Available online at
http://currentagriculturetrends.vitalbiotech.org/

ISSN (E): 2583 – 1933
Curr. Agri.Tren.:e- Newsletter, (2026) *5*(5), 32-34

Current Agriculture Trends:
e-Newsletter

Article ID: 633

Cow Dung to Carbon Credits: Changing Paradigms of Soil Fertility

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Article History
Received: 3.5.2026
Revised: 7.5.2026
Accepted: 12.5.2026

INTRODUCTION

The understanding of 'soil' has shifted from merely a passive growth medium to a complex, living ecosystem that regulates nutrient cycling, water dynamics, and atmospheric carbon levels. Previously, farmers used experiential knowledge, such as soil color, tilth, and crop vigor, to assess fertility. Currently, the parameters used to measure soil health include soil organic carbon (SOC), cation exchange capacity (CEC), microbial biomass, and nutrient indices. This development distinguishes three major phases in the evolution of agriculture:

1. The ecological phase: characterized by dependence on natural nutrient cycling;
2. The industrial phase: characterized by synthetic inputs and
3. The phase of ecological intensification: reconciling productivity and sustainability.

The progression in soil management today has shifted toward carbon, toward a paradigm in which soil is not only a production resource but also a key element in climate regulation strategies. Traditional agricultural systems have been based on the principle of closed-loop nutrient cycling, in which nutrients taken up by crops are replaced by organic inputs from the farm ecosystem itself. These inputs consisted of farmyard manure (FYM), compost, leaf litter, and green manure crops, which were the basis of the nutrient cycle. Livestock integration was paramount; cattle, for example, converted crop residues into manure, effectively recycling nutrients back into the soil. The process facilitated the emergence of a self-sustaining agroecosystem with low dependence on external inputs.

Biological processes are the primary driving force of nutrient transformations. Microorganisms helped to break down organic matter, releasing nutrients in forms that plants could absorb. This slow-release mechanism ensured that nutrient availability synchronized with crop demand and minimized nutrient losses. Cow dung was the backbone of soil fertility management due to its multifunctional properties:

- Chemical function: Supplies vital macro-nutrients and trace elements.
- Physical function: Increases aggregation, porosity, and water holding capacity of the soil.
- Biological function: It stimulates microbial activity and enzymatic functions.

Unlike synthetic fertilizers, cow dung helps form humus, which is important for the long-term productivity of the soil. Humus increases CEC, which improves nutrient retention and provides a reservoir for slow-release nutrients. Soils rich in organic matter are also more resilient to climatic stresses, particularly drought and heavy rainfall, because they have better infiltration and water storage. The indigenous farming practices were in tune with the principles of ecology, such as:

- Crop rotation: Prevented depletion of nutrients and broke pest cycles
- Legume integration: Improved biological nitrogen fixation
- Mixed cropping: better use of resources, less risk
- Residue recycling: Organic matter balance maintained

These systems were low-input but highly efficient in their use of resources, thus ensuring sustainability across generations. The systems were stable and environmentally benign, although the yields were moderate.

Shift to chemical-based farming methods.

The Green Revolution was the rise of input-responsive agriculture. Genetic engineering produced high-yielding varieties (HYVs) of wheat and rice that produced more biomass but required high levels of nutrient inputs. The introduction of irrigation infrastructure and fertilizer subsidies hastened the adoption of these practices. This change was important in reducing food shortages, but it also began a pattern of dependence on external inputs. Synthetic fertilizers provide nutrients in very soluble forms, so that plants can take them up quickly. Nitrogen fertilizers, especially urea, were mainly used for their short-term effects on vegetative growth. However, this method emphasized plant nutrition over soil health. The biological and organic aspects of soil fertility were largely ignored, and soil organic matter steadily declined. During the initial decades, fertilizer use led to important gains in crop productivity. But gradually, the system began to show diminishing marginal returns, and farmers had to increase fertilizer application rates to achieve similar yields. The economic consequences were higher production costs, less efficient use of inputs, and greater dependence on external inputs.

The imbalance revealed the unsustainability of a strictly chemical approach. Long-term exclusive use of chemical fertilizers has led to different forms of soil degradation: (1) Chemical degradation: nutrient imbalance and micronutrient deficiency; (2) Physical degradation: soil compaction and decreased infiltration capacity; and (3) Biological degradation: decrease of microbial diversity and activity. Limited organic inputs reduced soil organic carbon and impaired the soil's structural and functional integrity.

By the end of the 20th century, there were several signals of soil stress, including: plateauing or declining crop yields; increasing susceptibility to pests and diseases; environmental pollution, including nitrate leaching and eutrophication; and emissions of greenhouse gases such as nitrous oxide. Such challenges indicated the need to reinject ecological principles into modern agriculture.

Sustainable Transition and Regenerative Approaches

The present-day soil science approach recognizes that fertility results from the interaction of chemical, physical, and biological components. The goal of sustainable management is to optimize all three simultaneously, not just nutrient inputs. This holistic view blends traditional practices with modern science for more resilient farming.

Integrated Nutrient Management (INM)

INM is a strategic methodology that integrates Organic manures (such as FYM and compost), crop residues, biofertilizers, and chemical fertilizers. The goal is to keep the soil fertile and productive over the long run while reducing its environmental impact. INM increases nutrient-use efficiency by providing balanced nutrients and reducing nutrient losses through leaching and volatilization.

Biological and organic inputs

This renewed emphasis on soil biology has resulted in greater use of: - Biofertilizers – improve nutrient availability through microbial activity - Vermicompost – increase nutrient content and microbial diversity - Mycorrhizae – increase phosphorus uptake and stress tolerance. These inputs help to improve the biological functionality of soil, which is important for sustainable fertility management.

Regenerative Agriculture

Regenerative agriculture is taking sustainability to the next level by improving soil ecosystems. Its fundamental principles are: Minimal disturbance: reduces soil erosion and maintains soil structure; Permanent cover: protects soil from temperature fluctuations and moisture loss; and Diversity: enhances ecosystem stability and nutrient cycling. These practices enhance soil health and build farm resilience to climate variability.

Soil Carbon

Soil organic carbon (SOC) is gaining recognition as an important measure of soil health and sustainability. Higher SOC levels help improve soil structure and aggregation, increase water retention, enhance nutrient retention and bioavailability, and support diverse microbial life. Environmentally, SOC acts as a significant carbon sink, directly connecting soil management practices to efforts aimed at reducing global climate change.

Future Outlook & Carbon Economy

Carbon farming involves agricultural methods that boost carbon capture in soils and plants. This includes practices like agroforestry, cover cropping, and conservation tillage. Such methods transform farms into carbon sinks, aiding in climate change mitigation and boosting productivity. Carbon credits are units representing stored carbon. Farmers practicing climate-smart techniques can earn and sell these credits in carbon markets, resulting in environmental benefits and extra income. The process generally includes:

1. Adoption of approved carbon-sequestering practices
2. Measurement and monitoring of carbon levels
3. Verification by certified agencies
4. Issuance and trading of carbon credits

Technological innovations are speeding up this shift by using remote sensing for soil and crop monitoring, AI-driven nutrient advice, and digital platforms to track carbon credits. These tools improve the accuracy, efficiency, and scalability of sustainable practices. However, carbon farming encounters challenges such as high measurement and verification costs, low awareness within the agricultural community, and fragmented landholdings. Addressing these issues requires policy efforts, capacity building, and promoting digital inclusion to ensure fair participation.

CONCLUSION

The shift from using cow dung to issuing carbon credits marks a comprehensive transformation in agricultural practices. Traditional methods emphasized maintaining ecological balance; contemporary approaches focus on maximizing productivity; and emerging strategies seek to integrate both principles while meeting climate responsibilities. The future of soil fertility lies in understanding soil not merely as a resource but as a living ecosystem and an economic asset. By combining ancestral knowledge with scientific innovation, the agricultural sector can achieve sustainability, resilience, and profitability, thereby ensuring the continued viability of soil to support life for future generations.