Project description

Migration and transformation processes of fertilizer nitrogen and its loss mitigation strategies in Chinese main agricultural systems (grant number: 2017YFD0200100)

China has only 9% of global cropland but consumes more than 30% of global chemical nitrogen (N) fertilizers. The excessive use of N fertilizers in Chinese agriculture have resulted in not only decreased N-utilization efficiency by crops, but also increased N losses to environment, leading to enormous damages to environmental quality and human health. Thus, mitigating N losses from cropland without negatively impacting crop productivity is always a pressing environmental and economic challenge facing Chinese agriculture. The Ministry of Science and Technology of China launched a National Key R&D Program in 2016 entitled “Integrated technology development for the reduction in chemical fertilizer and pesticide use”. The program financed 43 projects, which started between 2016-2018.

The above mentioned project officially started from July, 2017. It involves 27 research institutions or universities with 183 researchers from over the country. With the complementary expertise of the team, this project is focusing on addressing three key scientific questions as follow:

1) **How do soil physicochemical and biological properties affect N transformation and retention in varying cropland soils?**

Basically, N turnover correlate closely with crop N uptake when fertilizer N is applied to soils. Various N transformation processes in soils dominate the retention, availability and distribution of fertilizer N in different soil pools, also directly impacting the fate of fertilizer N. Because most N transformations in soil are mediated by microorganisms and effected by soil nature, thus, well understanding the critical role of soil physicochemical and biological properties in dominating transformation rates among different soil N forms and soil N retention capacity is the premise for regulating internal soil N cycle. Net rates of N transformation cannot provide information on the individual processes inherent in the N cycle. Soil gross N transformations, which can be quantified by ^{15}N tracing techniques, can provide a full understanding of the dynamics of the internal N cycle controlling soil gross N transformations in different soils with varying properties. It will provide important insights into the connections between soil N transformations and soil key properties, which would be very critical for potentially realizing soil N internal cycle regulation (Fig.1).

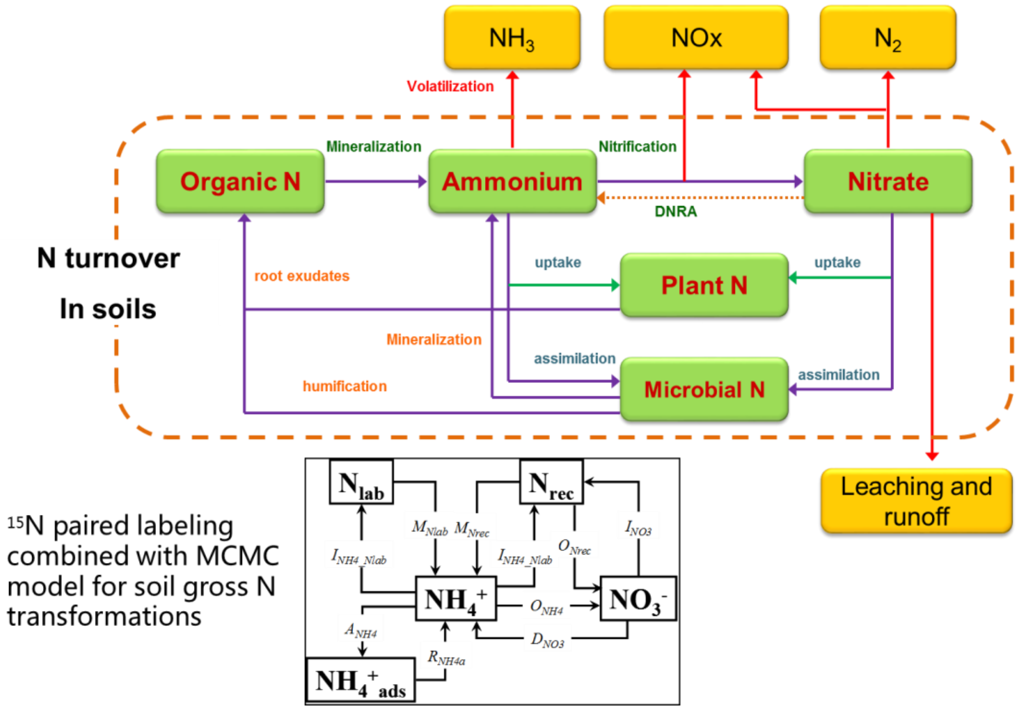

Fig. 1 Soil N turnover and the method for investigating gross N transformation rate

2) What's the critical factors dominate regional variability of fertilizer N recovery efficiency (RE_N) and N losses among different agricultural production systems?

Although numerous evidence have shown average RE_N of < 30% for Chinese major cereal crops, relative to >50% in America and in Europe, not all crop production systems of China have such low RE_N. There is great variability in RE_N in different regions with varying soils and cultivation practices. For example, northeastern and southeastern China are both featured with rice production, both with average rice yield of ~8 Mg ha^{-1}. However, RE_N of 50% can be achieved with a relatively lower fertilizer N input of 120-150 kg N ha^{-1} in northeastern China; while RE_N is generally below 30% with great N losses to environment in southeastern China, and fertilizer N input of ~250 kg N ha^{-1} is required to maintain the rice yield. Undoubtedly, this great discrepancy in RE_N can be resulted from varying climates, rice varieties, soils and cultivation practices. Current studies on RE_N and losses of fertilizer N among representative soil-crop production systems of China are very limited. Network in-situ field N experiment are thus an urgent need in different crop production systems across China for investigating RE_N and N losses and its underlying causes. In particular, better understanding the role of fertilizer N turnover in soil and agricultural cultivation practices in accounting for the regional discrepancies of RE_N and N losses among different agricultural regions is critical for the development of economic and environmental N rate reduction strategies (Fig.2).

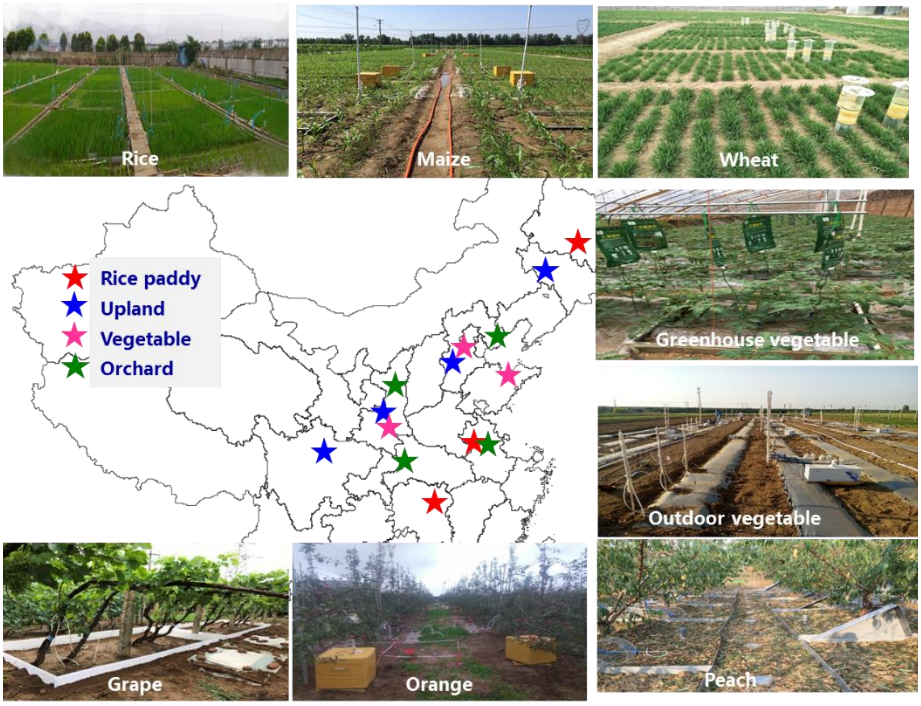

Fig.2 Field N fate and losses monitoring network

3) How can we improve the synchrony of N supply and crop demand that could enhance RE_N while mitigating N losses from Chinese agriculture?

Asynchrony between N supply and crop N demand is the main source of lower RE_N in most agricultural regions of China with many environmental hazards associated with great N losses. In soil-crop systems, both indigenous N from soils and applied fertilizer N mainly provide nutrient supply for crop plants. When fertilizer N is applied to soils, it also participates soil organic and inorganic N pool turnovers besides being direct absorbed by plants in mineral N forms, or lost. N supplies from the soil and fertilizer and crop N uptake, crop response are spatially and temporally variable. Current N management decisions generally overlook these variations and indigenous N supply and fertilizer N turnover in soil. The key to achieving synchrony between N supply and crop demand is to find suitable soil/crop-based indices to accurately identify the dynamic relationship between N supplies from the soil/fertilizer and crop N need while accounting for spatial and temporal variability of soil/fertilizer N and crop N uptake. It will be very instructive and straightforward for enabling the development of more scalable N management strategies to improve RE_N and minimize off-field losses in Chinese agriculture (Fig.3).

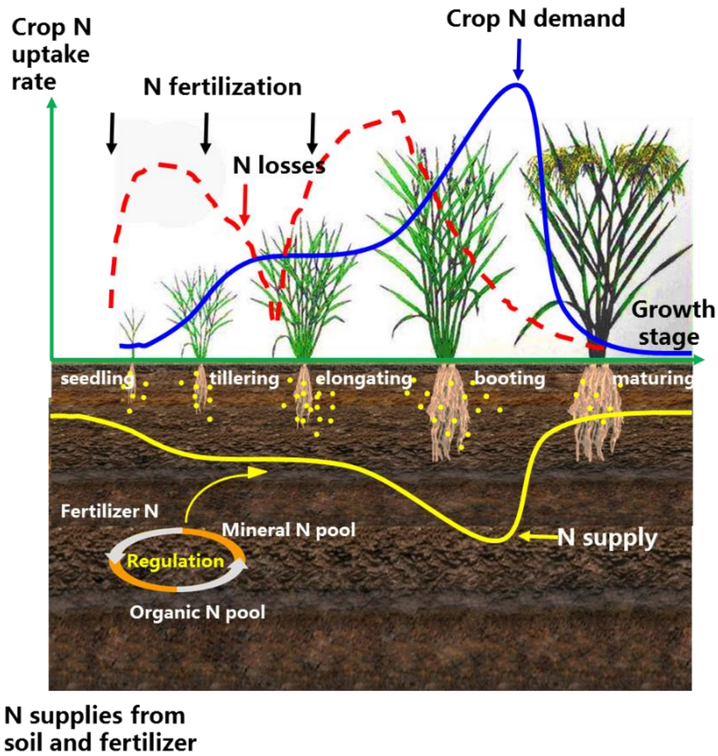

Fig.3 Schematic Diagram of the synchrony of N supply and crop demand

Taking representative soil types and soil-crop production systems from six main agricultural regions of north and south China as the targets of the research, the team intends to: 1) reveal the connections between soil N transformation processes and utilization and losses of fertilizer N in typical soil types; 2) investigate the microbiological mechanism of N turnover in the root zone of main crops; 3) develop high N-efficiency crop varieties with characterization of underlying biological mechanism; 4) clarify the fate of fertilizer N, the pathway of N loss and its driving factors in varying production systems; 5) explore robust and fast methods to determine the spatial-temporal relationship matching N supplies of soil and fertilizer N and crop demand; 6) establish region-scalable soil/crop-based N management decisions or cultivation practices to improve RE_N and migrating N losses without negatively impacting crop productivity. New technologies related to N emission fluxes monitoring, microbe detection, isotope tracing, data mining, etc. are incorporated to investigate the processes of N transformation, migration and crop N uptake in soil-crop systems. A field monitoring network compassing 14 sites with varying planting systems combined with ^{15}N labeled fertilizer is established for assessing the regional discrepancies of RE_N and N losses among different agricultural regions (Fig.4).

The total fund of the project is 55 million RMB with a duration of 4 years from 2017 to 2020. The principal investigator is Prof. Xiaoyuan Yan from Institute of Soil Science, Chinese Academy of Sciences (CAS). The whole project contains eight well connected work packages (Fig. 5) with Institute of Soil Science, CAS leading WP1 and WP4, Center for Agricultural Resources Research, Institute of Genetics and Developmental Biology, CAS leading WP2, China Agricultural University leading WP3 and WP8, Institute of Applied Ecology, CAS leading WP 5, Northwest A&F University leading WP 6, and Henan Agricultural University leading WP 7.

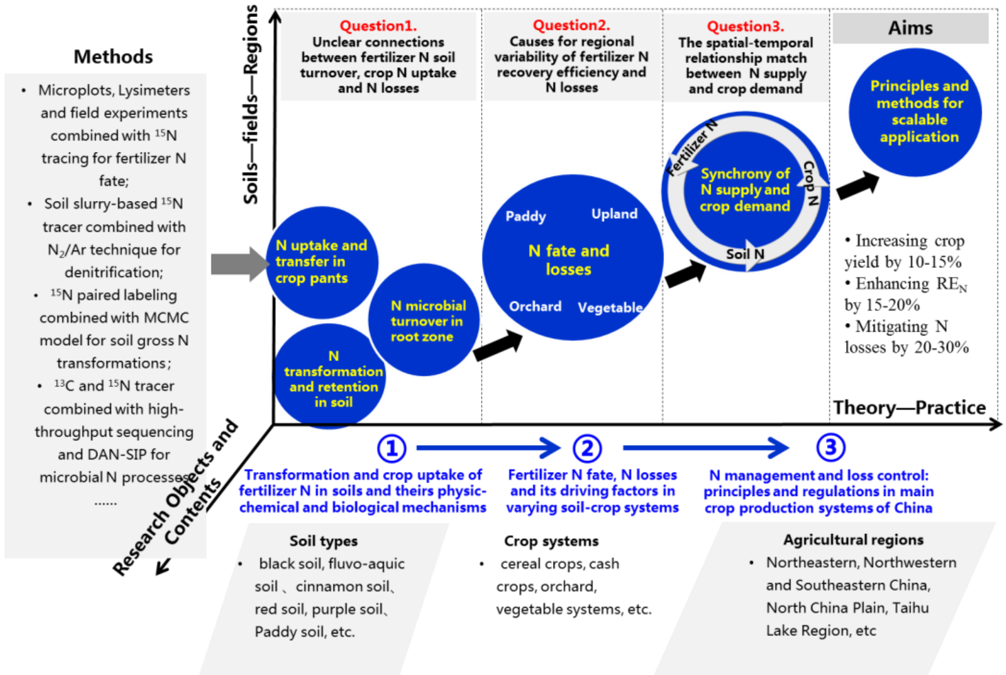

Fig.4 Technology Roadmap of the Program

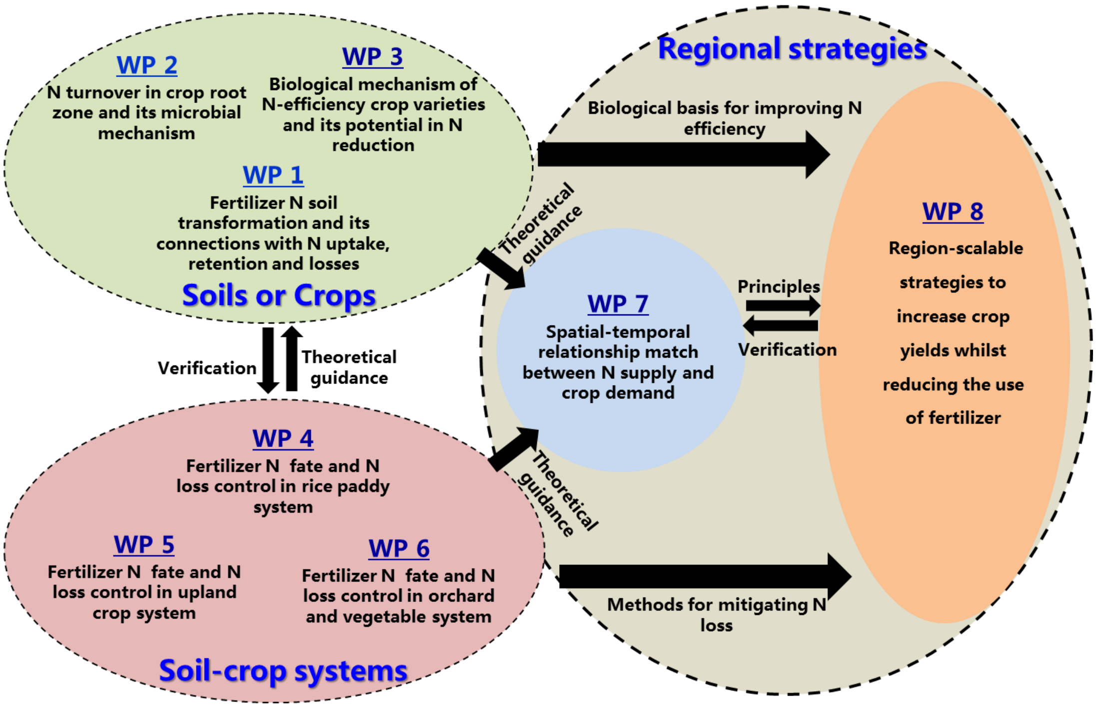

Fig. 5 Work Packages Breakdown Structure of the Program