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Toward Partial Reorientation of Land Management for Sustainability in View of Material Circulation: Biophysical and Historical Analysis

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Abstract

This paper explores two major issues, from biophysical and historical viewpoints. We examine land management, which we define as the long-term fertility maintenance of land in relation to agriculture, fishery and forestry. We also explore humans' positive role as agents aiming to reinforce harmonious materials circulation within the land. Liebig's view on nature, agriculture and land, emphasizes the maintenance of long-term land fertility based on his agronomical thought that the circulation of matter in agricultural fields must be maintained with manure as much as possible. The thoughts of several classical economists, on nature, agriculture and land are reassessed from Liebig's view point. Then, the land management problem is discussed at a much more fundamental level, to understand the necessary conditions for life in relation to land management. This point is analyzed in terms of two mechanisms: entropy disposal on the earth, and material circulation against gravitational field. Finally from the historical example of the metropolis of Edo, it is shown that there is yet another necessary condition for the sustainable management of land based on the creation of harmonious material cycles among cities, farm land, forests and surrounding sea areas in which humans play a vital role as agent.

Keywords: land management, material circulation, sustainability, Liebig, Edo

JEL Classification: Q10, A12, B10

1. Introduction

We are aware that any civilization, once flourished, has the same fragility and impermanence as a living thing. The fall of the Roman Empire is one of the most well known examples of the fragility and impermanence of any civilization. Many other historical instances of such collapses are well documented (e.g., Tainter, 1988; Diamond, 2005) and there is a number of conceivable causes for these collapses; economic, political, institutional, biophysical, etc. One such cause is biophysical or ecological in nature: land deterioration due to intensive agricultural production without maintaining nutritional circulation. We can see the crucial role played by land in early Greece and the results of the ill-treatment of land, in the fourth century B.C. in one of Plato's dialogues Critias (Plato 1977).

Recent concern with peak-oil and climatic change triggered a lot of heated discussions on energy use patterns and its possible consequences on the survival of human species on the earth. However, in our view, there has been no serious scientific investigation on both land management and humans' positive role as an agent aiming at maintaining harmonious material circulation within land.

These two issues, land management and humans' positive role, are the main concerns of this paper. By land management we mean the long-term fertility maintenance of land as a source of organic substances in relation to agriculture, fishery and forestry. One of the authors of this paper once discussed the importance of Liebig's view on material circulation and its relation to agriculture (Mayumi 1991). The critique of Liebig is based on his view that land and its natural power are the source of wealth for nations and of wealth for the human species as a whole. His scientific thought, which placed human beings in a natural existence with great cycles of nature going on without intervention by human beings, enabled him to posit his view and to part from the type of agricultural economics which treated nature as human property. Section 2 presents several classical economists' thoughts (the physiocrats, Adam Smith, and T. R. Malthus) on nature, agriculture and land that are reassessed from Liebig's point of view. Section 3 treats the land management problem from a much more fundamental level. In this section, two mechanisms, entropy disposal on the earth and material circulation against gravitational fields, are introduced to understand the necessary conditions for life to continue living in relation to the land management. After analyzing Schrödinger's theory of "what is life", we present the entropy disposal mechanism on the earth. This section also treats how the material circulation mechanism is maintained on the earth against gravitational fields, and why this mechanism is far from satisfactory when economic activities are enhanced. Tamanoi, et al. (1984) once presented a brief explanation of the material circulation system of the metropolis of Edo. Section 4 presents a more comprehensive analysis of the Edo scheme as a historically ingenious example of establishing and enhancing the material circulation mechanism among cities, farm land, forest and the surrounding sea area where human beings are actively involved to maintain material circulation. Thanks to this scheme, Edo, the capital city of Japan with more than a million people was maintained for more than two hundred and fifty years (1603-1867). Section 5 presents several concluding remarks.

2. Revisiting the Classical Economists

We have to recognize "the crucial importance of the entropic degradation of the soil through continuous cultivation" (Georgescu-Roegen, 1971, p. 302). An unfortunate fact is that we have been facing this entropic degradation of the soil ever since the time we learned to practice agriculture. It should be a top priority to try to prevent this erosion as much as possible. We should create an atmosphere where land is a property for the human species, future as well as present.

Let us begin with the Physiocrats whose 'leader', F. Quesnay, "always retained rural, agrarian sympathies" (Taylor, 1960, p. 14). According to L. A. Maverick, this esteem for agriculture by the Physiocrats was influenced by the Chinese. Quesnay and his colleagues reached a conclusion from the accumulated fund of information that "in China agriculture was held in great esteem and was given governmental assistance. ... Fernandez Navarrete suggests that the European nations should imitate the Chinese in their care for agriculture" (Maverick, 1938, p. 60 and p. 63). Their claim that agriculture was "the only 'productive' (or surplus-generating) economic activity" (Barber, 1968) had a grain of truth. Therefore the following statements by O. H. Taylor are off the point:

Quesnay's *particular* analysis, however, also embodied, in no real connection with any of those true and usefu1 ideas but as a fundamental doctrine in his system, a peculiar, mistaken notion which expressed his "agrarian bias" (Taylor, 1960, pp. 21-22).

The Physiocrats focused on production, considering land as the core producer of value. They regarded land as productive because a surplus could be taken from it once some inputs were used (Christensen, 1989). That is, they had in mind a kind of analogy between living systems and the provisioning of the economy. It is in this way that we have to interpret Quesnay's *Tableau Économique*, in which he tried to apply his Cartesian ideas to the analysis of wealth generation and value (see Mirowski, 1989 and Cleveland, 1987 for more details). Quesnay concluded that the production of goods could be seen as a mere transformation of materials and food taken from the land (Christensen, 1989), in what is, clearly, a biophysical interpretation of the economic process. Indeed, "[agricultural] production is well defined as the locus of the increase of the value substance; trade or circulation as where the value substance is conserved, and finally, consumption as the locus of value destruction" (Mirowski, 1989: 159).

The true error made by the Physiocrats is that they could not realize the meaning of the phrase "man cannot create material things", which is the sentence with which the third chapter of Book Two of Marshall's *Principles* begins (Schumpeter, 1954b, p. 237). The Physiocrats seemed to believe naively that "during every economic period a quantity of commodities newly enters into the economy -in their way of thinking from *the inexhaustible treasure of Nature* -and is taken over and passed on to the final stage of consumption by the various groups of members of the economy" (Schumpeter, 1954a, p. 52). They could not clearly see that the treasure of Nature is not inexhaustible. Therefore they did not try to reach a method of how to preserve or maintain the state of this treasure as did Liebig. While they had a great esteem for agriculture, they regarded nature as the inexhaustible source of treasure.

Contrary to the Physiocrats, the English classical school maintained that "agriculture was no longer the only productive activity; manufacturing could also generate a surplus" (Barber, 1968, p. 20). Yet Adam Smith regarded "agriculture as capable of yielding output far in excess of inputs" (Barber, 1968, p. 43). He realized the importance of natural bounty, land, which limited society's requirements for food. According to Liebig, while Adam Smith firmly appreciated the fact that land fertility ultimately determines the value of lands, the economists after him tried to make the national economy develop through a reduction in employment in the agricultural sector and the exhaustion of land fertility because they did not have an insight into the fact that lands are "treasures" of all humans. Malthus and Ricardo acknowledged that all human-made production of material goods was based on materials from nature, but they did not realize that the same logic could be applied to the products of nature.

Adam Smith, however, emphasized more the profit resulting from capital investment than the maintenance of land fertility itself:

"The most important operations of agriculture seem intended, not so much to increase, though they do that too, as to direct the fertility of nature towards the production of the plants most profitable to man.
Of all the ways in which capital can be employed, it [the capital employed in agriculture] is by far the most advantageous to the society" (Smith, 1937, p. 344).

His view was based on the presumption that most of the lands in England consisted of the worst cultivated soils, so that differences in additional capital investment on lands would create profit and rent funds. He did not write much about methods to improve the natural fertility of land, while he referred to some, one of which was "the use of the artificial grasses, of turnips, carrots, cabbages" (Smith, 1937, p. 151).

Smith realized the fact that "in agriculture too nature labours along with man" (Smith, 1937, p. 344). As far as we can maintain land fertility, we obtain the surplus profit as crops, which is the result of the capability of the soil to give quasi-permanently high produce. This surplus profit should be regarded as "the rent of lands". Smith considered the rent of lands as follows: "It [rent] is the work of nature which remains after deducting or compensating everything which can be regarded as the work of man" (Smith, 1937, p. 345).

However, his view did not have any implication of the compensation principle of material circulation as envisioned by Liebig and Marx. This point is best seen in his writing:

"We must not, however, upon this account, imagine that the gain of the town is the loss of the country. The gains are both mutual and reciprocal, and the division of labour is in this, as in all other cases, advantageous to all the different persons employed in the various occupations into which it is subdivided" (Smith, 1937, p. 356).

After all Smith did not seem to have a concern or an interest in nature per se.

It was Malthus who studied the importance of land for an increase in food. In the theoretical essence of the classical system, the principle of population does not play an important role (Schumpeter, 1954a). However, Shumpeter noticed that the principle of population for economics is all the more important for the exactness and the apparently *practical value* of some conclusions (Schumpeter, 1954a).

It is because of this latter reason that we discuss Malthus' theory here. Malthus proposed that a struggle between the powers of human reproduction and the production of food would be "eternal". According to him, population cannot exceed the limits set by the available food from land on the earth. Malthus writes:

"I think I may fairly make two postulata.
First, food is necessary to the existence of man.
Secondly, the passion between the sexes is necessary and will remain nearly in its present state. Assuming then, my postulata as granted, I say, that the power of population is indefinitely greater than the power in the earth to produce subsistence for man. Population, when unchecked, increases in a geometric ratio. Subsistence increases only in an arithmetic ratio. A slight aquaintance with numbers will show the immensity of the first power in comparison of the second" (Malthus, 1959, pp. 4-5).

With regard to population pressure two points should be noted. First, contrary to the mainstream view on the population explosion in developing countries, "many primitive societies, particularly before contact with Europeans disrupted their cultural systems, prevented population growth and managed to live in equilibrium with their resources without threat of hunger" (Wilkinson, 1973, p. 6). R. G. Wilkinson quoted two examples, the Tikopia, a community in the Polynesian Islands, and the Vunamani in New Britain, for an illustration of practices such as abortion and infanticide (Wilkinson, 1973, pp. 64-67).

Second, class societies such as ours are much less likely to invent sufficient social and cultural mechanisms for limiting the population. Wilkinson writes:

"The rich upper classes have no need to limit their family size for fear of inadequate subsistence. This affects practices such as abortion and infanticide which are, at best, necessary evils. If the upper classes find them unnecessary, then practising them will come to be regarded as unmitigated evil. Because the upper class has a disproportionate influence on the society's ideology and law, frequently infanticide and abortion cannot be carried on openly but become illegal, undercover activities" (Wilkinson, 1973, ppp. 67-68).

Let us move on to an argument against Malthus, the objections of which admittedly have an ideological tone. J. Spengler, in his paper "Was Malthus Right?" which basically supported Malthus' argument, stated: "Malthus will have been proven right in stressing the role of limitational factor, above all agricultural land" (Spengler, 1966, p.33). However, the following passages clearly showed that Spengler missed the destructive influence of excessive export of farm produce carried on, for example, by the U. S. A.:

“It is quite likely, however, that the limitation of food due to the limitation of land will become the limitational factor in parts of Asia, Africa, and Latin America. Elsewhere land in the sense of living space is likely to become the limitational factor” (Spengler, 1966, p. 33).

It is sufficient to recall the following message by Liebig in order to understand what is wrong with Spengler’s argument:

“Can it be imagined that any country, however rich and fertile, with a flourishing commerce, which for centuries exports its produce in the shape of grain and cattle, will maintain its fertility, if the same commerce does not restore, in some form of manure, those elements which have been removed from the soil, and which cannot be replaced by the atmosphere?” (Liebig, 1843, p. 112).

We can say that the limitation of food due to the limitation of land will also become a limitational factor in countries which deprived soils of the fertility by exporting an excess of agricultural outputs. That is to say, the food problem is essential for developed countries as well as for developing countries.

Barber (1968), however, claimed that Malthus considerably underestimated the pace of technological progress and its impact, and that Malthus did not realize the opportunities presented by international trade. It is true that technological progress and international trade actually did ease the food supply constraint. These impacts, however, work only temporarily. The truth is that actually we are postponing the timing of a disaster to come on future generations who will suffer because of our myopia. The destructive influence of the trade of food on lands and soils were discussed already. Marx stated the deteriorative effects of food trade on soils:

“it disturbs the circulation of matter between man and the soil, i.e., prevents the return to the soil of its elements consumed by man in the form of food and clothing; it therefore violates the conditions necessary to lasting fertility of the soil” (Marx, 1936, p. 554).

With respect to the technology of agriculture, Marx understood the essential feature of modern technology:

“All progress in capitalistic agriculture is a progress in art, not only of robbing the labourer, but of robbing the soil; all progress in increasing the fertility of the soil *for a given time*, is a progress towards ruining the lasting sources of that fertility (italics added)” (Marx, 1936, p. 555).

What, then, is the true error that Malthus made? K. Boulding writes in his Foreword to *Population: The First Essay* by Malthus: “Eventually, however, a stationary population must be reached on a limited earth or even in a limited universe”. The real error of Malthus, as Georgescu-Roegen noticed it, is “the implicit assumption that population may grow beyond any limit both in number and time *provided that it does not grow too rapidly*” (Georgescu-Roegen, 1976, p. 366).

3. Entropy Disposal Mechanism and Material Circulation Against Gravitational Field on the Earth: a way for a sustainable management of land

This section deals with the land management problem from a much more fundamental level. The two basic mechanisms, entropy disposal on the Earth and material circulation against the gravitational field are investigated to understand the necessary conditions for life to continue living in relation to the land management.

In 1944, Schrödinger raised a fundamental question in his seminal book, *What is life?*: "What is the characteristic feature of life? When is a piece of matter said to be alive?,,, How does the living organism avoid decay?" (Schrödinger 1967, pp. 69-70). His answer was: " 'It [a living organism] feeds upon negative entropy', attracting, as it were, a stream of negative entropy upon itself, to compensate the entropy increase it produces by living and thus to maintain itself on a stationary and fairly low entropy level" (Schrödinger 1967, p. 73). What is negative entropy? Schrödinger explained negative entropy as entropy with the negative sign. However, entropy can never be negative according to the third law of thermodynamics. At that time Schrödinger did not consider an important factor that plays essential role in maintaining life.

In 1945, Schrödinger added a note to Chapter 6, concluding "that we give off heat is not accidental, but essential. For this is precisely the manner in which we dispose of the surplus entropy we continually produce in our physical life process" (Schrödinger, 1967, p. 74). Schrödinger finally reached the right conclusion that disposal of surplus thermal entropy is necessary for living things to continue life.

A living thing continues life by feeding upon energy and matter of low entropy and by disposing of waste matter and heat of high entropy. Entropy exchange with the environment as well as entropy production within a living thing is fundamental in the maintenance of life. This is what Boltzmann means by the struggle for entropy (Boltzmann, 1974).

Then what is the mechanism of how the Earth as a whole disposes of thermal entropy and material entropy to the outer space?

The mechanism of thermal entropy disposal to outer space is in the following.
Air convection and water cycle constitute an atmospheric heat engine which guarantees the existence of life on Earth by continually discarding thermal entropy to outer space. Within this heat engine, water and air circulate between the surface area of the Earth (15 degrees centigrade on average) and the air at high altitudes (-18 degrees centigrade). Roughly (Murota and Tsuchida, 1985), thermal entropy generated after various activities on the Earth is discarded annually at a rate of 34.6cal/deg. cm2.

The degree of coldness of the upper air (-18 degrees centigrade) is also important. This low temperature is created by the adiabatic expansion of the air. It is possible to dispose more of the thermal entropy of radiation of the same quantity of heat at a lower temperature than at a higher temperature. In addition, at about -18 degrees centigrade, the vapor pressure is sufficiently low and air is dried so that sunlight can pass easily through atmosphere because of fine weather except close to ascending current.

Water cycles emerge due to the asymmetry of the atmosphere which is created by the fact that molecular weight of water vapor is 18, while the average molecular weight of air is 29 (Tsuchida, 1985). This difference in molecular weight creates an air pump, as it were, to lift water vapor up to the upper atmosphere against gravity. Plants use sunlight to produce glucose. Entropy generated in a plant is discarded mainly by evaporation of water from leaves. Activities of animals are accompanied by production of waste heat and matter. This heat entropy is disposed of ultimately by water cycles and air convection. When organic wastes, excreta and dead matter from the grazing food chain are decomposed, water plays vital role in the disposal of thermal entropy generated during the process of decomposition. There are water cycles outside of the food chain. There is a heat radiation system outside of water cycles. In this way entropy produced at each stage in the system of the Earth is passed to a larger system which contains the original system: a nested hierarchical structure (Mayumi, 2001).

As far as matter is concerned, the Earth is virtually a closed system in the sense of classical thermodynamics. Because the Earth is a closed system, special types of matter, i.e., air and water, are not dispersed and lost to outer space due to gravity, so that air and water keep the Earth in quasi steady state by continual thermal entropy disposal.

Since the Earth is a closed system with respect to matter, waste matter in general must remain on the Earth due to gravitational field. Then what is the mechanism of material entropy disposal on the Earth?

Soil and sea are contact points, so to speak, with the water cycle and the food chain. Soil is composed of inorganic minerals as well as humus. Humus transforms ultimately material entropy (detritus) into heat entropy. Without sufficient moisture in land, soil cannot dispose of material entropy and no life in humus, a typical situation in the desert.

The material entropy disposal mechanism described above is only a part of the story concerning the material circulation system happening on the Earth.

More generally, there are several of the material cycles that dictate the balance between the four spheres: life (biosphere), the earth (lithosphere), and air and water (atmosphere and hydrosphere). The major elements cycled in nature are carbon, phosphorus, nitrogen, and sulfur, along with oxygen which forms part of all the cycles (Odum, 1997).

However, due to the gravitational field on the Earth, all material elements, in particular water-soluble elements, tend to sink toward the bottom of the Earth, the deep ocean. Rivers originated in land take nutritional elements into the ocean. Therefore, the seashore area is a place full of fish and other resources including a variety of planktons due to nutritionally rich materials transported by the river water. However, dead bodies of ocean resources are difficult to circulate, especially when the depth of sea water reaches more than 1,000m where the average temperature is sufficiently low (between 0 and 3 degrees centigrade) and the water there is relatively heavy. So, as it were, the deep ocean is a grave for vegetation life. In fact, there is no phytoplankton at 500 meters! Phytoplankton lives/grows in the euphotic zone, not deeper than 80-100 meters. There is only a little blue light in deeper waters, not sufficient for photosynthesis.

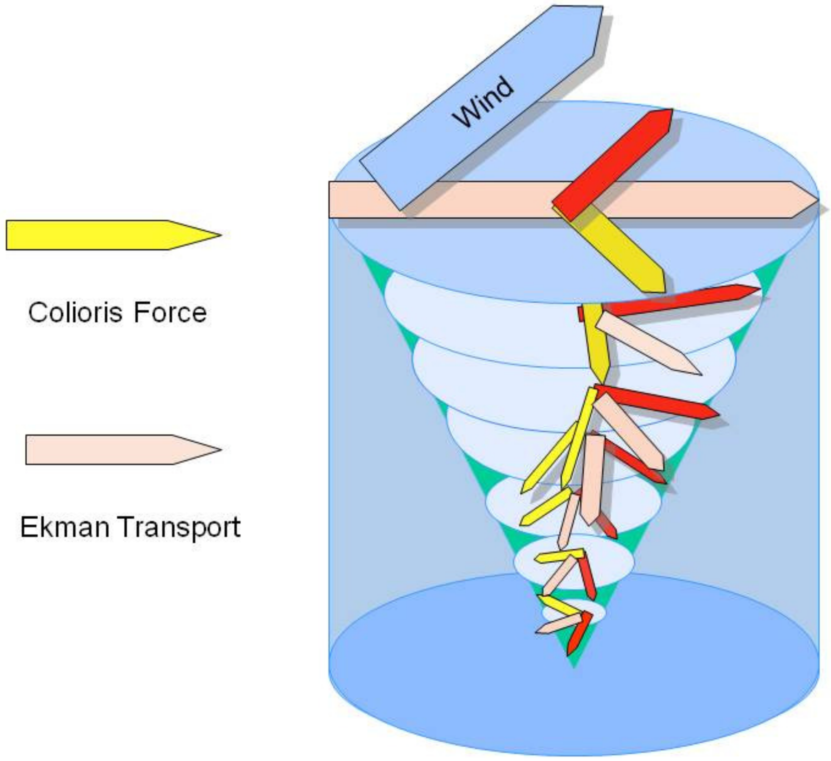

Figure 1. Wind-Driven Ocean Currents create Ekman Transport

Similar to the way water cycles emerge due to the asymmetry of the atmosphere, the material or nutritional circulation system in the sea is maintained by the asymmetry of the ocean currents against the gravitational field.
There are several components that create the ocean currents. First of all, there are the wind-driven ocean currents famously studied by Ekman (1905)—see Figure 1. Since the depth of the ocean is much shorter than the length of ocean surface, the Earth's rotation has a crucial effect on the ocean currents due to the Colioris force. In the northern sphere, for example, if the southern wind continues blowing along the east coast, the Ekman transport toward off-shore appears and upwelling starts. On the

other hand, in the southern sphere, if the northern wind continues blowing, a similar phenomenon will appear. In fact, on the east coast of North and South America, the upwelling can be observed. Therefore, thanks to these ocean currents, phytoplankton can easily make photosynthesis consuming nutrients such as NO3-, PO43-, NH4+ and SiO2. A variety of fish move around the world sea waters and supply nutrition over the world. This is one of the basic mechanisms of material circulation in the sea. The well known fishery field (anchovy) near the Peruvian offshore is related to the wind-driven ocean currents. Of course, the wind-driven ocean currents mechanism plays a partial contribution to the total material circulation within the sea water. Sverdrup extended the Ekman model by considering the link between meridional currents and the curl of the wind stress (Sverdrup, 1947). Meanwhile, Stommel created a beautiful model (the Colioris factor is a linear function of latitude) by which he analytically showed a common phenomenon of the ocean circulation mechanism, i.e., the westward intensification of the wind-driven ocean in the case of using the Colioris force (Stommel, 1948). Stommel's model was further extended by Munk (1950).

These models explain the wind-driven currents over the relatively shallow water areas in the sea. On the other hand, Stommel created an abyssal circulation model to explain a mechanism of material circulation happening in the deep ocean. There are two areas that show this mechanism: the Greenland area located between the Arctic and Atlantic Oceans, and the Weddell Sea, part of the Southern Ocean. In the former, the downward current appears due to a decrease in the sea water temperature in the winter season. In the latter, the downward current appears due to higher concentration of salt in the winter season. So, there must exist upwelling currents compatible with the strength of downward currents shown above.

The next question is what is the mechanism of material circulation from the ocean to the land? Common sense might tell us that the spray of sea water containing nutritional elements is carried to land by wind power. However, this mechanism must also apply to the nutritional transfer from the land to the sea, which might balance out the former mechanism.

Yet, there is another mechanism to be considered. There are a variety of birds that can lift nutritional elements in terms of their excretion to the land and the forests. There is a method of determining energy expenditure, called the doubly labeled water stable isotope method. Stable isotopes of hydrogen (deuterium oxide) and oxygen (oxygen 18) are routinely used to measure energy expenditure in free-living humans. The doubly labeled water method using these isotopes is a form of indirect calorimetry that has been extensively validated in animals and humans. Nagy applied this method to deducting a correlation between the necessary daily caloric intake for a bird and its weight (e.g., Nagy, 1980). However, his estimated relations can only apply to specific types of birds. Thus, the amount of energy necessary usually results in an underestimation for birds in the forests. So, Yui (1988) derived the energy expenditure for a great tilt using Walsberg's general method (Walsberg, 1983). According to Yui's estimates, in fact, a small bird can eat a surprisingly huge amount of larva. A great tilt of 16g, for example, can eat 1.5kg of larva per year! Many birds are omnivorous and eat a variety of foods. For example, Kiuchi (1975) estimated the amount of insects that birds in Shiga Kogen, Nagano, Japan (per km2) eat between May and October. Under several reasonable assumptions he concluded that birds there eat about 10 tons of insects. So, birds can at least ‘produce’ several tons of excretion (per km2 per year) that cannot be ignored in view of material circulation mechanism against the gravitational field. In fact, any excrement from birds, seals, or bats, with value to humans as fertilizer, is known as guano. The discovery during the 1840s of the use of guano as fertilizer as well as saltpeter as a key ingredient in explosives made the area strategically valuable involving several wars among Bolivia, Chile and Peru together with USA and Spain. The most well know war is the War of the Pacific that was fought between Chile and the joint forces of Bolivia and Peru between 1879 and 1883.

Other living things play vital roles in material circulation. For example, in the northern part of the globe, salmon is another key actor besides birds and other animals for material circulation. The Russian explorer V. K. Arseniev described the richness of one of the tributaries of the Amur river in his famous book, *Derus The Trapper*. Derus Uzala appears as a nomadic, aboriginal tribesman in a movie directed by Akira Kurosawa.

Arseniev states on the wonderful material circulation mechanism in nature:
“The stream was literally crammed with fish, the dog salmon,,,,,For cleaning up these swamps of fish nature sent sanitary officials in the form of bears, pigs, foxes, badgers, raccoon dogs, crows, rollers, and jays. ,,,,In the shallows the water was already starting to freeze in places. A fish caught in the ice would be a prisoner for the whole of the winter. Only in the spring, when the sunshine warms the Earth, will it be carried down-stream with the lumps of ice into the sea, there to be the object of attack of all marine creatures. What a chain of nature! How wise it all is! Nothing wasted! Even in the depths of remotest *taigá* there are scavengers to collect the carrion” (Arseniev, 1996, pp. 196-197).

Some part of dead salmon also becomes nutrients for salmon fries.

Japan caught about 15 million salmon in 1911 in the Amur River of Siberia. According to Shibata’s estimation (1992) based on the record by the Russian authority in 1911, about 60,000 tons of dead salmon were left along the Amur river of 10,000km. This means that about 3 tons of nutrition was left per km2 along this long river. This amount of nutrition is not negligible at all, compatible with the estimate for birds by Kiuchi (1975). Salmon migrating upstream recover some part of nutrients from the sea. Birds and other living things such as salmon are the living pumps for returning nutritional elements to the land against the gravitational fields. The role of these living things is forgotten in our modern era.

4. An Ingenious Material Circulation System: The Edo Scheme Reconsidered

Edo, the former name of Tokyo, was the capital city of Tokugawa Shogunate (1603-1867) with more than one million population size. Before the Tokugawa Shogunate was established, the forests in Musashino region, situated northwest of Edo, were heavily cut off as fuels and compost materials for paddy fields, and became a barren land. However, an ingenious material circulation system was systematically introduced in Edo and its surrounding regions including Musashino and Edo Bay, so that Musashino region had overcome its ecological crisis. The Edo scheme is a rare historical example of a big city that successfully maintained deep forests, healthy fishery and land fertility in agricultural fields, and secured the growing crops demand for the Edo region, in particular rice, based on *active participation of local people as an agent of material circulation*.

Before presenting several components for the Edo scheme, let us briefly make an overview of the climate and the land situation in the Edo period. In general it is abundantly rainy in Japan whose landscape is relatively steep. Therefore, the pH level of most of the land in Japan does not contain enough Ca, Mg and K. So, the land in Japan is not suitable for growing cereals such as barley and wheat. However, in the paddy field, on average 150,000 liters of water per 100m2 is supplied. This amount corresponds to a water depth of 1.5 meters. Therefore, Ca and Mg are supplied with this much water. Since water's specific heat is larger than that of soil, the temperatures of the paddy water and the soil do not decrease much preventing the rice filed from suffering cold-weather damage. Water can wash away contaminated substances such as hydrogen sulfide. Water in the paddy field can also be a source of underground water.

There are several components that helped establish the Edo Scheme, the forced circulation system, as it were.

First of all, the running water system of Tama River, originated in the Musashino forests, was constructed for supplying fresh water for the Edo region in 1653. Its total length was 44km, one of the largest running water systems in the world at that time. The water running system of Tama River as well as another big river, the Ara River, together with the two rivers' tributaries, was an effective water supply network for paddy fields in Edo regions. This water supply network utilizing the appropriate slopes of surrounding mountains is a system that prevents nutritional elements of river water from flowing directly into the Edo bay. The salty elements contained in the river water were effectively absorbed in the underground of paddy fields, so that no serious salinity problems occurred. Therefore, the network system was also useful for utilizing nutritional elements originated in the Musashino region.

Secondly, there is a religious element that played a crucial role in creating the Edo scheme. In Buddhism, there is a word, Kamma which means a mental force seeking to actualize the mind's will (e.g., Holmes, 1997). Buddhism teaches us to avoid unwholesome Kamma and avoid the following ten bad actions: bodily (destroying life, talking what is not given, and wrong sexual conduct); speech (false speech, slanderous speech, harsh speech, and idle chatter); mental (covetousness, ill will and wrong views).

So, the Japanese farmer did not adopt the intermediate stage of cattle feeding typical in the farming system in the West. H. Maron, a member of the Prussian East Asian Expedition, who visited the Edo region, made a detailed report to the Ministry of Agriculture at Berlin on Japanese Husbandry (Liebig, 1972[1863], p. 364) in which he stated:

“The religious belief of the two great sects in Japan, the Sintoists and the Buddhists, forbids the eating of flesh, and not alone of flesh, but of everything derived from animals (milk, butter, cheese)”.

The subsistence level of meal nutrition in Japan was maintained without eating animal food, since the main energy source for people in Japan came from foxtail millet and rice, supplemented by soybeans and dried fish with bones together with fruits and vegetables.

Of course, as Maron noticed, the very limited area of the homesteads in Japan practically made the maintaining of cattle superfluous. But in view of long-term agronomical thought, the cattle feeding system is a great loss. Maron stated on this point: (Liebig, 1972[1863], p. 364);

“it [the intermediate stage of cattle feeding] must cost a great deal of unnecessary and expensive labor to have the produce of the field first eaten by cattle, so troublesome and expensive to breed, and that this system must involve more considerable loss of matter than his own. How much more simple it must be to eat the corn yourself, and to produce your own manure!”

The prohibition of killing animals and no intermediate stage of cattle feeding are important elements for maintaining the forests, agricultural fields and soil fertility. The rich forest landscape was maintained without feeding pigs and goats. Birds were also effective tools to return nutritional elements to the forests land against the gravitational fields.

Thirdly, perhaps the most important element of the Edo scheme was the fact that the only manure-producer in Japan was human beings.

Maron stated: “the greatest care should be bestowed in that country upon the gathering, preparing, and applying his excrements” (Liebig, 1972[1863], p. 365).

Maron also stated with great admiration: “The educated sensible farmer of the old world would certainly think it a most surprising circumstance to see a country even much better cultivated, without meadows, without fodder production, and even without a single head of cattle, either for draught or for fattening, and without the least supply of guano, ground bones, salpetre, or rape-cake. This is Japan.” (Liebig, 1972[1863], p. 363).

There started intensive transactions of human excreta with agricultural products between farmers and city dwellers, as the population size of the Edo became large. But the system collecting manure as much as possible is beyond imagination: “He [the peasant] places wherever his field is bordered by public roads, footpaths, c&c., casks or pots buried in the ground nearly to the rim, urgently requesting the traveling public to make use of the same.” (Liebig, 1972[1863], p. 866)

“I need simply state the fact that, an all my wonderings through the country, even in the most remote valleys, and in the homesteads and cottages of the very poorest of the peasantry, I never could discover, even in the most secret and secluded corners, the least trace of human excrements. How very different with us, in Germany, where it may be seen lying about in every direction, even close to privies!" (Liebig, 1972[1863], p. 366)

Two other foreign visitors' views around the similar period on material circulation system in Japan deserve citation here.

Philipp Franz von Siebold, a German physician who was the first European to teach Western medicine in Japan, states:

"The soil is naturally sterile, but the labour bestowed upon it, aided by judicious and diligent irrigation, and all the manure that can be in any way be collected, conquers its natural defects, and is repaired by abundant harvests" (Siebold, 1852, p. 329).

Isabella L. Bird wrote an interesting travelogue, *Unbeaten Tracks in Japan*, in 1878 in which she describes all aspects of life---the travel conditions, the weather, habits and customs. She mentions on the straw shoes of the horse for manure:

"The bridle paths are strewn with them [the straw shoes] and the children collects them in heaps to decay for manure" (Bird, 1911, p. 88).

At this moment western readers might wonder how the sanitary problems were resolved. Marion stated: "As he [the Japanese] ignores altogether the notion of a 'seat,' the cabinet, which, as a general rule, is very clean, neat, and, in many case, nicely papered or painted and varnished, has a simple hole of the shape of an oblong square running across. I never saw, a dirty cabinet in Japan, even in the dwelling of the very poorest peasant. It appears to me that there is something very practical in this form of construction of closet" (Liebig, 1972[1863], p. 365).

"He [The Japanese peasant] simply holds fast to one indisputable axiom, viz. without continuous manuring there can be no continuous production" (Liebig, 1972[1863], p. 363)

"Thus in Japanese agriculture we have before us the representation of a perfect circulation of the forces of nature: no link in the chain is ever lost, one is always interlaced with the other" (Liebig, 1972[1863], p. 369)

As an ecologist, B. Commoner (1971, p. 188) states the importance of material circulation: "Given that many people no longer live in close proximity to the soil but are collected in cities, clearly the ecologically appropriate technological means of removing sewage from the city is to return it to the soil"

There is yet another type of material circulation mechanism among the Edo bay, Edo city, agricultural fields, and the Musashino forests. The rich at that time used rape seed oil for lighting. The poor, on the other hand, used sardine fish oil. This oil was extracted after boiling sardines. This sardine production process left an enormous amount of dried sardine which was sold to farmers as 'golden manure' for agricultural fields, in particular for paddy fields. Golden manure introduced into paddy fields was partly eaten by a variety of birds that return their excretions to the Musashino forests as well. Nutrition rich water went through the Musashino, agricultural fields including paddy fields, Edo city and finally flowed into Edo bay where a variety of fish, shellfish and seaweed were collected. The tasty dish full of such sea foods was called 'Edomae', literally meaning sea food collected in front of the Edo castle. Fish bones and waste materials in the area of Edo bay were used by nearby farmers as an ingredient for their compost together with human excreta and fallen leaves.

5. Conclusion

Keeping a healthy relation between ecosystems (including forests) and humans seems to be an eternal theme. In one of Hayao Miyazaki's films, *Princess Mononoke*, he presents a mythical belief of the Japanese that the forest is full of gods who occupy superior position to humans, and that when humans are aggressive against the forest, the oak forest god, 'Shishigami', tortures humans in return (Mayumi, et al., 2005). A similar mythical belief also appears in *The Epic of Gilgamesh* (George, 1999), a well known epic poem from Ancient Mesopotamia. Gilgamesh and Enkidu killed the ogre Humbaba, in the full knowledge that the god Enlil, the greatest power on Earth, had given Humbaba the job of guarding the cedar. Gilgamesh also felt cedar trees in the sacred groves. But eventually Enkidu was cursed to death by bad dreams.

Concerning the material circulation mechanism between nature and humans the following description in *Kojiki*, the oldest surviving book in Japan, is suggestive for the importance of material circulation:

"Then the Princess-of-Great-Food took out all sorts of dainty things from her nose, her mouth, and even her fundament, and made them up into all sorts [of dishes], which she offered to him. But His-Swift-Impetuous-Male-Augustness watched her proceedings, considered that she was offering up to him filth, and at once killed the Deity- Princess-of-Great-Food. So the things that were born in the body of the Deity who had been killed were [as follows]: in her head were born silkworms, in her two eyes were born rice-seeds, in her two ears was born millet, in her nose were born small beans, in her private parts was born barley, in her fundament were born large beans. So His Augustness the Deity-Producing-Wondrous-Ancestor caused them to be taken and used as seeds" (*Kojiki*, 1981, p. 71).

Liebig (1972[1863], p. 229) mentions the important aspect of *human will* for maintaining the material circulation mechanism: "Not the fertility of the Earth, but the duration of that fertility, lies within the power of the human will". Perhaps this is the most important lesson from the Edo scheme.

James Lovelock postulates Gaia hypothesis that "the physical and chemical conditions of the surface of the Earth, of the atmosphere, and of the ocean has been and is *actively* made fit and comfortable by the presence of life itself" (Lovelock, 1979, p. 144). Here we emphasized the term, *actively*, in italics. The material circulation scheme of Edo is an example of human active participation in reinforcing a harmonious relationship with nature in the sense of Gaia hypothesis. Our present life is far removed from the situation where the Edo scheme was effectively functioning. Concerning the evolutionary process of life, Popper once stated (1994, p. 123):"the *selection* of a mutation will be strongly dependent on the behavior which has been adopted".

However, since we "adopted" the exosomatic evolution transgressing the somatic evolutionary process of living things, the meaning of a mutation by Popper should properly be reinterpreted. Here, we should adopt a different mode of exosomatic evolution. This is our choice, a new type of selection beyond the endosomatic evolution of living things. Thus what we need is a new way of behavioral changes that would be compatible with the new mode of exosomatic evolution. We should start learning a way of life where human beings try to adjust to environmental constraints. We believe that the Edo scheme is a crucially important lesson for the future of us. The revival of the Edo scheme should not viewed as Utopian imagination.

Concerning the criticism of sewage system the two great contemporaries' views of Marx and Victor Hugo deserve special attention.

Marx states (1959, p. 100): "So far as their utilization is concerned, there is an enormous waste of them in the capitalist economy. In London, for instance, they find no better use for the excretion of four and a half million human beings than to contaminate the Thames with it at heavy expense".

Hugo states: "After long experimentation, science now knows that the most fertilizing and the most effective of manures is that of man. The Chinese, we must say to our shame, knew it before us. No Chinese Peasant, Eckeberg tells us, goes to the city without carrying back, at the two ends of his bamboo pole, two buckets full of what we call filth. Thanks to human fertilizer, the earth in China is still as young as in the days of Abraham. Chinese wheat yields a hundred and twenty fold. There is no guano comparable in fertility to the detritus of a capital. A great city is the most powerful of dung producers. To employ the city to enrich the plain would be a sure success. If our gold is manure, on the other hand, our manure is gold. What is done with this gold, manure? It is swept into the abyss" (Hugo, 1987, p. 1257).

We conclude this paper with F. H. King's view of permanent, e.g. sustainable agriculture:

"One of the most remarkable agricultural practices adopted by any civilized people is the centuries-long and well nigh universal conservation and utilization of all human waste in China, Korea, and Japan, turning it to marvelous account in the maintenance of soil fertility and in the production of food. To understand this evolution it must be recognized that mineral fertilizers so extensively employed in modern western agriculture, like the extensive use of mineral coal, had been a physical impossibility to all people alike until within very recent years. With this fact must be associated the very long unbroken life of those nations and the vast numbers their farmers have been compelled to feed" (King, 1911, p. 193).

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