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LTFE: A tool to study changes in soil properties

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Abstract
Long-term experiments are conducted to assess the long-term viability of a particular agro-ecosystem. Long-term field experiments will become more necessary in the future since new analytical methodologies and models will be unable to replace them. Instead, they serve as a necessary foundation for the calibration and validation of these techniques. In order for agriculture to remain viable, soil fertility must be maintained. As a result, the article focuses primarily on finding soil indicators that are amenable to management strategies for long-term sustainability.

Keywords: long-term field experiments (LTFE), soil fertility, sustainability, agro-ecosystem

Introduction

Long-term fertiliser experiments (LTFE) are a treasure trove of vital knowledge about intensive agriculture's long-term viability. Fertilizer use has become a crucial role in increasing agricultural production over time, and as a result, its use has skyrocketed. The indiscriminate application of chemical fertilizers is thought to have a negative impact on the soil and environment which entails a full study of the influence of fertilizers. LTFE's with a large focus on plant and soil nutrient characteristics have been proven to be of substantial relevance in this regard, as evidenced by the 'Rothamsted Classical Experiments,' which were conducted at Rothamsted in South East England between 1843 and 1856 by J.B. Lawes and J.H. Gilbert. There have been some concerns about the soil fertility and crop output being adversely affected by extended use of chemical fertilisers since the early days of their use. LTFE's started out as agronomic trials to figure out what nutrients agricultural crops needed. Despite the fact that the major aims have yet to be fully justified, they continue to generate valuable agronomic, ecological, environmental, and scientific data. Using the Rothamsted model as a guide, a number of LTFE's were established in various parts of India during the last century, with a primary focus on fertilizer production and development for diverse cropping systems, as well as offering practical direction to extension workers. Long-term experiments are conducted to establish the long-term viability of a particular agro-ecosystem and determine what adjustments, if any, are required to maintain viability; to provide crucial data to farmers, ecologists, and environmentalists; to provide a source of soil and plant material for further scientific research into the soil and plant processes that control soil fertility, plant productivity, water quality, and habitat quality; to allow a realistic assessment of the impact of non-agricultural anthropogenic activities on soil fertility and plant quality; and to offer long-term data sets that may be used to construct mathematical models for anticipating the effects of management methods and climate change on soil parameters, as well as on soil productivity and the environment. Initially, LTFEs were primarily done with a focus on the agronomic element of crop production; soil science did not become important until the early 1900s. Long-term soil experiments (LTSE's), which provide direct observations of soil change and functioning across time scales of decades, data critical for biological, biogeochemical, and environmental assessments of sustainability, are being used to meet economic and environmental demands for food production for the burgeoning population; for predicting soil productivity and soil-environment interactions, as well as constructing models at various scales.

Need for Long-Term Experiments

Treatments provided to an experimental unit for a crop in agricultural trials may not be able to have a major influence in one cropping season, resulting in a residual effect on the following crop. The fact that greater plant growth from repeated nitrogen treatment, as well as reaction to phosphate and potassium, is noticeable in the second or third year (following years) of the experiment may help to explain it. The experiment should be repeated over time at the same site to determine the effect of climate, soil, fertilizer agronomic practices, and other factors on yield and soil properties in order to formulate fertilizer recommendations for crops or to form a conclusive statement about the effect on yield and soil properties. After a few years, they become more stable and predictable, as do reactions to fertilizer treatments (Vats, 2006) [16]. Multiple cropping, irrigation, and pest management strategies, all aimed at increasing output, inevitably have a considerably greater influence on the soil and crop environment. It becomes critical to determine how far the soil may be altered without jeopardising the farm's long-term viability, which is ultimately the source of sustenance. In general, LTFEs play an important role in identifying soil constraints that limit crop yields and in monitoring soil conditions in order to protect crop plants and the food chain from harmful levels of various environmental pollutants in the future, as well as maintaining soil fertility and productivity through appropriate soil ameliorative measures (Santhy *et al*., 1998) [13].

Importance of LTFE's

Major constraints that are being addressed include:

We have optimal values for all macro- and micronutrients in the soil for many decades; we also have limit values for pollutants; however, we do not have optimal values for the most crucial elements in soil i.e. carbon and nitrogen. Crop yields, soil health, and chemical, physical, and biological soil characteristics are all affected by crop rotations. The impact of different management practises, especially fertilisation, on nutrient leaching and ecological soil functions. The effects of climate change on soil qualities are being investigated. Nutrient balances provide evidence of the nutrient effectiveness of various fertilization strategies.

Only long-term field experiments (LTFE) may be able to tackle these challenges.

There are currently roughly 600 long-term experiments with a length of more than 20 years around the world, including grassland studies. However, given the huge diversity of soil and climate conditions, and the fact that each experiment is only unique for local (or very comparable) conditions, this figure appears to be very large (Körschens, 2006) [5]. There are multiple long-term experiments operating in India, with varied mandates and aims designed with local conditions and priorities in mind throughout various states. Because all such trials cannot be considered in order to determine their impact on soil quality and characteristics, AICRP-LTFE can be thought of as a standard collection of experiments for the given cause.

The Indian Council of Agricultural Research began the All India Coordinated Research Project on Long-Term Fertilizer Experiments (AICRP-LTFE) in September 1970 to investigate the effects of chemical fertilisers on productivity and soil quality.

Short-Term vs Long-Term Experiments

When long-term experiments are combined with measurements of essential processes, it is more likely that the full trajectory of system reaction, as well as the trajectories of change in system components, can be interpreted (i.e., species or pools of organic matter and elements). Long-term studies reveal the causes of changes in the slope of responses, the causes of inflection points, and the degree of the long-term change, whereas short-term experiments focus just on the starting trajectories. Long-term experiments can thus explore mechanisms and temporal dynamics in a complementary manner, especially when paired with other research methods (e.g., observational and gradient studies). Long-term trials can demonstrate the relevance of indirect effects in ecological processes that aren't visible in the short term, as well as long-term responses that may vary in long term (Tilman, 1982).

Soil Fertility and LTFE

Long-term experiments are called "listening places" because they require us to push our ears against the soil and strive to hear its pulse (Janzen, 2009) [2]. But what are we listening for exactly? A shift in carbon stocks, a measure of stored solar energy, is one clear "vital indication" (Keeling, 2008) [4]. An ecosystem that is accumulating carbon is growing, whereas one that is losing it is shrinking (Janzen, 2005) [3]. This approach could be especially important because we haven't always done a good job of conserving carbon in the past; in fact, "it is our mismanagement of carbon that threatens the human future" (Orr, 2007) [10]. Similarly, we can track nitrogen flux and storage in soils. Such locations will be increasingly important in the future decades, as ecosystems around the world are under increasing stress, primarily due to human influence. Because of its impact on other physical, chemical, and biological elements of soil quality, soil organic carbon (SOC) is the most frequently reported soil attribute from long-term agricultural studies and is frequently chosen as the key indicator of soil quality and agronomic sustainability (Reeves, 1997) [12]. Long-term fertility experiments (LTFE) are the key source of information for determining the effects of cropping systems, soil management, fertilizer use, and residue use on the quantitative and mechanistic changes in soil fertility and SOC pools (Rasmussen *et al*., 1998) [11].

If agricultural production and environmental quality are to be sustained for future generations, soil fertility must be maintained and improved. In current agricultural production systems, increased inputs and technologies may often compensate for and disguise productivity losses caused by poor soil quality. Increased agricultural inputs, on the other hand, not only impair economic sustainability but also increase the risk of negative environmental consequences (National Research Council, 1993) [7].

Soil Properties and LTFE

Soil pH

The use of nitrogenous fertiliser, regardless of the combination of other nutrients, resulted in a decrease in soil pH, according to an analysis of Alfisols from Bangalore. The degree of the decrease in soil pH increases as the rate of N application increases. The application of nitrogen alone resulted in the greatest decrease in soil pH. However, using FYM kept the soil pH at the same level as it was at the start of the experiment. The addition of lime, on the other hand, improved the pH of the soil. It's interesting to see that the soil pH in the control plot has improved. The decrease in soil pH after applying N is most likely owing to urea's acidity, while the rise in soil buffering capacity after applying FYM is likely related to soil's increased buffering capacity (AICRP-LTFE, 2009) [2].

Bulk density

Regardless of the treatments, bulk density ranged from 1.18 to 1.24 g/cc, and there was no significant influence of the treatments on soil bulk density. As a result, the results demonstrated that 32 years of cultivation or even application of various dosages of NPK fertiliser or manure had little effect on its value (AICRP-LTFE, 2009) [2]. Similar findings were also reported by Swarup (2000) in a long-term fertility trial.

Electrical Conductivity (EC)

Though there was a modest increase in EC relative to the initial level in virtually all of the soils, this was due to the addition of fertilisers to the soils, the increase in EC was not to the extent that it may have an unfavourable effect on soil health and plant growth (AICRP-LTFE, 2009) [2].

Soil Organic Carbon (SOC)

The fundamental soil property that reflects a soil's fertility state is soil organic carbon (SOC). The results of SOC experiments done at several sites with diverse cropping systems under LTFE demonstrated that balanced nutrient delivery resulted in an increase in SOC at all locations. Although the balanced application of nutrients (NPK, NPK+FYM) resulted in an increase in soil organic carbon in Alfisols, Mollisols of Pantnagar and Inceptisols of Barrackpore are exceptions, where fertiliser application and addition of a relatively larger amount of biomass resulted in an increase in soil organic carbon. Cultivation of the soil and fertiliser application increased the rate of oxidation of easily oxidizable organic matter, resulting in a decrease in SOC. The addition of extra carbon by FYM was clearly responsible for the maintenance of SOC under FYM+NPK. At Barrackpore, the situation was almost identical. As a result, the data collected under LTFE at several locations contradicted the theory that fertilizer use and soil cultivation lowered SOC. When chemical fertilizer and FYM were used together, the amount of SOC was always higher than when chemical nutrients were used alone. As a result, the drop in SOC should not be attributed to the usage of chemical fertilizers. SOC decreased only when chemical nutrients were applied in an unbalanced form, such as N or NP, or in less amounts. Many experts have documented the shift in carbon stock as a result of long-term use of manures and chemical fertilizers (Mandal *et al.*, 2008) [6]. The use of FYM for 31 years resulted in a considerable improvement in soil physical quality, which could be related to an increase in SOC, which could lead to a reduction in BD by diluting the soil matrix with less dense material (organic matter) and increasing aggregation (Sur *et al.*, 1993) [14]. The pH and EC of the soil did not differ appreciably. The SOC content (gkg^{-1}) ranged from 4.49 in the control to 7.54 in the NPK+FYM. In the FYM treated plot, the increase in SOC (5.20 gkg^{-1}) over the initial value (2.03 gkg^{-1}) was 56.3 per cent. This could be owing to the resistant organic matter in the FYM, as well as increased root biomass as a result of improved crop development (Manjaiah and Singh 2001; Masto *et al.*, 2006) [7, 8].

Soil Biological Activities and LTFE:

From unbalanced nutrient use to balanced nutrient use, there was an increase in soil respiration. The highest rate of soil respiration in the NPK+FYM treatment is attributed to the addition of carbon, which aids in increasing microbial growth-friendly soil conditions. Both soil C and N biomass are excellent markers of microbial activity, as well as C, N, and other nutrient element mineralization and release into the soil solution from the organic components of soil. The biomass C content measured in the 100 per cent NPK + FYM and 100 per cent NPK treatments was 265 and 212 mg g^{-1}, respectively, and the biomass N content was 30.9 and 24.7 mg g^{-1} soil. These concentrations were significantly higher than the 174 and 20.3 mg g^{-1} values obtained in the control treatment (AICRP-LTFE, 2009) [2]. The data on microbial population counts demonstrated that the NPK+FYM treatment had the highest population of bacteria. However, increasing fertilizer treatment from 50 per cent to 150 per cent resulted in a decrease in population, whereas the opposite was observed in the case of fungal population. The use of FYM led in a decrease in the population of fungi. Increased nutrient application had a negative impact on actinomycetes population, whereas including FYM with fertilizer resulted in a rise in actinomycetes population (AICRP-LTFE, 2009) [2].

Facts derived from the AICRP-LTFE model

- Under upland conditions, continuous treatment of N alone in Alfisols resulted with a severe loss in yield. The addition of FYM, regardless of crop or soil conditions, resulted in an increase in crop yields. The results collected under LTFE at several locations contradicted the theory that fertilizer application and soil cultivation lowered SOC. When chemical fertilizer and FYM were used together, the amount of SOC was always higher than when chemical nutrients were used alone. As a result, the drop in SOC should not be attributed to the usage of chemical fertilizers. The results on available N dynamics clearly showed that, regardless of cropping scheme or soil, balanced nutrient treatment always resulted in an increase in available N status in soil. However, the legume cropping method aided in the accumulation of available nitrogen in the soil, whereas heavy rainfall and soil porosity decreased the available status of nitrogen in the soil. According to soil studies, the amount of P applied is always greater than the amount of P taken up by the crop. Excess fertilizer P applied to crop uptake resulted in a build-up of accessible P in the soil. The results of K status in soil measurements taken at several locations revealed that the absence of K in fertilizer schedules resulted in a decrease in available K, regardless of soil type or cropping method. The application of NPK+FYM improved the soil's available K status.
- Continuously growing a crop with fertilizer resulted in a decrease in bulk density and cone penetration resistance, according to the analysis of soil physical conditions. In the case of hydraulic conductivity and mean weight diameter, however, the opposite was found to be true. The combination of fertilizer and organic manure in tandem had the greatest impact on all soil physical parameters.
- Microbial population studies revealed a decrease in populations of actinomycetes and bacteria as fertiliser nutrient administration increased. However, even in the presence of fertiliser, the population of these microorganisms increased when FYM was added, whereas the population of fungus decreased.

Limitations of LTFE

Despite the many benefits of long-term trials, there are certain limitations like chances of spatial variability; variations in plot size result in edge effect; quantification of landscape-scale processes is challenging; failed to capture the diversity of agricultural practices; unsuitable for small-scale farming; and ineffective in generating policy and management recommendations.

Future thrust

We don't have defined key soil quality parameters for assessing soil quality, unlike air and water. As a result, future efforts should focus on identifying soil indicators that are responsive to management approaches and are responsible for long-term sustainability; evaluation of the soil quality index (SQI) under various management and agricultural methods; to understand how organic pools and dynamics of carbon, nitrogen, phosphorus, potassium, and micronutrients in soil affect soil quality and crop yield, more research is needed; determining why there is no cationic micronutrient deficiency despite the fact that there is no external application of the same.

Conclusion

Long-term experiments are conducted to assess the long-term viability of a particular agro-ecosystem and identify what adjustments, if any, are required to maintain viability. Long-term field experiments will become increasingly important in the future, as new analytical approaches and models will not be able to replace them. They constitute, on the contrary, an essential foundation for the calibration and validation of these procedures. Soil fertility must be maintained in order for agriculture to be viable. Balanced fertilization with organic matter addition found to have a considerable positive influence on soil fertility and productivity. LTFE's aid in determining the precise effects of various treatments on soil and crop environment.

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