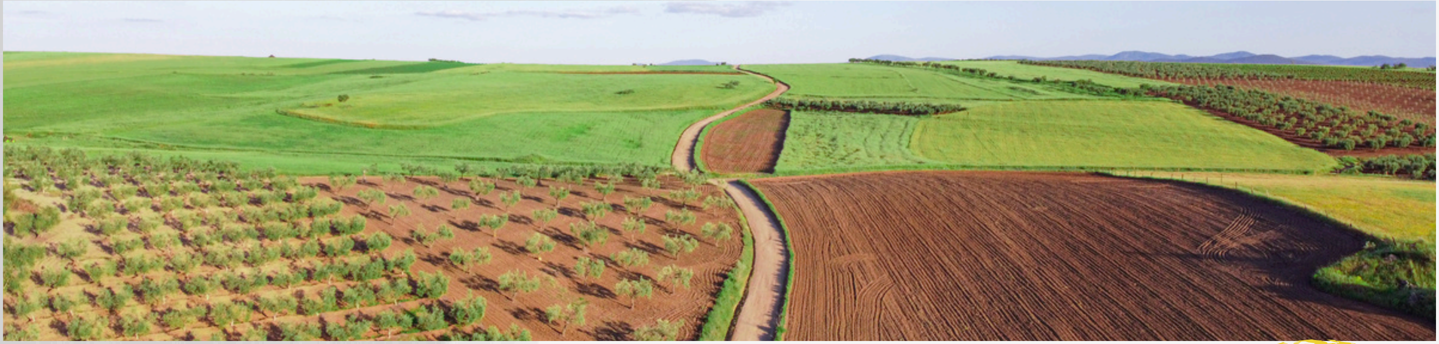

NBS CASE

Partial Substitution of Synthetic Fertilizers with Organic Resources for Sustainable Vegetable Production in Chongqing, China

In the rapidly developing agricultural regions of Southwest China, intensive vegetable production has led to serious soil fertility and environmental challenges. The overuse of synthetic fertilizers, common in high-yield systems, has resulted in nutrient imbalances, declining soil health, and increased greenhouse gas emissions. Meanwhile, the region faces a parallel problem of livestock waste accumulation, which represents both an environmental hazard and a potential untapped nutrient resource.

To address these interlinked issues, a long-term Nature-Based Solution (NBS) experiment was initiated in 2019 at the National Purple Soil Fertility and Fertilizer Effectiveness Monitoring Station (Beibei District, Chongqing, China; 29°48′45″N, 106°24′31″E). This site, representative of the purple soil agroecosystem common across the Sichuan Basin, is characterized by an average annual precipitation of 1161 mm, mean temperature of 18.3°C, and a chili pepper–Chinese cabbage rotation system. The soil is classified as purple soil, consisting mainly of sand (88%), with low organic matter content (4.69 g kg^{-1} organic carbon) and slightly alkaline pH (8.44).

The experimental design aims to develop and test an integrated nutrient management approach that partially substitutes synthetic fertilizers with locally available organic resources, such as biochar, chicken manure, kitchen waste compost, and straw residues. By doing so, the project seeks to enhance nutrient recycling, reduce environmental pressures, and maintain or increase crop productivity in vegetable-based systems.

This Nature-Based Solution thus contributes to the broader goals of sustainable soil management, climate-smart agriculture, and circular nutrient economies by integrating agronomic, biophysical, and socio-economic dimensions at both the field and farm scales.

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Challenges addressed by the NBS

Agricultural intensification in developing countries has long relied on excessive chemical fertilizer use. In Southwest China, farmers typically apply 30% more synthetic fertilizers than the national average. This overuse leads to:

- Low nutrient use efficiency, with large amounts of nitrogen (N) and phosphorus (P) lost to the environment.
- Greenhouse gas emissions and diffuse nutrient pollution in water and soils.

At the same time, livestock density in the region—particularly pigs—is 33% higher than the national average, producing manure rich in N and P. Without proper recycling, these materials contribute to non-point source pollution and eutrophication of water bodies.

The key challenge, therefore, is to reduce dependence on synthetic inputs while transforming organic waste into valuable fertilizer resources, thus promoting a closed-loop nutrient management system that benefits both farmers and the environment.

Which indicators/criteria are used to assess the success of the NBS in addressing the challenge?

To monitor and evaluate the effects of partial organic substitution, a conceptual framework on aggregate organic carbon stability was established. It includes three main indicators:

- Aggregate stability
- Physically protected carbon content within aggregates
- Decomposability of aggregate carbon

An improvement in aggregate stability and physically protected carbon, coupled with reduced carbon decomposability, indicates enhanced soil carbon stability.

Additional indicators include:

- Crop yield stability and nutrient use efficiency
- Reduction in nitrogen and phosphorus surpluses
- Lower gaseous nitrogen emissions
- Farmer adoption rates of organic fertilizer practices

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Which biophysical, agronomic, and farm management implications does the NBS have at field and farm level?

The NBS involves a partial substitution of synthetic fertilizers with different organic materials, maintaining equivalent total nutrient inputs per hectare (250 kg N, 160 kg P_2O_5, and 1700 kg C annually). Substitution rates range from 20–49% for nitrogen and 3–100% for phosphorus, depending on the organic resource used.

Key results and implications include:

- **Soil health improvements:**
  - Enhanced aggregate organic carbon stability under all organic treatments.
  - Biochar in particular improved aggregate stability by 5.8–11.4%, aggregate organic carbon by 83.9–152.4%, and recalcitrant carbon by 36.6–75.0% compared to conventional fertilization.
  - Straw returning had the lowest impact due to higher microbial respiration and carbon degradation.
- **Yield performance:**
  - Yields increased substantially compared to no fertilization—+350–442% for chili pepper and +125–152% for Chinese cabbage.
  - Biochar and kitchen waste treatments achieved comparable yields to traditional farmer practices.
- **Nutrient efficiency and environmental gains:**
  - Nitrogen surplus reduced by 63–71%, phosphorus surplus by 106–108% for chili pepper.
  - Nitrogen use efficiency increased by 24.5–29%, phosphorus use efficiency by 6.9–8%.
  - Gaseous nitrogen losses also declined, indicating reduced environmental footprint.

At the farm management level, these results demonstrate that integrating organic fertilizer sources can sustain yields, lower production costs, and improve soil quality, while contributing to circular bioeconomy practices.

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What methods/tools are used for the NBS assessment?

Assessment combines field-based experiments and laboratory analyses, supported by data synthesis and modelling:

- In-situ monitoring of gaseous nitrogen losses and nutrient cycling processes.
- Laboratory analysis of soil carbon, nitrogen, and phosphorus dynamics.
- Modelling tools to estimate nutrient balances and long-term soil organic matter changes.
- On-site demonstrations and training through the Science and Technology Backyards to evaluate socio-economic feasibility and technology adoption.

NBS site and scale

Site: National Purple Soil Fertility and Fertilizer Effectiveness Monitoring Station, Beibei District, Chongqing, China

Coordinates: 29°48′45″N, 106°24′31″E

Scale: Field-scale, long-term experimental site representative of regional vegetable production systems

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trans4num ambition is to broadly enhance the NBS implementation in Europe with an integrative and tested multi-level approach, in dialogue with academic partners, practice partners and societal stakeholders.

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