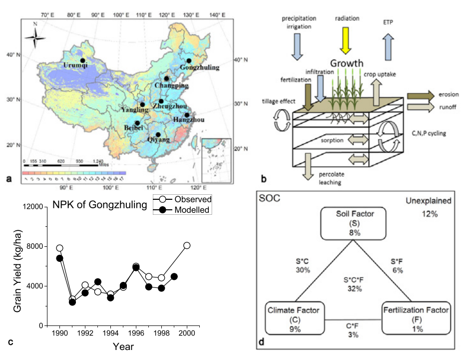
Jie Zhang [a], Juraj Balkovič [b,c], Ligia B. Azevedo [b], Rastislav Skalský [b,d], Alexander F. Bouwman [e,f], Guang Xu [g], Jinzhou Wang [h], Minggang Xu [h,*], Chaoqing Yu [a,*]

[a] Department of Earth System Science, Tsinghua University, Beijing 100084, China
[b] International Institute for Applied Systems Analysis, Vienna A-2361, Austria
[c] Department of Soil Science, Faculty of Natural Sciences, Comenius University in Bratislava, 84215 Bratislava, Slovak Republic
[d] National Agricultural and Food Centre, Soil Science and Conservation Research Institute, 82713 Bratislava, Slovak Republic
[e] Department of Earth Sciences-Geosciences, Faculty of Geosciences, Utrecht University, P.O. Box 80021, 3508 TA Utrecht, The Netherlands
[f] PBL Netherlands Environmental Assessment Agency, P.O.Box 30314, 2500 GH The Hague, The Netherlands
[g] School of Earth, Atmosphere and Environment, Monash University, Clayton 3800, Australia
[h] Institute of Agricultural Resources and Regional Planning, Chinese Academy of Agricultural Sciences, Beijing 100081, China

HIGHLIGHTS

- The effect of diverse fertilizer management on crop yield and SOC from simultaneous 11-year datasets of 8 long-term field experiments in China was synthesized.
- The yield and SOC under NPKM treatment were the highest while the yield under control treatment was the lowest (30%-50% of NPK yield) at all sites.
- The SOC in northern sites appeared more dynamic than that in southern sites.
- Fertilization factor contributes the most to the total variance of crop yield (42%), followed by climate and soil factor.
- The interactive influence of soil and climate determines the largest part of the SOC variance (32%).

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 17 May 2017
Received in revised form 8 January 2018
Accepted 10 January 2018
Available online xxxx

Editor: Ouyang Wei

Keywords:
Crop yield
Soil organic carbon

ABSTRACT

This study analyzes the influence of various fertilizer management practices on crop yield and soil organic carbon (SOC) based on the long-term field observations and modelling. Data covering 11 years from 8 long-term field trials were included, representing a range of typical soil, climate, and agro-ecosystems in China. The process-based model EPIC (Environmental Policy Integrated Climate model) was used to simulate the response of crop yield and SOC to various fertilization regimes. The results showed that the yield and SOC under additional manure application treatment were the highest while the yield under control treatment was the lowest (30%–50% of NPK yield) at all sites. The SOC in northern sites appeared more dynamic than that in southern sites. The variance partitioning analysis (VPA) showed more variance of crop yield could be explained by the fertilization factor (42%), including synthetic nitrogen (N), phosphorus (P), potassium (K) fertilizers, and fertilizer NPK combined with manure. The interactive influence of soil (total N, P, K, and available N, P, K) and climate factors (mean

* Corresponding authors.
E-mail addresses: xuminggang@caas.cn (M. Xu), chaoqingyu@tsinghua.edu.cn (C. Yu).

https://doi.org/10.1016/j.scitotenv.2018.01.090
0048-9697/© 2018 Published by Elsevier B.V.

Long-term field experiments
EPIC model
Fertilizer management

annual temperature and precipitation) determine the largest part of the SOC variance (32%). EPIC performs well in simulating both the dynamics of crop yield (*NRMSE* = 32% and 31% for yield calibration and validation) and SOC (*NRMSE* = 13% and 19% for SOC calibration and validation) under diverse fertilization practices in China. EPIC can assist in predicting the impacts of different fertilization regimes on crop growth and soil carbon dynamics, and contribute to the optimization of fertilizer management for different areas in China.

1. Introduction

Global food demand is expected to increase rapidly in the coming decades due to population and economic growth, and food security is becoming an important issue (West et al., 2014;Godfray et al., 2010). Modern intensive agriculture relies heavily on fertilizer application, which is essential for providing crop nutrients and increasing global food production (Koning et al., 2008). Soil organic carbon (SOC) is an important factor in determining the potential productivity of agricultural soil and the arrangement of soil aggregates and their stability. Mineralization of SOC is an important source of soil nitrogen (N) and phosphorus (P). SOC content is directly affected by climate (precipitation and temperature), anthropogenic activities, and soil factors such as soil texture (Jiang et al., 2014). In addition, soil and crop management, including crop residue management and fertilization practices, especially the use of mineral fertilizers, and manure amendments, have a large influence on soil fertility and thus crop yields (Zhang et al., 2010). Therefore, assessing the effect of long-term fertilization on crop yields and SOC content is currently an important issue for soil fertility, crop production, and food security.

In China, a national network of long-term fertilizer experiments has been established since the early 1980s across highly diverse soil types, climatic zones and management practices (National Soil Fertility and Fertilizer Effects Long-term Monitoring Network) (Zhao et al., 2010). Numerous datasets of soil physical and chemical properties, nutrient content, climate records and agricultural management have been collected annually, which enable researchers to explore the relationship between fertilization and multiple factors across a wide range of spatio-temporal scales. However, previous studies in China focused on the changes in crop yields or SOC content based on a few experimental sites (Zhang et al., 2008), while long-term comparative studies on a large scale are lacking. Also, studies in China that combine long-term field experiments and model simulations of both crop yield and SOC content, enabling extrapolation to other regions, are not available.

Process-based models are useful tools for describing and predicting the consequences of long-term fertilizer management. The Environmental Policy Integrated Climate model (EPIC, Williams et al., 1989) is a field-scale, process-based model that can simulate plant growth and crop yield, soil erosion, soil nutrient cycling and the effects of crop management on plants, water, and soil (Gaiser et al., 2010). It has been successfully employed worldwide to study crop yield and yield gaps (Schierhorn et al., 2014;Lu and Fan, 2013), climate change impacts on crop yield (Niu et al., 2009;Xiong et al., 2016), environmental impacts (Liu et al., 2010;Liu et al., 2016b), soil erosion and nutrient leaching (Bouraoui and Grizzetti, 2008), and crop management operations (Thomson et al., 2006). However, it has rarely been validated against

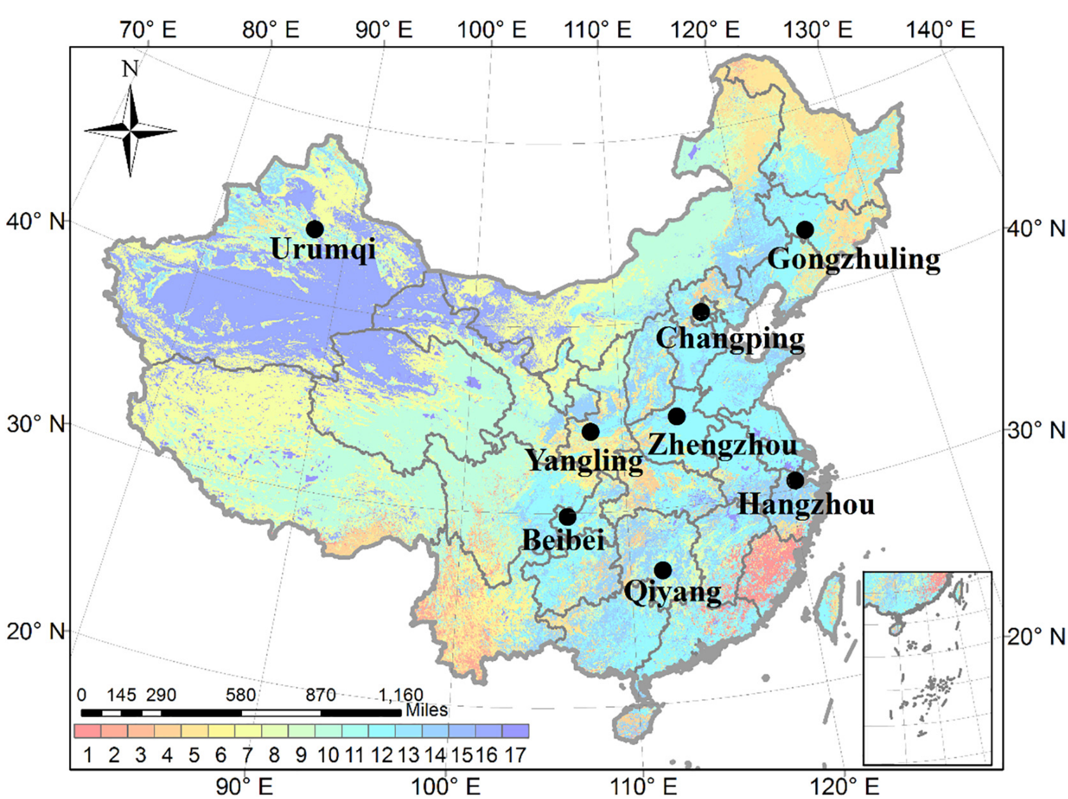


Fig. 1. The eight experimental sites of the National Soil Fertility and Fertilizer Effects Long-term Monitoring Network, including Gongzhuling (GZL) in Jilin Province, Changping (CP) in the Beijing City area, Urumqi (Urum) in Xinjiang Province, Yangling (YL) in Shaanxi Providence, Zhengzhou (ZZ) in Henan Province, Hangzhou (HZ) in Zhejiang Province, Beibei (BB) in the Chongqing City area, and Qiyang (QY) in Hunan Province. The background map is the 1 km resolution MODIS land cover data with the IGBP classification scheme.