

# PEDOSPHERE AND ATMOSPHERE

## Changes in Earth Environment and Agriculture

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### 1. INTRODUCTION

In 1969 everything changed. That year for the first time we saw a photograph of the entire blue earth, taken from the Space Ship Apollo. It was just like viewing one's own image reflected on the surface of a river. The photograph becomes a physiological symbol of the age, expressing a certain self-awareness that is growing everywhere in the world. This is the self-awareness that the earth and we are parts of a single system and that we cannot separate ourselves from the earth as a whole.

The figure of the earth seen from the cosmos gave us a new insight into the possibility that the earth as a whole may be a living creature. "The earth is an oasis in the cosmos." said one astronaut, Jean Surman. These words express the feeling of the astronaut who has travelled through cosmic space, which is a desert free of life, the feeling that the earth is a living creature.

The year 1969 was a most creative year for mankind, James Lovelock suggested at that time that the earth was the largest creature (GAIA) in the solar system. The concept of GAIA, the living earth, may be the most unique idea of the century. According to this concept, the living creatures, air, oceans and ground surface of the earth form one complex system, which can be considered as a single organic body. This system is able to maintain the planet as a place suitable for life. This concept clearly showed space scientists, biologists, geologists, agronomists, and other scholars and researchers that environmental problems couldn't be solved unless the earth is treated totally and as a part of a complex cosmic ecology.

### 2. Origin of Ecosystem

The earth came into existence 4.6 billion years ago, and since then, vast and immeasurable time has

passed. Life appeared on the earth for the first time 3.5 billion years ago. The first life is thought to have been unicellular organisms, then, followed by photosynthetic organisms. 500 million years ago, the earth started to form the ozone layers which is a precious barrier for life. As a result, primitive plants and animals finally appeared on the land. Oxygen density reached almost 21% 400 million years ago, and strangely enough the earth has kept the same level even now. Then, the archetype of soils was completed 350 million years ago in the Silurian period.

In this process a crosslinked system was completed in the interdependence between material circulation and life through the relation among the soil ecosystem, atmosphere and the biological system, and life has maintained its existence on the earth. Life can maintain its existence because the ozone layer was formed in the stratosphere and the earth has been given a necessary and comfortable environment for life by the greenhouse effect gases. And the human race can survive because oxygen density has been kept at about 21% for as long as 400 million years and soil has been generated continuously for 300 million years.

The human race first appeared on the earth 1.7 million years ago. Human activity started to effect the material circulation of the earth only 200 years ago since the Industrial Revolution. If the above-mentioned 400 million years old crosslinked system is printed out on a 1-year-scale film, this 200-year period started only after 23;59 of December 31.

The thickness of the soil which externally supports the food production for the human race, is said to be about 18 cm on average. And birds fly in the sky, forest fires hardly occur and we can breath easily almost 21% oxygen concentration is maintained in the troposphere reaching 15 km above the ground.

To protect life against ultraviolet rays emitted from the sun, and to make life possible, the earth created its own precious barrier, the ozone layer, by spending on astounding 500 million years. Nevertheless, if all of the ozone is condensed by the present atmospheric pressure onto the surface of the earth, the ozone layer is only 3 mm thick. All of us, the human race, are living thanks to the soil of 18 cm, atmosphere of 15 km, and the ozone layer of 3 mm.

However, the ozone layer in the atmosphere, which is the barrier of the earth, the atmosphere composition related to the greenhouse effect, and the soil, which is the source of food production, are now about to change rapidly.

### 3. Birth of Anthroposphere

Human activities are closely related to the changes in the earth's environment. The global of material cycle has been transformed as a result of the clearing of forests for increasing the arable land area, expansion of the livestock industry, changes the combustion of fossil fuels, discharge of wastes, cutting through mountains for mineral deposits and the distribution of heavy metals on the earth. Mankind is now modifying the original environment of the earth.

The biosphere of the earth is suffering from environmental disruption as follows: global warming, depletion of the ozone layer, deforestation, marine pollution, air pollution, acid rain, water pollution, soil erosion, pollution with metals, diminishing of biological diversity, pollution from nuclear wastes, pollution from livestock and human wastes and the depletion of underground water.

Environmental limits have also been reached in agriculture, forestry and fisheries. Productivity in a large number of existing farmlands has been reduced though new arable land can not be found easily. Deforestation, overgrazing, excessive fishing, and salinization of soils and desertification have recently reduced the production of food. Water resources in many regions have been depleted and contaminated. Agricultural production and urban water resources will be strictly limited in the future.

Agricultural activities themselves, through the increase of food production, affect the environment.

Nitrous oxide derived from the application of nitrogen fertilizers, from livestock wastes, and methane produced from flooded rice fields and ruminant livestock, effects the atmosphere, causes global warming, and destroys the ozone layer.

### 4. Fluctuation of Soil

As mentioned before, soil formation started 350 million years ago in the Silurian period. After that the soil continued to grow for many ten thousands of years mutually depending on plants and animals living on the land, and continued to form fertile and thick layers of soil.

All kinds of plants and animals were forced to maintain soil formation by the law of natural selection. No plant could survive on the slopes of mountain if they didn't help prevent soil erosion, and no animal could develop the intelligence and knowledge to propagate if they didn't support the growth of plants and soils. Supposing that plants and animals had evolved to destroy the soil, they would have destroyed food resources for themselves or led themselves to ruin.

By the way, how long does it take to form the soil? Though it depends on the type of rock, climate, geographic feature, vegetation, and other various factors, in North America, for example, it is estimated that 500 years may be required to form 1 cm of soil.

It was no more than 1.7 million years ago that the human race appeared on the earth. They had adapted themselves to the natural environment in order to survive without breaking the natural process of mutual reliance between the soil and plants or animals. However, when civilization appeared about 6 000 years ago, the soil formation process completely changed in most of their dwelling areas. Since then many living things coexisting with the soil, and the quantity and quality of soil, began to decline.

Civilization has refused to comply with the law of nature and considered itself the lord of creation. Since then, the human being established agricultural systems, which seem to be eternal, based on our intelligent use of soils the soil using and tools we invented. Agricultural civilization took root in a

plundering and destructive way. The human being civilized every part of the world using the soil as a resource. In other words, the human being has lived on plants produced by the soil as their source of energy. Of course it required the fixation of carbon dioxide by solar energy or other necessary conditions besides solar energy.

Carter and Dale<sup>1)</sup> started in the introduction of their book, "Topsoil and Civilization", along with civilization, the human being acquired so many techniques, but very few learned to preserve the soil which is the source of food for themselves. Viewed from the opposite side, the most excellent accomplishments of the human being always destroyed the natural resources on which their own culture depended.

The world's history tells us that the collapse of soil is also the collapse of civilization. Why did the Greeks fall after a short glorious period that lasted no longer than 30 to 40 generations? They relied on agriculture to live as well as other folks. However, as the population grew they exploited soil fertility. The demand for commercial farm products accelerated soil erosion. As the result the soil resources were exhausted and the ecosystem started to be destroyed. When Greece had great power they could maintain their prosperity by borrowing the soil of their colonies, but when they were attacked by other nations the Greek Civilization started falling rapidly. This incident suggests that the history of civilization is also the history of the exploitation of the soil resources provided nature.

Rome and other civilizations also had similar histories. And it is shown that the Mesopotamian civilization fell because of soil salinization. We may say that the first chemical pollution in history was the soil salinization in Summer. The situation of Lebanon seems to be very similar to Minos. It is also said that Syrian civilization fell because of the exhausted soil fertility and soil erosion.

As mentioned so far, the rise and fall of the world's civilization is closely related with the soil. The more glorious the civilization, the shorter its existence.

In 1840, a German scientist, Liebig, stated that it is necessary to regain all the losses plundered from

there to maintain the fertility of soil and he radically changed scientific understanding about the fertility of soil. Liebig cited Chinese and Japanese farming methods as models to be respected. But those are a thing of the past now.

The human being is not only eating food but also living on the ground. As a result of exhausting the soil, the ground was washed away and eroded to reveal bare slopes and every grain of soil washed away from the slope shows the actual condition of our consuming society. All the desertified forests and grasslands, soil erosion and soil salinization, are nothing else but the results of our metabolism.

## 5. Change of Atmosphere

Qualitative and quantitative changes in recent human activities brought various environmental problems. These problems have been observed at first as some specific problems caused by heavy metals such as cadmium and mercury, then as extensive phenomena, such as the eutrophication of lakes, and finally developed into environmental problems on a global scale. The results can be seen in the destruction of the ozone layer in the atmosphere caused by chlorofluorocarbon (CFCs), methyl bromide ( $\text{CH}_3\text{Br}$ ) and nitrous oxide ( $\text{N}_2\text{O}$ ), the global warming due to increased  $\text{CO}_2$ ,  $\text{CH}_4$ , CFCs and  $\text{N}_2\text{O}$ , and changes in the atmospheric environment such as acid rain caused by nitrogen oxide or sulfur oxide.

Greenhouse effect gases in the atmosphere are increasing at a very rapid rate, that we have never experienced. The Intergovernmental Panel on Climate Change (IPCC)<sup>2, 3, 4)</sup> summarized composite changes in atmospheric composition. Until the 18th century  $\text{CO}_2$  and  $\text{CH}_4$  had been stable but have increased with the human activity  $\text{N}_2\text{O}$  started to increase since the middle of the 18th century and in particular, it has increased at a remarkable rate in the past several decades, CFCs had never existed before the 1930's. Annual increase rates of  $\text{CO}_2$ ,  $\text{CH}_4$ , CFCs and  $\text{N}_2\text{O}$  are 0.3; 0.9; 4 and 0.25% respectively and these values are very significant.

Principal reasons for these changes in atmosphere composition have been considered to be volcanic activities, mining and the combustion of chemical fuels and nuclear explosions. However, in agriculture ecosystems particularly in the soil ecosystem

the principle components of organisms such as nitrogen, carbon and sulfur are transformed into gases in the process of material circulation to be discharged from the soil to the atmosphere. And these gases discharged into the atmosphere have come to be considered as one reason for changes in atmosphere composition. In fact  $\text{CH}_4$  and  $\text{N}_2\text{O}$  are the most remarkable gases because  $\text{CH}_4$  which is generated from paddy fields has increased with the worldwide expansion of paddy field, and  $\text{N}_2\text{O}$  which is generated from farmlands where nitrogen fertilizer is used, has increased with increasing production and utilization of nitrogen fertilizer.

## 6. Respiration between Pedosphere and Atmosphere

The composition of the air in the soil differs much from the atmosphere composition we breathe. This is because the substances existing in the soil affect the breathing of plant roots and innumerable bacteria, and they transform themselves by various physical chemical and biological reactions. And in this process many gas components are repeatedly produced and lost ceaselessly.

In the soil generally  $\text{O}_2$  is consumed and  $\text{CO}_2$  is produced. Accordingly,  $\text{CO}_2$  density in the soil is several tens or several hundreds of times higher than the approximately 360 ppmv in the atmosphere. On the other hand,  $\text{O}_2$  density is lower in proportion to the  $\text{CO}_2$  density. Though it is much lower than  $\text{CO}_2$  production, other gases, such as  $\text{N}_2$  nitrogen compounds, sulfur compounds and hydrocarbons are also being produced and consumed repeatedly. As mentioned so far, air in the soil consists of different compounds from atmospheric components.

Under the conditions like these, when the density of a certain component of the air in the soil increases, it is partly discharged from the soil into the atmosphere. On the contrary when the density of a certain component of the air in the soil decreases and the density increases in the atmosphere, the soil absorbs this gas by a similar mechanism. In addition active gases in the atmosphere can be absorbed directly to the soil molecule.

The pedosphere and atmosphere closely and continuously interact. This gas exchange between pedosphere and atmosphere can be observed as

results of gas metabolism and physical or chemical reactions of the soil ecosystem. This gas exchange between pedosphere and atmosphere is related to two mechanisms. One is the convection where the air in the soil moves entirely without changing the components because a bias of pressure exists as a whole between the air in the pedosphere and atmosphere. The other important mechanism is the diffusion where flux occurs in proportion to the bias in density from the higher side to the lower side as a result of molecular movement when the bias exists. We often hear a saying that the soil is alive and breathing organism.

We now know more about how gases in the pedosphere influence the changes in gas composition in the atmosphere. In particular some micro-gases such as  $\text{CH}_4$  and  $\text{N}_2\text{O}$  produced in the soil ecosystem and discharged into the atmosphere, are closely related to the greenhouse effect and ozone destruction on a global scale. In recent years many researchers have paid attention to the production reactions, and flux of these gases in the soil ecosystem as well as the techniques to mitigate their efforts.

## 7. Conclusion

The soil which supports our food production is on average only about 18 cm thick. The troposphere containing 21% oxygen was formed about as long as 400 million years ago and its thickness are said to be only about 15 km. To prevent ultraviolet rays emitted by the sun and enable life to evolve, the ozone layer a precious barrier of the earth, was formed over the immeasurable time of as long as 2 billion years, but the thickness of the ozone layer is only about 3 mm at surface atmospheric pressure.

Although we must keep relationships forever with the 18 cm soil layer, 15 km atmosphere and 3 mm ozone layer, we are about to exhaust these precious resources so easily.

The human being is not only living comfortably, but also we also consuming and exhausting the ground, atmosphere and the ozone layer. Every grain of the soil washed out by erosion as a result of the soil exploitation, every molecule of micro gases and every molecule of ozone in the atmosphere, the former continuing to increase and the latter continu-