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Chapter 10
Using SOFIX Analysis for Soil Fertility Evaluation in Japan

Quoc Thinh TRAN, Tomoya ONISHI, Motoki KUBO

Summary: Modern agriculture faces significant challenges due to agrochemical farming methods. While conventional farming relies on synthetic chemicals to boost yields, these practices harm soil microbes and organic matter, ultimately degrading soil health. Though organic farming improves soil fertility without chemicals, it typically produces lower yields. These tradeoffs have led to new approaches that aim to balance soil health with crop productivity. This study examines how SOFIX analysis is being applied in Japanese agriculture, demonstrating how organic fertilizer use can improve both short-term soil quality and long-term agricultural sustainability. The findings offer practical guidance for farmers shifting toward more environmentally sustainable farming practices.

1. Introduction

Throughout history before the twentieth century, agriculture deeply relied on traditional organic practices. Farmers refined their growing methods through careful observation and practical experience, creating farming systems that worked in harmony with nature's cycles and local environments. The agricultural landscape underwent a revolutionary transformation in the twentieth century, driven by the emergence and widespread adoption of chemical-based farming methods. Farmers started using more chemical fertilizers and pesticides during this time because they promised better harvests and made farming easier to manage. However, agrochemical farming approaches are now confronting numerous significant challenges:

- Pesticide residues and chemical fertilizers contaminate soil and water, endangering human health and biodiversity
- Rising costs of agricultural chemicals create financial strain on farmers who depend on these inputs
- Chemical exposure poses health risks to agricultural workers through long-term contact with harmful substances
- Weakening of crops' natural disease resistance, leading to greater susceptibility to pests and diseases, while also reducing the nutritional value of harvested crops

On the other hand, while organic farming represents an environmentally conscious approach to agriculture, it continues to face several significant operational challenges:

- Complex organic farming methods require extensive expertise, creating barriers to entry for newcomers to the farming sector
- Long waiting periods are needed for soil to naturally regenerate and establish sustainable cycles
- Lower crop yields compared to chemical farming methods, reducing production efficiency
- Limited scaling potential due to labor requirements and natural growth constraints

In examining the broader agricultural landscape, several critical challenges emerge:

- Heavy use of chemicals in farming has made it hard to find safe food products that consumers can trust
- Consumers have lost confidence in farm products because there is not enough transparency and reliable quality

checking in food production

- Farmers are struggling financially because rising production costs are cutting into their profits
- Current farming methods are not sustainable and make it hard for Japanese agriculture to compete in international markets

Like many nations, Japan relies heavily on imported raw materials for chemical fertilizers in its agricultural practices. This dependency has become particularly problematic due to the global surge in fertilizer prices, a direct consequence of the Russia-Ukraine War (Ben Hassen and El Bilali 2022). In response to these challenges, there is growing recognition that transitioning to organic fertilizers could significantly enhance both the environmental sustainability and economic viability of Japan's rice cultivation practices. The Japanese government has shown a long-standing commitment to sustainable agriculture, beginning with the implementation of the "Law for promoting the introduction of sustainable agricultural production practices" in 1999. Building upon this foundation, the more recent MIDORI program was enacted in July 2022 to further accelerate the development and adoption of organic farming practices throughout Japan. However, the transition to organic farming methods presents significant challenges, particularly in terms of organic fertilizer application. Farmers, having extensive experience with chemical fertilizers, often struggle with determining appropriate application rates and selecting the most suitable organic alternatives. This transition is further complicated by the fact that improper implementation of organic management practices can potentially compromise both soil fertility and rice yield outcomes.

Soil fertility is extremely important for plant growth. While conventional farming uses synthetic chemicals to increase yields, this reduces soil health by harming microbes and organic matter. Organic farming offers a chemical-free alternative that improves soil fertility, though with lower yields. This has prompted new farming approaches focused on balancing soil fertility and improving yield.

A research group led by Professor Motoki Kubo at the College of Life Sciences, Ritsumeikan University, developed the Soil Fertility Index (SOFIX) based on the assessment of soil biological characteristics, announcing their breakthrough on December 10, 2012. This pioneering development marked the world's first soil fertility index based on microbial health. SOFIX methods assess soil fertility by measuring biological, chemical, and physical factors (Adhikari et al. 2014; Aoshima et al. 2006). Our research shows SOFIX's effectiveness for soil analysis in Japanese organic farming (Pholkaw et al. 2019; Tran et al. 2021). Our research attempts to introduce the necessity of soil analysis, SOFIX analysis, and SOFIX applications in Japan.

2. SOFIX Analysis and Its Applications

(1) Necessity of Soil Analysis

To effectively assess and quantify the presence, persistence, and environmental impact of pesticides and chemical fertilizers in agricultural soils, we must implement a thorough and methodical microorganism evaluation process. This evaluation requires multiple carefully coordinated analytical steps that examine both direct chemical impacts and broader ecological effects through:

Microorganism Quantification and Community Analysis: through eDNA isolation from soil samples (Figure 10.1)

- Detailed bacterial communities' assessment through genomic sequencing

- Comprehensive measurement of microorganism populations and diversity

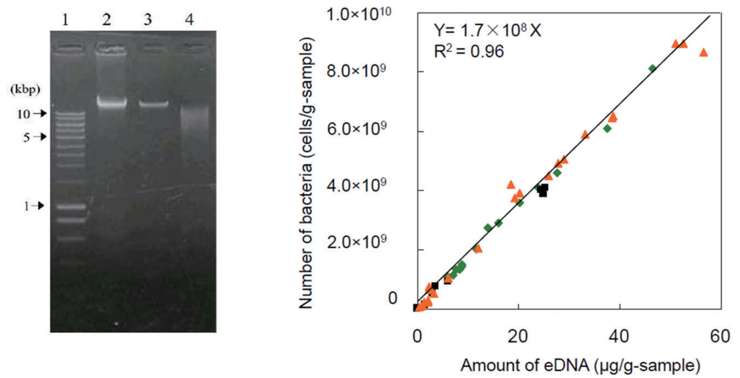

Fig. Agarose gel electrophoresis of eDNA extracted from soil in an agricultural field using various eDNA extraction methods.
Lane 1 Smart Ladder (mass marker)
Lane 2 slow stirring method
Lane 3 heat treatment method
Lane 4 the bead method

Fig. Relationship between the bacterial number obtained using DAPI staining and the amount of eDNA in 57 soils.
■; the amount of eDNA in an agricultural field
◆; oil-polluted field
▲; non-agricultural field.

Figure 10.1. Evaluation of Bacterial Communities in Soil
Source: (Aoshima et al. 2006)

Microbial Activity Assessment

- In-depth analysis of nitrogen metabolism pathways and rates (Figure 10.2-10.4)

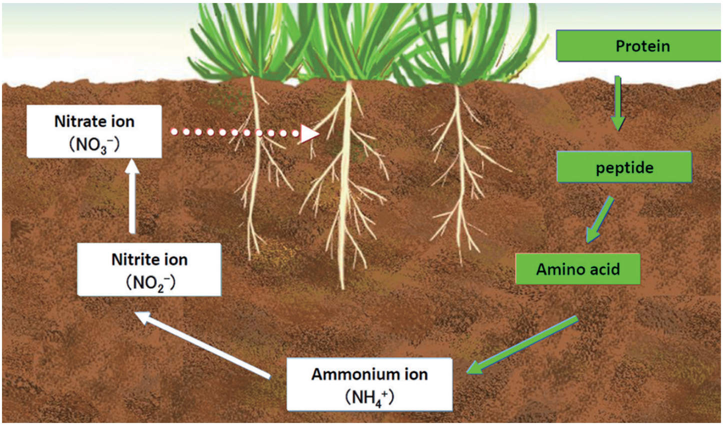

Figure 10.2. Nitrogen Transformation in Soil
Source: Author

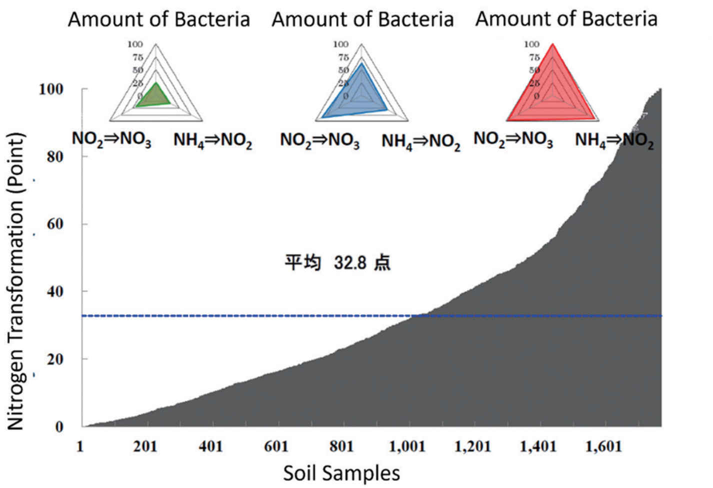

Figure 10.3. Agricultural Soil Nitrogen Transformation Database
Source: Author

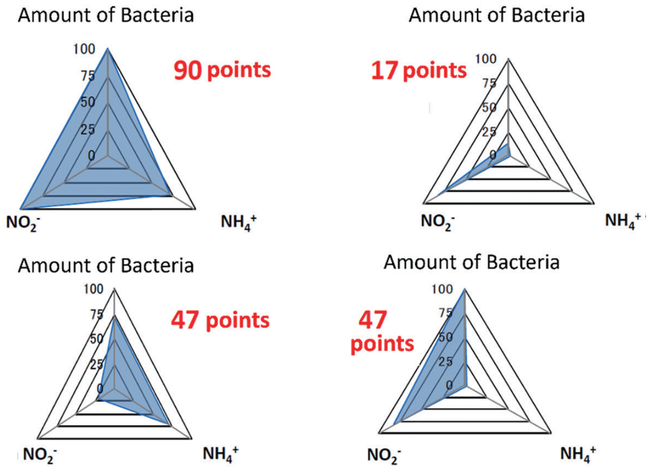

Figure 10.4. Nitrogen and Amount of Bacteria
Source: Author

- Detailed examination of phosphorus metabolism and cycling (Figure 10.5)

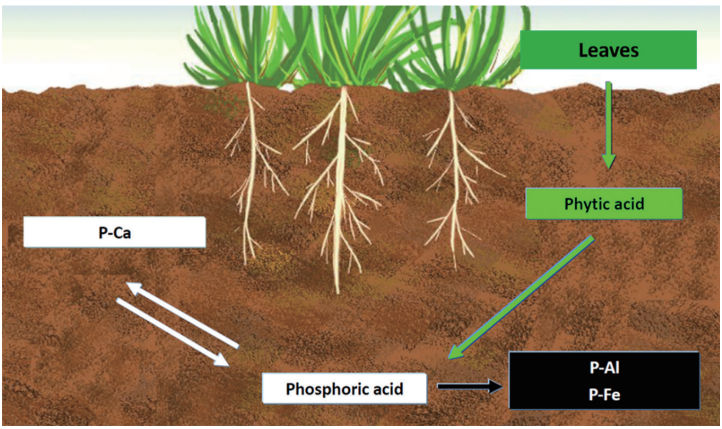

Figure 10.5. Phosphorus Transformation in Soil
Source: Author

- Evaluation of overall soil microbial health and function (Figure 10.6)

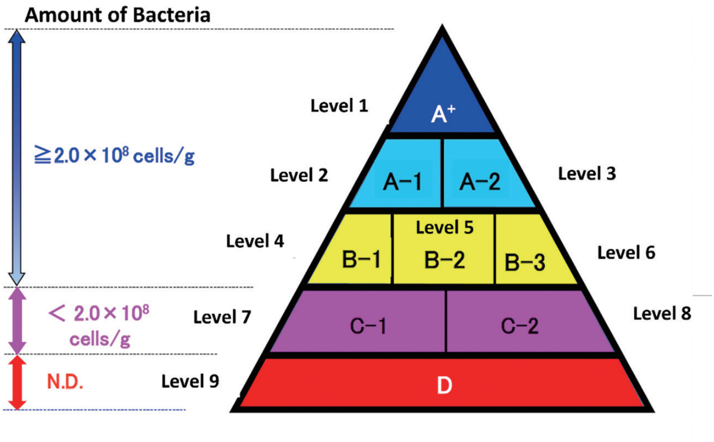

Figure 10.6. Soil Classification
Source: Author.

(2) Soil Diagnosis in SOFIX Analysis

In the SOFIX analysis, several techniques are used to analyze soil biological properties:

- Analysis of bacterial biomass: The bacterial biomass in the soil samples was measured by quantifying the environmental DNA (eDNA)
- Analysis of nitrogen (N) circulation activity: Nitrogen (N) circulation activity was analyzed based on bacterial biomass, ammonium oxidation rate, and nitrite oxidation rate in the soil
- Analysis of phosphorus (P) circulation activity: Phytate (the most dominant form of soil organic P) is used as a substrate in this method

- Analysis of chemical properties: total carbon (TC), total nitrogen (TN), total phosphorus (TP), total potassium (TK), C:N ratio, C:P ratio

Figure 10.7 shows results from soil samples using the SOFIX analysis, which provides detailed insights into soil composition, microbial activity, and nutrient availability through systematic laboratory testing and evaluation.

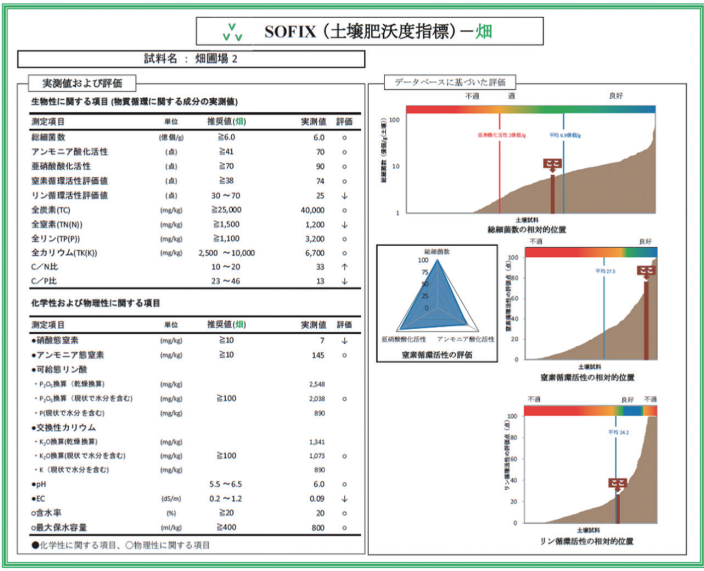

Figure 10.7. A Sample of SOFIX Analysis Result
Source: Author

(3) Impacts of Organic Agriculture on Soil Fertility

According to Tran et al. (2021), the soil type does not determine soil fertility in upland soils. The large variations in bacterial biomass, TC, and TN in all soil types are probably explained by agricultural practices (i.e., chemical or organic farming).

Soils amended with organic fertilizer (SOFIX) and chemical fertilizers showed different tendencies of soil fertility, especially biological properties. Providing organic fertilizers supplies carbon sources for microorganism development in soil. According to Islam et al. (2024), the application of organic fertilizers increased soil bacterial biomass and bacterial community compared to chemical fertilizers (Table 10.1). In addition, SOFIX analysis showed the increase of nitrogen and phosphorus circulation activities in organic fertilizer-amended soils (Pholkaw et al. 2019).

Table 10.1. Difference between Chemical Soil and Organic Soil Regarding TC, TN, and Bacteria

Soil Types	TC (mg/kg)	TN (mg/kg)	Bacteria (x108 cells/g)
Chemical soil	13,600	700	N.D.
Organic soil	41,800	1,300	3.5

Source: (Islam et al. 2024)

Plants cultivated in organic soils demonstrate significantly enhanced growth rates compared to those grown in chemically treated soils (Figure 10.8). The natural composition and biological diversity of organic soil significantly strengthens plants' natural defense mechanisms, resulting in markedly improved resistance to various diseases and environmental stresses (Figure 10.9). Based on comprehensive SOFIX analysis and evaluation metrics, specific soil conditions can be recommended to optimize plant health and productivity while maintaining sustainable agricultural practices.

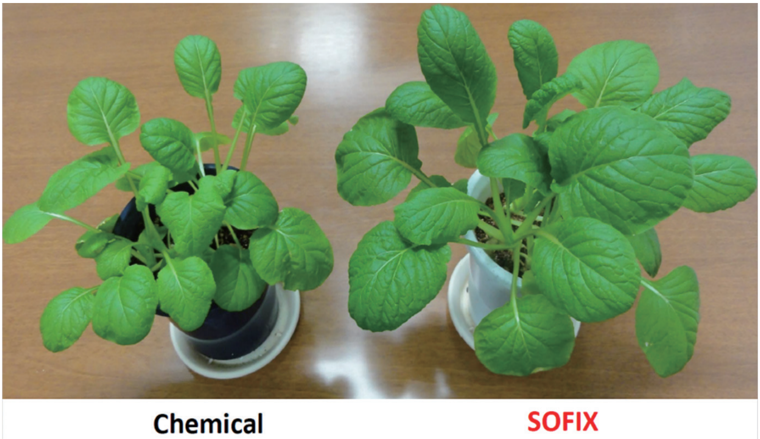

Figure 10.8. Lab Experiments on Komatsuna Plant between Chemical Farming and SOFIX Farming
Source: Author

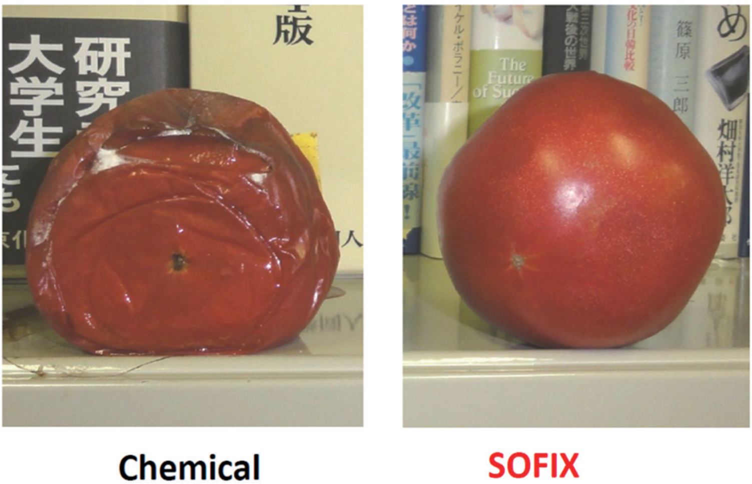

Figure 10.9. Shape Change of Tomatoes at Room Temperature for One Month
Source: Author

(4) SOFIX Applications for Agricultural Development

SOFIX is an innovative soil enhancement system designed to systematically improve soil fertility and boost agricultural productivity. Through a carefully developed process, SOFIX transforms low-quality Type C soil into premium Type A+ soil, implementing specific interventions at each stage of improvement. Figure 10.10 illustrates this transformation pathway, demonstrating how the SOFIX methodically enhances soil quality through multiple stages to achieve optimal fertility levels.

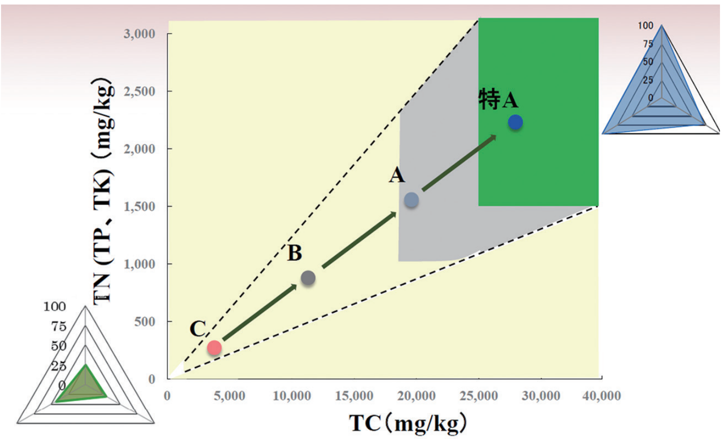

Figure 10.10. Soil Improvement Using SOFIX Techniques
Source: Author

SOFIX is being increasingly adopted throughout Japan's agricultural sector as farmers seek to enhance their organic production capabilities. This innovative approach has gained significant traction among producers who aim to transition from conventional to organic farming methods while maintaining soil health and crop productivity (Figure 10.11).

(1) (2) (3)

Figure 10.11. (1) Organic Rice with SOFIX Application, Shiga Prefecture, (2) Organic Pumkin with SOFIX Application, Nara Prefecture, (3) Juice Product with SOFIX Application
Source: Author

3. Conclusion

This study introduces the efficacy and real-world applications of SOFIX analysis within the context of Japanese agricultural practices. Through detailed examination of soil composition and nutrient profiles, the study demonstrated that the strategic application of organic fertilizers leads to measurable improvements in soil fertility parameters. The findings from case studies suggest that this SOFIX approach represents a particularly promising avenue for developing sustainable agricultural systems that can maintain their productivity over extended periods. The study also highlights how organic fertilizer integration can enhance both immediate soil health metrics and long-term agricultural sustainability, providing valuable insights for farmers transitioning to more environmentally conscious farming methods.

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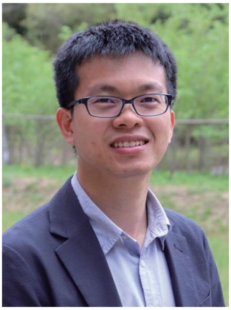
10. Dr. Quoc Thinh TRAN



Chapter 10. Using SOFIX Analysis for Soil Fertility Evaluation in Japan

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