

“Biological Production, Ecology” field

Achievement : Sustainable soil management for global food security and mitigation of climate change

Prof. Rattan Lal (United States of America)

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Summary

Soil is important not only for food production but also for a wide range of functions in environmental conservation, such as carbon sequestration, environmental cleanup, material circulation and preservation of biodiversity. Prof. Rattan Lal demonstrated in Africa’s sub-Saharan region that the “no-tillage cultivation method” can ensure stable biological production while preventing soil erosion, and has undertaken great efforts to spread this technique and promote the idea that a healthy soil is the basis of sustainable agriculture and good environment.

While the soil is usually plowed in agriculture, the no-tillage cultivation method which does away with plowing was adapted and tested by Prof. Lal who had noticed the outflow mechanism of soil organic matter. Based on this finding, Prof. Lal began studying the relationship between soil and global environmental issues.

As a result of the analysis of the global carbon cycle, he found out that with appropriate management, soil not only isolates carbon and reduces CO₂ in the atmosphere but also becomes fertile, thereby improving food production.

And as a result of his continuous appeal to the international community of the importance of appropriate soil management, Prof. Lal’s ideas were formulated into the policy of international effort for soil preservation called the “4 per 1000 Initiative”, and is closely tied to the promotion of the UN’s Sustainable Development Goals (SDGs).

The degradation of soil by humankind

Soil is made over a very long time span. For example, immediately after a landslide, the ground is covered with rocks. The rocks then weather and gradually become finer, turning into sand and eventually to clay. Meanwhile, as the growth of plants gradually increase, microorganisms decompose the dead plants over a long period of time. This results in the formation of organic matter called “humus”. It takes hundreds of years for clay, microorganisms and humus to form aggregates and become stable soil.

Ever since mankind began agriculture, soil has been exposed to human-induced changes. The plowing of soil increases the supply of oxygen and fuels the activities of microorganisms, thereby driving the decomposition of organic matter. The decomposed organic matter then becomes the nutrients that help agricultural crops grow. In other words, agriculture is originally a process of extracting organic matter accumulated in the soil over a very long span and turning it into crops. As mankind gained experience in agriculture, productivity has increased through the use of fertilizers, but this also meant the faster depletion of organic matter in soil.

In fact, when averaged out, the soil thickness for the whole earth is only about 30 to 40 cm. Despite there being very little soil, it produces food for the world’s population that now exceeds 7 billion people. If we keep using the organic matter in soil at the current pace, we will be in danger of not being able to produce enough food for the growing world population. Furthermore, the organic matter in the soil will eventually become CO₂ and escape into the atmosphere.

Between 1750 (immediately prior to the industrial revolution) and 2017, the amount of CO₂ emitted into the atmosphere (in carbon equivalent) was 235±95 gigatons (1 billion tons) due to human-induced changes to land such as deforestation. This is almost half the amount that was emitted by the burning of fossil fuel and cement production, which stands at 430±20 gigatons.*

As described, soil has a major impact on food production and global environment. From this perspective, Prof. Lal addressed these issues by focusing on the importance of soil physical management and has made two major achievements.

No-tillage agriculture will save our soil

Prof. Lal’s first achievement is the adaptation of the “no-tillage cultivation method” that increases crop production while preserving the stable state of soil organic matter in Africa’s sub-Saharan region suffering from severe soil erosion, and the subsequent spreading of the technique throughout the tropics and elsewhere.

Prof. Lal, who was born in India, graduated from the Punjab Agricultural University, then earned a master’s degree from the Indian Agricultural Research Institute. He then moved to the United States and earned a Ph.D. from the Ohio State University in 1968. In 1970, he began researching at the International Institute of Tropical Agriculture (IITA) in Nigeria and worked on addressing the issue of soil erosion and physical degradation.

The sub-Saharan region at the time was suffering from soil deterioration due to the use of heavy machinery for deforestation and cultivation. The problem was made worse by the prevalence of erosion due to rain and wind, making it difficult for the crops to grow sufficiently.

Prof. Lal, who specializes in soil physics, conducted a detailed investigation of the size distribution and kinetic energy of raindrops and clarified the conditions under which soil erosion occurs. He also quantified the effect of mulch (the covering of soil surface) for the prevention of soil erosion. Plowing not only makes soil erosion more likely to happen but also makes it easier for aggregates in the soil to break due to temperature rise on soil surface and raindrops. By elucidating this mechanism, he discovered how soil organic matter is lost. Based on these analyses, Prof. Lal promoted the “no-tillage cultivation method” as a way of preventing soil erosion and stabilizing biological production. He gradually increased the scale of his cultivation experiments, repeating and refining it until the method could yield production increase that would be adequate for farmers to consider adoption.

The method he devised was:

- 1) Leave the surface soil protected with roots and stumps when cutting forests,
- 2) Plant and grow cover crops (such as plants of Leguminosae family) immediately after cutting,
- 3) Plant the seeds of target crops where the cover crops have died without plowing.

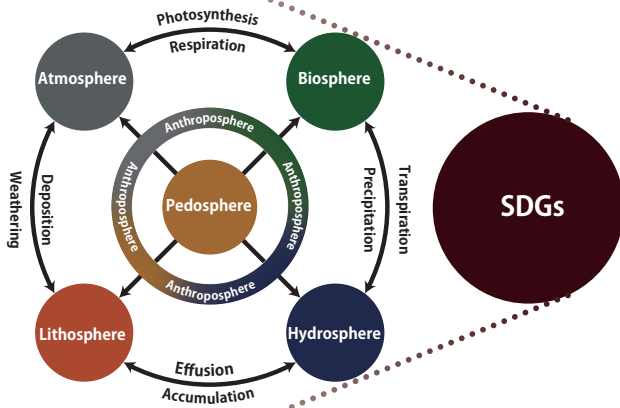
The dead cover crops will not only prevent soil erosion but also serve as mulch and compost for the target crops while conserving water and moderating soil temperature.

Following this discovery, Prof. Lal, who devised the method to prevent soil erosion and improve the growth of crops by the counterintuitive concept of “no-tillage”, worked in Asia including his home country India as well as Brazil and Australia to spread the no-tillage cultivation method. Prof. Lal has also taught the “non-tillage cultivation method” to researchers worldwide who came to IITA, leading to its adoption throughout the tropics and globally. Translation of his academic findings in soil physics into a sustainable method of farming with real-life applications is Prof. Lal’s biggest achievement.

Isolating carbon into the soil

In 1987, Prof. Lal became a professor at the Ohio State University. With nearly 20 years of experience accumulated while researching at IITA, Prof. Lal conducted research on the relationship between soil and global environmental issues. He revealed that the proper management of soil is crucial if we are to solve the major issues of food production and conservation of the global environment. In addition, he continued to promote the proper management of soil so that the real-life application of his academic findings would become established in society. His efforts eventually led to the realization of international efforts. This is Prof. Lal’s second achievement.

When viewed from a different perspective, it can be said that organic matter contained in the soil serves to isolate carbon. Whereas there are 1,550 gigatons of carbon that exists as soil organic matter and 950 gigatons as soil minerals, coming to a total of 2,500 gigatons. This is more than three times the carbon contained in the atmosphere (800 gigatons) and 4.5 times the carbon that exists as plants (560 gigatons).



The relationship between the pedosphere and the ecosphere of Earth seen in relation to the SDGs. The pedosphere at the center is related with everything else, and plays a major role in the achievement of SDGs. Diagram based on Fig. 15-2 of “Soil and Sustainable Development Goals” (Catena soil sciences publications) edited by R. Lal et al.(2018).

If we can confine more carbon into soil which we now understand it to be a huge “warehouse”, we can suppress the rising levels of CO₂ in the atmosphere and perhaps help to alleviate global warming. In addition, this can also stop the decline of soil organic matter caused by agriculture and improve food production, as well as bring about secondary effects such as the reduction of water pollution and the conservation of biodiversity. While many methods of carbon sequestration have problems such as technical difficulty, cost, adverse effects on the environment and so on, soil management is a relatively simple, safe and inexpensive method that is more superior.

With this goal, Prof. Lal analyzed the circulation of earth’s carbon from data, examined the relationship between soil, the environment and agricultural production in detail, and studied how soil should be managed in order to increase the isolation of carbon. And in 2004, he published the results in “Science” magazine. His paper proposed not only the no-tillage cultivation method for areas with eroded soil but also various other types of soil management methods, and estimated that every year 0.4 to 1.2 gigatons of carbon could be isolated in cropland soils throughout the world.

Following the publication of his paper, Prof. Lal has served as a committee member at relevant academic conferences, government agencies and international organizations, and has even made presentations to appeal for the implementation of the countermeasures he put forth. His efforts eventually bore fruit at the 21st Conference of the Parties to the United Nations Framework Convention on Climate Change held in Paris in 2015, when the initiative to “increase soil carbon by 4/1000 per year” (4 per 1000 initiative) was launched.

It is calculated that if this goal is achieved, the increase in carbon due to the burning of fossil fuels could be offset, thereby drastically reducing the annual increment of atmospheric CO₂. His ideas have also been reflected in the AAA Initiative (the initiative for the Adaptation of African Agriculture) adopted at the COP22 held in Marrakesh in 2016. Furthermore, Prof. Lal’s ideas are expected to contribute towards the achieving of 4 of the 17 of sustainable development goals (SDGs) formulated by the United Nations in 2015, namely Goal 1 “No Poverty”, Goal 2 “Zero Hunger”, Goal 13 “Climate Action”, and Goal 15 “Life On Land” and achieving land degradation neutrality.

Prof. Lal, who initially began his research to stop soil erosion in the sub-Saharan region, expanded his activities in order to help solve global food and environmental issues, and has consistently conveyed the importance of soil to the international community. With his unstoppable enthusiasm and spirit of inquiry, today, Prof. Lal is also conducting research on the relationship between urbanization and soil.

*According to the Global Carbon Budget (2018) by Le Quere et al. published in Earth System Science Data 10:2141-2194