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

- *Preliminary version* -

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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) and there is a number of conceivable causes for these collapses; economic, political, institutional, biophysical, etc. One of such causes is of biophysical or ecological in nature: land deterioration due to intensive agricultural production without maintaining nutritional circulation.

As an agronomist, concerning the importance of material (or nutritional) circulation Liebig stated:

"We find that all countries and regions of the earth where man has omitted to restore to the land the conditions of its continued fertility, after having attained the culminating period of the greatest density of population, fall into a state of barrenness and desolation " (Liebig, 1972, p. 228)

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 stated:

"You are left (as with little islands) with something rather like the skeleton of a body wasted by disease; the rich, soft soil has all run away leaving the land nothing but skin and bone. But in those days the damage had not taken place, the hills had high crests, the rocky plain of Phelleus was covered with rich soil, and the mountains were covered by thick woods, of which there are some traces today" (Plato, 1977, p. 134)

Critias' lament can be applied to many civilizations in the past, as human society tends to expand beyond the limits of its capacity to reproduce itself, resulting in the reduction of land fertility and the desertification lf large expanses of the earth.

Recent concern with the global warming and the rapid climatic change triggered a lot of heated discussions on the energy use pattern 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 the land management and humans' positive role as an agent aiming at maintaining harmonious material circulation within land.

These two issues, the land management and humans' positive role, are main concerns in 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. The fist two sections present several issues of modern agriculture. Section 1 presents some destructive influences of modern economies on the agricultural land by investigating the differences and similarities between farming and manufacturing. The argument here is that agriculture cannot achieve a higher productivity than manufacturing, due to the fundamental asymmetry between two sources of low entropy, sunlight and fossil fuels. Yet modern agriculture has been placed on an industrial basis in opposition to nature' patterns of ecological succession, thus threatening the basis of human life itself. Section 2 first gives Liebig's view on nature, agriculture and land which emphasizes the maintenance of long-term land fertility based on his agronomical thought, i.e., the law of compensation: the circulation of matter in agricultural fields must be maintained with manure as much as possible. It is not well know that Liebig's agronomical views greatly influenced Marx's on agriculture and nature. Then Marx's, and several classical economists' thoughts (Adam Smith, the physiocrats, and Multhus) on nature, agriculture and land are reassessed from Liebig's point of view. Section 3 treats the land management problem from much more fundamental level. In this section, two mechanisms, entropy disposal on the earth and material circulation against gravitational field, are introduced to understand the necessary conditions for life to continue living in relation to the land management. Section 3 first presents Schrödinger theory of "what is life", i.e., one of the necessary condition for life to continue living. Then the entropy disposal mechanism on the earth is presented. Section 3 also treats how material circulation mechanism is maintained on the earth against gravitational field. However, this material circulation mechanism on the earth is not 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 the more detailed analysis of the Edo scheme, as an historically ingenious example of establishing and enhancing the material circulation mechanism among cities, farm land, forest and 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 years in the Edo period (1603-1867). Section 5 presents several concluding remarks.

2. Farming and Manufacturing

Modern industrial society, which emerged from the English industrial revolution, then flourished in the United States, has a tendency to ignore the true situation of degraded lands over the world. However, in actuality we have the continuous entropization of soil conditions.

The five basic factors of soil deterioration are the following (e.g., Dragan and Demetrescu, 1986):

1. The spread of deserts that is the process of land deterioration associated with the invasion of deserts produced by exceedingly intensive grazing, increasingly shorter periods between crops and consumption of wood plants used as fuels.
2. Saturation with water, salination and alkalinization which usually appear when irrigation systems, especially on arid soils, use the water without taking into account the absorption capacity of the land as well as other characteristics of the land and the water.
3. The degradation of arable soil following the deforestation on slopes and sloping grounds as well as on many humid tropical areas.
4. General erosion and loss of the humus in most of the agricultural zones as a consequence of the currently practicised agriculture.
5. Loss of grounds due to urbanization, road construction, extension of human settlements and to other uses of lands following the economic development and the growth of the population.

A brief examination of these factors shows that the fundamental cause of land deterioration is that we in the modern industrial society are far removed from the content of natural cycles. In ancient times, human beings used to live concomitant with natural cycles of each year based on traditional agriculture.

However, after the industrial revolution, agriculture itself, which by its own nature cannot compete with manufacturing, has been forced to enter into the framework of modern industry, so that it has an inherited tendency to be removed from yearly natural cycles.

In order to understand several basic differences between agriculture and manufacturing, we can explore the scheme developed by Georgescu-Roegen.

Georgescu-Roegen writes:

The new analytical conception [Flow--Fund Model] immediately brought to light the immutable reason for the essential difference between the process of a farm (almost everywhere on the globe) and the process of a factory. The immense economic advantage of the factory over a farm lies in the possibility of eliminating the idleness of all agents. A glaring illustration is the economy achieved by the transformation of the chicken farms in the United States' into "chicken factories," which now produce chickens in line (as in a factory), instead of in series (Georgescu-Roegen, 1976, p. xiv)

Georgescu-Roegen invented a new analytical tool to represent a process. In his analysis, "no boundary, no process" implies that the boundary of a process must necessarily have two analytical components. One is the frontier of the process which sets the process against its environment at any point in time. The other component is the duration of the process. The boundary is a void by which we have a partial process and the other partial process, i. e., its environment.

This scheme allows us to investigate what is happening on the boundary.

In order to understand the essential difference between farming and manufacturing, the concept of elementary process must be introduced. Elementary process "is the process defined by a boundary such that only one unit or only one normal batch is produced. The most instructive illustration is the sequence of operations by which an automobile is produced on an assembly line" (Georgescu-Roegen, 1984). The individual elementary process, P, may be arranged in series, in parallel, or in line (Figure 1 should be prepared). The partial processes arranged in series are such that no process overlaps with another in time. The partial processes arranged in parallel are such that a certain number, n, of elementary processes start at the same time and repeat after they are finished. The partial processes arranged in line are such that the time of production is divided into equal intervals and one elementary process is started at each division point, i. e., the elementary processes are uniformly staggered in time so that the arrangement of this type can eliminate technical idleness completely.

Georgescu-Roegen writes:

Since processes are arranged in line (and in a proper fashion), the flow that moves through the process moves without any waste of time from one agent to another. The agents are thus never idle. In this lies the essential difference between manufacturing and farming processes. In agriculture elementary processes cannot be started at any time of the year as is ordinarily the case in manufacturing (Georgescu-Roegen, 1984, p. 25)

Georgescu-Roegen expounded his analysis of the difference between the two processes by noting the fundamental asymmetry of the two sources of low entropy: sunlight, and the mineral resources and fossil fuels of the earth. The disadvantage of agriculture has three characteristics: first, "nature dictates the time when an agricultural elementary process must be started if it is to be successfu1 at all" (Georgescu-Roegen, 1971, p. 297). Second, because of the impossibility of mining the stock of solar energy at a rate we want, we have to wait and to be patient. As Adam Smith noted, “in agriculture too nature labours along with man” (Smith, 1937, p. 344, italics added). We are forced to wait for the duration in which nature works. Third, the most important element of the asymmetry is that we will have a lasting obstacle to our manipulating living matter as efficaciously as inert matter due to the impossibility of attaining the microcosmic as well as the cosmic dimension of space and time.

Due to these three reasons we cannot expect agriculture to achieve a better position than manufacturing from the beginning. The productivity difference between manufacturing and farming comes from two sources. First, manufacturing can move from natural cycles (day and night, season, change in climatic conditions, nature and rhythm of animals, plants, food chain, interaction between water and soils, etc.) into an artificial process so that it can produce economic goods at a higher rate both in scale and in variety than farming.

Second, manufacturing is usually independent of soils so that the amount of production per unit of area can be raised dramatically.

Let us explore the fundamental difference and similarity between agriculture and manufacturing from a slightly different angle.

Each agricultural operation performed by man and machinery consists mostly of mechanical movements. The basic work done by man and machinery is nothing but an attempt to move or to transport something. We have to wait, while nature works. Even in modern manufacturing industrial society, the situation is essentially the same. Without moving or transporting raw materials and labour on a large scale, our industrial society can never carry out production on a large scale even for a while. To put it differently, without fossil fuels such as oil and coal, which are the “motive” basis of modern civilization, large scale production will never be accomplished, even if we have other mineral resources in abundance. In other words, our civilization is based on a motive power and transportation. Most of oil, for example, is used for transportation and motive power. After Georgescu-Roegen’s expression, our civilization is based on Prometheus II (T. Savery and T. Newcommen) and Prometheus ll’ (N.Otto and R. Diesel). No coal and oil-no modern civilization. These two types of fossil fuels are contributions made by animals and plants in vast stretches of land over several thousand million years so that they can guarantee the essential merits of modern industry, i. e., land and time saving. We are now dissaving these at a much faster rate than the rate at which coal and oil were accumulated in the past. Therefore we still depend upon landbased resources in manufacturing as well as in agriculture. In this respect there is no difference between farming and manufacturing.

There is another similarity between the two processes concerning a secure water supply. Whenever a site for manufacturing was to be selected, a secure water supply had been the key factor until the large scale pumping up of underground water was made possible. As long as we have a sufficient amount of underground water available near the industrial site, no competition for a site between agriculture and manufacturing will occur. Also the demand for water resources except irrigation is increasing. In the near future, very severe competitions for suitable sites and water resources between agriculture and industry will emerge.

In order to appreciate the situation of agriculture compared with manufacturing, we need to investigate the characteristics of ecological succession (Kurihara, 1975). The changes in structure and composition of the community are rapid at the early stages, slowing gradually until a point of dynamic equilibrium, climax, is reached, and the community is “more or less” stable afterwards.

The characteristics of ecological succession are the following:

1. In the early stages of ecological succession, a variety of living creatures is limited and becomes complex with the advancement of stages of ecological succession.

2. The quantities of organic and inorganic elements are the same except in the early stages of ecological succession. in the early stages the quantities of these elements are very small. Therefore, the utilization of nourishment is higher in the early stages. In other words, fertilizers work better in the early stages.

3. The weight of living things per unit area is smaller in the early stages than that in the mature stages.

4. The rate of increase in total production in the early stages is higher than that in the mature stages.

5. After a dynamic equilibrium is reached (climax), it is more or less stable unless there is intervention by human beings.

In agriculture, in some sense we are forced to create the early stages of ecological succession artificially. We need a simple community, full of same plants and animals which we want. We do not want unnecessary things. We want the strong effect of fertilizers on crops and a higher productivity of land. Therefore we conduct agriculture by taking advantage of the characteristics that the early stages of ecological succession have. However, there are some troublesome characteristics about the early stages of ecological succession. In the first place, the weight of plants per unit area tends to be small. We can not expect large yields from the land in the early stages of ecological succession. Second, as flora is simplified in the early stages of ecological succession so that fauna, which depends on size and variety of the flora, becomes simplified at the same time. Therefore the number of a special group of herbivora tends to become larger because of favorable conditions for these herbivora. Third, the early stages of ecological succession are not stable and easily succumb to disturbances from the outside. These unfavorable aspects are the original sources of the disadvantages to agriculture.

We attempt to increase the weights of plants by the use of fertilizer and the improvement of plants breeding in order to overcome the first weak point. Then due to the second aspect, a special group of herbivora becomes more and more dominant. The frequent occurrence of “harmful” insects is due in part to the intensive use of chemical fertilizers. Furthermore, we need extra matter, energy order to keep agricultural land at early stages. Due to the third aspect, we need labour for cultivation, control and weeding. Also we need to spread fertilizers, pesticides and herbicides. Unfortunately, agriculture itself is up against the pattern of nature by ecological succession.

In traditional agriculture, matter and energy within a particular area circulated properly so that actually no waste matter was produced. However, in modern agriculture most matter and energy are introduced from the outside of the area. Also these matter and energy are difficult to circulate harmoniously within the area so that waste matter and polluted substances flow inside as well as outside of the area. Modern agriculture in our industrial society is nothing but a manufacturing. in this respect also there is no fundamental difference between farming and manufacturing in our present society.

3. Revisiting the Agronomical Views of Liebig, Marx and the Classical Economists

If temperature and precipitation are sufficient for the growth of plants, the ultimate form of plant succession is said to be the forests. From this point of view the final stage of plant succession is the forest in Japan, for example. At the final stage of plant succession, since the changes in the structure and composition of the forests are stopped and a point of dynamic equilibrium is reached, therefore the forests are more or less stable (Clapham, 1973). One of the features that forests have is the ability to keep water in the underground. For instance, the permeability of soil is one index to measure the capacity for transmitting water from the surface area into the underground in a given interval of time (Donahue, et al., 1971). In forest, the permeability of flattened leaves is 272 mm/hour and that of needle leaves is 246 mm/hour. On the other hand, the permeability of grass land is 191 mm/hour, and that of mountain roads 11 mm/hour

(Oosaki, 1986).

Climatic conditions within forests are milder than those outside the forests. The conditions under fallen leaves are mild, humid and appropriate for the life of soil animals (mites, annelid worms etc.), of fungi (mould, mushroom etc.) and of bacilli, which play an important role in decomposing fallen leaves. Therefore these are termed as the decomposers. The surface areas of forest land are the best habitats for living creatures both in terms of climatic conditions and in terms of food.

Forests store water and foster the water supply in the long run. They have been the main character as a source of oxygen on the surface area of the earth. They also provide us with timber. They hold water and prevent soil erosion. Agricultural lands are originally the bounties from forests. It would be wrong to regard the degradation of forest land only as a shortage of timber production. It would be even a mistake to regard it as the destruction of areas for sightseeing or recreation. The degradation of forests occurs precisely because we lose soil productivity or the soil itself. The erosion of forest lands retards the reproductive rate of forest resources, reduces the variety and number of animals and plants that prevent unwittingly soil erosion in forests, loses water resources, and may end up in a disaster. History shows that every civilization will be destined to disappear if it loses the productivity of soil.

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 practise 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. This is also an ethical problem. As Carter and Dale have put the matter:

With the advent of civilized man, about six thousand years ago, the soil-building process was reversed in most areas where he resided: the quantity and quality of soil and the amount of life the soil supported all began to decline. His superior tools and intelligence enabled civilized man to domesticate or destroy a great part of the plant and animal life around him. But more important, his improved tools and techniques helped him, unwittingly, to destroy the productivity of the soil that supported life. His intelligence and versatility made it possible for him to do something no other animal had ever been able to do--greatly alter his environment and still survive and multiply.

Civilized humans were nearly always able to become master of their environment temporarily. Their chief troubles came from their delusions that their temporary mastership was permanent. They thought of themselves as "master of the world", while failing to understand fully the law of nature (Carter and Dale, 1974, p. 6).

Recent acceleration of the soil erosion is mainly due to chemical substances such as synthetic plastic, DDT, lead etc., all foreign to the environment in nature (e.g., Commoner, 1971). These materials are not transformed harmoniously into an ecosystem so that the resultant intrusion may result in a potential menace through the food chain to all species, including humans. Therefore we believe that that "our task is to discover how human activities generate environmental impacts - external intrusions into the ecosystem which tend to degrade its natural capacity for self-adjustment" (Commoner, 1971, p. 127).

Even after organic agriculture has become a social concern recently, most people still think that Justus von Liebig is solely responsible for the intensive use of chemical fertilizers in modern agriculture. However, as explained later, the principle of his agronomy (the law of compensation) consists in his view that the circulation of matter in agricultural fields must be maintained with manure as long as most of agricultural products are consumed in cities, and fundamental elements of soils are never returned back. Liebig wrote about the law of compensation:

The Chinese husbandman has, for thousands of years past, made it a practice to restore to his fields the mineral constituents removed from them in the produce, and the fertility of his land has accordingly kept pace with the increase of the population.

The law of compensation, which makes the recurrence or permanency of effects dependent upon the recurrence or permanency of the conditions which produce them, is the most universal of the law of nature; it governs all the production of man's industry (Liebig, 1859, pp. 205-206, italics added).

It is not well known that his view greatly influenced Marx's on agriculture and nature (to be explained later).

Liebig had a special view on cycles of nature which is very similar to Rinne in the East; human beings can reincarnate again and again. He claimed that the agricultural principle consists in perfect replenishment of plant nourishments removed from land by harvesting. That is:

In fact, the development of a plant is in a direct ratio to the amount of the matters it takes up from the soil. ff, therefore, a soil is deficient in these mineral constituents, required by plants, they will not flourish even with an abundant supply of water (Liebig, 1840, p. pp. 151-152).

His view on this principle is also synopsized in the following phrases:

The prudent agriculturist who purchases potatoes from the peasant in his neighborhood, for the purpose of distilling alcohol from them, or rape seed for its oil, knows that every two acre crop of potatoes which the peasant sells to him, will in the residuary matter yield him three crops of rye (seed), or a full crop of rape. He knows that every cwt. of rape in oil-cake is worth two cwt. or oil mill, he takes into due amount the advantage derived from this additional to the conditions of the fertility of his land.

The peasant from whom he purchases the potatoes or rape-seed knows that the buyer looks upon this additional supply of fertilizing matter from the residues as important, but he himself considers it of no value to his land. It never occurs to him that it would be a prudent act to retain the manure constituents for his own fields at the sacrifice of a portion of the money received for his produce (Liebig, 1859, p. pp. 180-181).

Humankind has a tendency to forget the importance of the circulation of matters removed from soils in the form of crops. This tendency can be seen both in capitalism and in socialism. This is the main reason why Liebig emphasized the importance of agronomy and the maintenance of cycles. He stated:

There is no profession which can be compared in importance with that of agriculture, for to it belongs the production of food for man and animals; on it depends the welfare and development of the whole human species, the riches of states, and all commerce (italics added) (Liebig, 1843, pp. 138).

Liebig also writes on the maintenance of land fertility:

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 soil, and which cannot be replaced by the atmosphere? (Liebig, 1843, p. 112)

Liebig worried about the loss of phosphate because “man carries [it] with him to his grave”(Liebig, 1840, p. 200).

In addition to these points, he worried about the fact that Germany exported fertilizers which had to be returned to lands in Germany. Some people erroneously thought that Liebig denied the viability of organic agriculture. According to Liebig, humus itself is an organic matter in the process of decomposition. "It is, however, an established and indisputable fact, that the maintenance of the fertility of our fields is impossible without replacing the minerals withdrawn by the crops” (Liebig, 1859, p. 118).

He discussed the importance of humus in the following way:

Humus, as a source of carbonic acid in cultivated lands, is not only useful as a means of increasing the quantity of carbon--an effect which in most cases may be very indifferent for agricultural purposes--but the mass of the plant having increased rapidly in a short time, space is obtained for the assimilation of the elements of the soil necessary for the formation of new leaves and branches.

The fertility of the year depends in general upon the temperature, and the moisture or dryness of the spring, if all the conditions necessary to the assimilation of the atmospheric nourishment be secured to our cultivated plants. The action of humus, then, as we have explained it above, is chiefly of value in gaining time. In agriculture, this must even be taken into account; and in this respect humus is of importance in favoring the growth of vegetables, cabbages, etc. (Liebig, 1843, p. pp. 155-157).

In this way he developed his Mineral Theory and at the same time explained the importance of organic fertilizer from that point of view.

Liebig called agricultural methods in Europe at his time *a spoliation system* because these methods contributed only to the agriculturarists’ further exploitation of the total sum of elements from the soils. These methods sought to produce more in a given time period (Liebig, 1859). He had an insight into the essential characteristic of modern agriculture - EFT2 complex. Why did agriculturists do farming based on a spoliation system where they ignored the importance of the maintenance of land fertility? Because agriculturists at that time sought to obtain the maximum amount of crops with minimum labour input and a large amount of fertilizers (Liebig, 1859)

Liebig’s agronomical view was entirely different from that of the agricultural economists at that time. Because, first, Liebig clearly grasped the fact that the basic cause of degradation of land fertility is due to the sales of agricultural products and the expansion of the Sewage system in urban areas without returning the residues of agricultural products and excreta to soils. Second, the agricultural economists in Europe at that time did not pay any attention to the importance of circulation of matters in order to maintain land fertility in the long run. Their interest was to increase the amount of crop yields in a short span of time.

Liebig's position is clearly seen in his writings:

Hence, little “Japhet in search of his Father,” the poor child called “Mineral Theory,” was so ill-used and ridiculed, because he was of the opinion that the big purse at least be emptied, by always taking out money without putting any in. But who could have thought twenty years ago, when there was plenty of manure, that it would ever occur to these obstinate and wilfu1 fodder plants to produce no more manure, and no longer to spare and enrich the ground? The soil is naturally not the cause of this; for they teach that it is inexhaustible, and those still enough believe that the source from which it is derived will always flow. Truly, if this soil could cry out like a cow or a horse which was tormented to give the maximum quantity of milk or work with the smallest expenditure of fodder, the earth would become to these agriculturists more intolerable than Dante's infernal regions. Hence, the advantageous prosecution of this system of modern agriculture is only possible on large estates, for the *spoliation* of a small one would soon come to an end (underlined added) (Liebig, 1859, pp. 130-131).

In short, 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.

According to Howard L. Parsons, who edited and compiled *Marx and Engels on Ecology* (149). Marx's view on man, nature, and their relations to one another is exemplified in the following:

man is inconceivable apart from his evolution in nature and his collective labors upon nature by means of his tools. Humans' dialectical relations with nature, in which humans transform it and are thereby transformed, is the very essence of humans' own nature. For humans, nature is definable as the materials and forces of the environment that create humans and are in turn created by humans; and humans are definable as a natural creator interacting with their environment. Thus, Marx and Engels had an understanding of an approach to ecology before the German zoologist, Ernst Haeckel, coined the term Oekologie in 1869, and long before the current "ecological crisis" and "energy crisis" (Parsons, 1977, p. xi).

Parsons also writes:

The position of Marx and Engels on ecology embraces their position on technology, for they understood man as a natural being in dialectical interpenetration with the rest of nature by means of his perceptions, his reflections, his manipulatory practice with tools, machines, and techniques, his consuming, and his enjoyments. As nature and the practice of man reciprocally call out and influence each other, so the concepts pertinent to nature and human techniques-i. e., the science of ecology and technology--must be reciprocally advanced. (Parsons, 1977, p. 3).

Marx's view on nature, man, and labour can be clearly seen in his *Critique of The Gotha Programme*:

Labour is *not the source* of all wealth. *Nature* is just as much the source of use values (and it is surely of such that material wealth consists!) as is labour, which itself is only the manifestation of a natural force, human labour power....And in so far as man from the beginning behaves towards nature, the primary source of all instruments and subjects of labour, as her owner, treats her as belonging to him, his labour becomes the source of use values, therefore also wealth. The bourgeois have very good grounds for fancifully ascribing *supernatural creative power* to labour (Marx, 1977, p. 3)

There are tremendous degradations of nature and land by the rapid development through industrialization everywhere, in socialist countries as well as in capitalist countries. Strangely enough, the Marxian economists, who are supposed to inherit Marx's genius, could not appreciate his view on nature and man.

Throughout the industrial revolution, there began to occur the separation between cities and farm villages. In this regard Marx, clearly influenced by Liebig, writes:

The capitalist mode of production extends the utilization of the excretions of production and consumption. By the former we mean the waste of industry and agriculture, and by the latter partly the excretions produced by the natural exchange of matter in the human body and partly the forms of objects that remains after their consumption. In the chemical industry, for instance, excretion of production are such byproducts as are wasted in production on a smaller scale; iron filings accumulating in the manufacture of machinery and returning into the production of iron as raw material, etc. Excretions of consumption are the natural waste matter discharged by the human body, remains of clothing in the form of rags, etc. Excretions of consumption are of the greatest importance for agriculture. 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 (Marx, 1959, p. 100).

The picture drawn by Marx has much worsened ever since. He succinctly grasped the fundamental cause of destruction of nature--in our society man's dialectical relations with nature (material circulation between man and nature) are executed through the exchange of economic goods.

Marx writes about Liebig in several places:

To have developed from the point of view of natural science, the negative, i. e., destructive side of modern agriculture, is one of Liebig's immortal merits. His summary, too, of the history of agriculture, although not free from gross errors, contains flashes of light (Marx, 1936, p. 555)

His comments on Liebig can be seen in his letter to Engels:

I had to wade through the new agricultural chemistry in Germany, especially Liebig and Schönbein, who are more important in this matter than all the economists put together.

I feel proud of the Germans (Liebig and Schönbein. It is our duty to emancipate this "deep" people (Marx, 1979, p. 205 and p. 207).

Liebig's influence on Marx is often seen in Marx's writings in *Capital*:

It [Capitalist production] 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. By this action it destroys at the same time the health of the town labour and the intellectual life of the rural labour (Marx, 1936, p. 554)

Moreover, he keenly grasped the syndrome of modern agriculture in the following passages:

All progress in capitalistic agriculture is a process in the 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. The more a country starts its development on the foundation of modern industry, like the United States, for example, the more rapid is this process of destruction. Capitalist production, therefore, develops technology, and the combining together of various processes into a social whole, only by sapping the original sources of all wealth---the soil and the labourer (Marx, 1936, pp. 555-556).

Marx also reached a deep understanding about the difference between agriculture and manufacturing:

It is possible to invest capital here successively with fruitful results, because the soil itself serves as an instrument of production, which is not the case with a factory, or holds only to a limited extent, since it serves only as a foundation, as a place and a space providing a basis of operations. ... The fixed capital invested in machinery, etc., does not improve through use, but on the contrary, wears out (Marx, 1959, p. 761-762).

Marx also mentioned the similar characteristics between large-scale industry and large-scale mechanized agriculture:

Large-scale industry and large-scale mechanized agriculture work together. If originally distinguished by the fact that the former lays waste and destroys principally labour-power, hence the natural force of human beings, whereas, the latter more directly exhausts the natural vitality of the soil, they join hands in the further course of development in that the industrial system in the country-side also enervates the labourers, and industry and commerce on their part supply agriculture with the means for exhausting the soil (Marx, 1959, p. 793).

From the discussion above, it has become clear that Marx effectively evaluated and appreciated the development process of agriculture and the destructive aspect of modern industry in terms of the circulation of matter between nature and man as presented by Liebig.

We close this section with Marx's concern for the forest problem:

The long production time (which comprises a relatively small period of working time) and the great length of the periods of turnover entailed made forestry an industry of little attraction to private and therefore capitalist enterprise, the latter being essentially private even if the associated capitalist takes the place of the individual capitalist. The development of culture and of industry in general has ever evinced itself in such energetic destruction of forests that everything done by it conversely for their preservation and restoration appears infinitesimal (Marx, 1957, p. 244).

The Physiocrats and Adam Smith

In the previous two sections deep insights into agriculture and land by two distinguished scholars, Liebig and Marx, were discussed. In this section, several other economists' general views on nature, land,and agriculture will be examined.

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. French thinkers in the latter half of the eighteenth century, discouraged by several wars, especially by the Seven Years' War with England, looked for guidance in a different way. 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". This doctrine ran to the effect that a nation's agricultural land and labor -its farms and working farms- are the sole producers of its annual produit net -i. e., the (small) part of its annual gross output of weakh which is surplus over and above the (main) part which must be used up in consumption by the people and replacement, maintenance, or upkeep of the previously existing stock of capital (Taylor, 1960, pp. 21-22).

The true error made by the Physiocrats is that hey 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. Therefore they did not seem to realize the importance of circulation of matter in the form of manure to maintain the land fertility (Liebig, 1859).

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). His account seemed to rest on an implicit assumption that nature is generous. He clearly 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 the land fertility ultimately determines the value of lands, the economists after him tried to make the national economy develop through reduction in employment in agricultural sector and exhaustion of land fertility because they did not have an insight into the fact that lands are “treasures” of all humans.

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 a 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 lands in England consisted of 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 turips, 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 the 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”. However, Smith considered the rent of lands as follows: “It [rent] is the work of nature which remains after deducting or compensating every thing which can be regarded as the work of man” (Smith, 1937, p. 345).

While Smith's view on division of labour had some important points in order to keep a harmonious balance between agriculture and manufacturing industry, and a balance between farming villages and cities thanks to his esteem for agriculture, the balance is nothing but a balance via the flow of economic goods. 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 writings:

We must not, however, upon this account, imagine that the gain of the town is the loss of the country. The gains of 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.

Malthus and the Limitation of the Food Supply

It was Malthus who studied the importance of limited space for an increase in food. In the theoretical essence of the classical system, the principle of population does not play an important role. In this respect there is the phrase given by Schumpeter:

In estimating the importance of the principle of population for economics we have to make the following distinctions: for the theoretical essence of the classical system it is of no importance at all since this system would remain what it is, even if the principle of population were omitted from it. It is, however, all the more important for the exactness and the apparently practical value of some conclusions (Schumpeter, 1954a, p. 111-112).

It is because of this latter reason that we discuss the 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, That food is necessary to the existence of man. Secondly, That 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 gr6ater 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 shew 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 limitation of food due to 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 (italics added) (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 the developed countries as well as for the developing countries.

Barber, 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. (Barber, 1968, p. 63). 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 the 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, 1946, p. 555).

In Chapter II an entropy theory on land was given so that we can understand now that modern technology per se is the cause of soil destruction.

What, then, is the true error that Malthus made? K. Boulding.writes in his Foreword to Po ulation: The First Essa by Malthus: "Eventually, however, a stationary population must be reached on a limited earth or even in a limited universe". This is the same mistake as claimed by H. Daly that "ecological salvation lies in the stationary state" (cited by Georgescu-Roegen, 1976, p. 367). 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).

The Law of Diminishing Returns: The Classical School and Liebig

In Chapter II four types of the law of diminishing returns were examined, showing that the thermodynamic limitations on matter--energy balance in a system were essentially responsible for those laws.i9i in this section, the law of diminishing returns in the English classical school and physiological analysis of this law given by Liebig will be discussed.

The concept of the law of diminishing returns in the current practice of standard economics can be formulated as follows: if all factors of production save one are held constant, the increments to output obtainable from the addition of successive units of a variable factor will, beyond a certain point, diminish (Barber, 1968, pp. 64-65)

All leading classical economists, however, restricted this law to land. But the following formulation by N. W. Senior seems the most effective:

Agricultural skill remaining the same, additional labour employed on the land within a given district produces in general a less proportionate return, or, in other words, that though, with every increase of the labour bestowed, the aggregate return is increased, the increase of the return is not in proportion to the increase of the labour. (Schumpeter, 1954b, p. 584).

On this law Schumpeter writes:

Although we find the law of diminishing returns from land already in the eighteenth century in the scientific literature of the time (Turgot, Ortes), in the English discussions on economic policy of the early part of the nineteenth century we meet with the opposite view that increased capital expenditure in agriculture as well as in industry is accompanied by a fall in cost per unit. It was only through the efforts of Anderson, Malthus, West and Ricardo that the view prevailed according to which there existed in this respect an essential difference between agriculture and industry and that for the former the law of diminishing returns is valid, while for the latter the law of increasing returns operates (Schumpeter, 1954a, p. 108).

Apart from the lack of physiological and thermodynamic analyses in the classical school, the classical school economists did not realize that another type of the law of diminishing returns, the stock type, would operate in the long run.

Yet Schumpeter further writes:

The proposition of diminishing returns or rising costs per unit in agriculture played a considerably smaller part in the French and German literature than it did in England (Schumpeter, 19541, p. 108).

What kinds of explanation can be offered for this fact? Two explanations are possible without claiming to give any definite evidence on this matter. First, according to Carter and Dale (1974), France and Germany remained feudalistic, with a feudalistic agriculture of longer duration than England's. Especially in Germany, the feudal system did not collapse until the Prussian kings came to power around the middle of the seventeenth century. Modern agriculture and freedom of capital investment in agriculture in England seemed to accelerate the degradation of soil fertility more than in France and Germany, so that the economists in England ultimately began to worry about the constraint set by the limitation of land. Therefore the law of diminishing returns seemed to play a more critical role in England. Second, in England a timber shortage as well as land shortage of availability was a serious problem. E. A.Wrigley writes that “the supply of some types of timber was causing much less difficulty on the continent than in England in the seventeenth century” (Wrigley, 1962, p. 14). In sum, the limitation of land in England seemed to be more serious than that in Germany and France so that the economists in England paid more attention to the law of diminishing returns.

As Schumpeter once noted, the classical school economists grasped the meaning of the law of diminishing returns intuitively:

The leading ‘classics'’were of the opinion that finally the limited supply of better types of land and the increasing difficulties of producing more on all types of land would make further improvements in production impossible and in consequence any further extension of production of food would meet with insurmountable obstacles (Schumpeter, 1954a, p. 109).

The classical economists advocated the law of diminishing returns without analyzing its cause and presenting the way how to keep this law from operating. However, the era of the agronomis-cum-agricultural economist had perhaps ended already. Liebig clearly grasped that the principle of agronomist-cum-agricultural economist should be to accomplish an enlargement of crop yields and an expansion of profit (economic rationality) based on the law of compensation to soils (a natural scientific rationality concerning circulation of matter in nature). It was unfortunate that after him, the agronomy was divided into two parts; the agricultural chemistry and the agricultural economics. That is to say, a science, whose object is to unite the economic rationality concerning yields and profit with a natural scientific rationality concerning preservation of land fertility, was never established. The classical economists were not agronomist-cum-agricultural economists, but rather agricultural economists per se. It seems tragic that the separation of economics from agronomy unwittingly played a role in the rapid degradation of soils in most of the countries over the world.

Probably the only exception was, again, Marx. In the third volume of pat ital Marx writes: “Concerning decreasing productiveness of the soil with successive investments of capital, see Liebig” (Marx, 1959, p. 72). Marx regarded the diminishing returns as decreasing productiveness of soil instead of as decreasing productiveness of additional capital. The law of diminishing returns as considered by Liebig was the law of natural science deeply related to his Gesetz des Minimums (the Doctrine of Minimum).

Liebig writes:
Every field contains a *maximum* of one or several, and a *minimum*, of one or several, other nutritive substances. It is by the *minimum* that the crops are governed, be it lime, potash, nitrogen, phosphoric acid, magnesia, or any other mineral constituent; it regulates and determine the amount or continuance of the crops (Liebig, 1972, p. 207).

The soil nourishment that exists in a minimum amount compared with necessary amount of it for a plant, determines the amount or continuance of the crops.

4. Entropy Disposal Mechanism and Material Circulation Against Gravitational Field on the Earth: Another View

In 1944, Schrödinger states 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. 74-75). His answer is: “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. 78). What is negative entropy? Schrödinger explains 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 steady state.

In 1945, Schrödinger adds a note to Chapter VI, concluding "that we give off heat [thermal entropy] is not accidental, but essential. For this is precisely the manner in which we dispose of the surplus [thermal] entropy we continually produce in our physical life process" (Schrödinger, 1967, p. 80). Schrödinger finally reaches the right conclusion that disposal of surplus thermal entropy is necessary for living things to continue life. Schrödinger's view of *disposal of thermal entropy* by heat emission was a new idea in physics. Since entropy is defined as a state variable and in essence an attribute inherent to energy and materials, entropy transfer or exchange must be accompanied by heat or material transfer.

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 steady state. This is what Boltzmann means by the struggle for entropy (Boltzmann, 1974, p. 24).

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 34.6 cal/deg. cm^2.

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. This asymmetry 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, is 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 describe above is only a part of the story concerning the material circulation system happening on the earth.

More in general, there are several of the material cycles that dictate the balance between 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, Chapter 5,).

However, due to the gravitation field on the earth, all material elements, in particular water-soluble elements, are tend to sink toward the bottom of the earth, the deep ocean. Rivers originated in land introduce 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 life. In fact, there is no phytoplankton at 500 meters! Phytoplankton lives/grows in the euphotic zone (that which has light), so not deeper than 80-100 meters. There is only a little blue light in deeper waters, not sufficient for photosynthesis.

However, as 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 is the wind-driven ocean currents famously studied by Ekman (1905). 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 duet 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, the similar phenomenon will appear. In fact, the east coast of North and South America, the upwelling can be observed. Therefore, thanks to these ocean currents, phytoplankton can easily do photosynthesis consuming nutrients such as NO^{3-}, PO_4^{3-}, NH^{4+} and SiO_2. A variety of fish moves around over 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 s 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 shows this mechanism: the Greenland area located between the Arctic and Atlantic Oceans, and the Weddell Sea, apart of the Southern Ocean. In the former, the down ward current appears due to sea water temperature decrease in the winter season. IN the latter, the down ward current appears due to higher concentration of salt in the winter season. So, there must be upweling currents compatible with the amounts of downward currents shown above.

The next question is what is the mechanism of material circulation from the ocean to the land? The common sense tells us that the spray of sea water containing nutritional elements is carried to the land by wind power. However, this mechanism can also apply to the nutritional transfer from the land to the sea, which might balance out the former mechanism. 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 necessary calorie per day for a bird and its weight (e.g., Nagy, 1980). However, his estimated relations can only apply to a specific types of birds. Thus, the amount of the necessary energy usually results in underestimation for birds in the forests. So, Yui (1988) derived the energy expenditure for great tilt using Walsberg's general method (Walsberg, 1983). According to Yui's estimates, in fact, a small bird can eat surprisingly huge amount of larva. Great tit of 16g, for example, can eat 1.5kg of larva per year! Many birds are generalists and eat a variety of foods. For example, Kiuchi (1975) estimated the amount of insect that birds in Shiga Kogen, Nagano of Japan (per km^2) 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 km^2 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 tributaries of the Amur river in his famous book, *Through the Ussuri Region*. After describing a variety of animals' interesting behaviors (such as bear, wild boar, fox, raccoon, eagle, crow, Eurasian jay, etc.) of devouring salmons and their dead bodies, Arseniev states:

"The river was totally frozen everywhere. So, dead remaining fish bodies are locked in this frozen state during the winter season. When warm spring comes, dead fish bodies are carried away with icy water into the seashore where dead fish bodies becomes important nutrients for living things in the sea. Here how marvelous the way of material circulation functions! How efficient the mechanism of material circulation is! There is nothing that becomes in vain" (Arseniev, 1941, Mayumi's translation from the Japanese translation).

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

Japan caught about 15 million salmons 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 km^2 along this long river. This amount of nutrition is not negligible at all, compatible with the estimate for birds by Kiuchi (1975). Salmons migrating up rivers 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.

5. 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 in north-western direction from 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, Musashino region has 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 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 land in Japan without containing 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 the average 150,000 liter of water per one are is supplied. This amount corresponds to the water depth of 1.5 meter. Therefore, Ca and Mg are supplied with this much water. Since water's specific heat is larger than that of soil, the temperatures of paddy water and the soil do not decrease much preventing the rice from suffering cold-weather damage. Water can wash away contaminated substances such as hydrogen sulfide. Water in the paddy wield 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 Edo region in 1653. Its total length was 44km, one of the largest running water system 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 field 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 there occurred no serious salinity problems. Therefore, the network system was also useful for utilizing nutritional elements originated in Musashino regions.

Secondly, there is a religious element that played a crucial role in creating the Edo scheme. In the Buddhism, there is a word, Kamma which means a mental force seeking to actualize the mind's will (e.g., Holmes, 1997). The 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 quite 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 Barlin 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 were the human beings.

Maron stated: “the greatest care should be bestowed in that country upon the gathering, preparing, and applying his excrements” (Liebing, 1972[1863], p. 365).
Mario 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 catte, either for draught or for fattening, and without the least supply of guano, ground bones, salpetre, or rape-cake. This is Japan.” (Liebing, 1972[1863], p. 363)

There started an intensive transactions of human excreta with agricultural products between the farmers and the 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)

The 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)

B. Commoner (1971, p. 188): “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”

Marx (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”

There is yet another type of material circulation mechanism among the Edo bay, the 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 sardine. 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 Musashin, agricultural fields including paddy fields, and the Edo city and finally flowed into the Edo bay where a variety of fish, shellfish and seaweed were collected. The tasty dish full of such sea foods was called as Edomae, literally meaning sea food collected in front of the Edo castle. Fish bones and waste materials in the area of the Edo bay were used by nearby farmers as an ingredient of their compost together with human excreta and fallen leaves.

Liebig (1972[1863], p. 229) “Not the fertility of the earth, but the duration of that fertility, lies within the power of the human will” This is the lesson from the Edo scheme.

6. Conclusion

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 the Edo is an example of human active participation in reinforcing a harmonious relation with the 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 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 leaning a way of life where human beings try to adjust the environmental constraints. We believe that the Edo scheme is a lesson for the future of us. We conclude this paper with F. H. King’s view of permanent 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).

References

Arseniev, V. K. 1941. *Through the Ussuri Region* (translated into Japanese by the Mantetsu Research Group). Tokyo, Asahi Shimbun.

Barber, W. J. 1968. *A History of Economic Thought*. New York, Frederick A. Praeger.

Boltzmann, L. 1974. “The second law of thermodynamics”, in B. McGuinness (ed.) Theoretical Physics and Philosophical Problems, Boston, Mass., D. Reidel Publishing Company.

Carter, V. G., and Dale, T. 1974. *Topsoil and Civilization.*, revised ed. Norman, University of Oklahoma Press.

Clapham, W. B., Jr. 1973. *Natural Ecosystems*. New York, The Macmillan Company.

Commoner, B. 1971. *The Closing Circle*. New York, Alfred A. Knopf.

Donahue, R. L., Shickluna, J. C., and Robertson, L. S. 1971. *Soils: An Intorduction to Soils and Plant Growth*, 3rd ed. Englewood Cliffs, New Jersey, Prentice-Hall, Inc.

Dragan, J. C. and Demetrescu, M. C. 1986. *Entropy and Bioeconomics: The New Paradigm of Nicholas Georgescu-Roegen*. Milan, Nagard Srl Editorice.

Ekman, V. W. 1905. “On the influence of the Earth’s Rotation Ocean Currents”, *Arkv för Mathematik Astronomi Och Fysik*, Band 2, pp. 1-53.

Georgescu-Roegen, N. 1971. *The Entropy Law and the Economic Process*. Cambridge, Mass., Harvard University Press.

Georgescu-Roegen, N. 1976. *Energy and Economic Myths: Institutional and Analytical Economic Essays*. New York, Pergamon Press.

Georgescu-Roegen, N. 1984. “Feasible recipes versus viable technologies”, *Atlantic Economic Journal*, vol. 12, pp. 21-31.

Holmes, D. 1997. *The Heart of Theravada Buddhism: The Noble Eightfold Path*. Bangkok, International Commercial Company.

King, F. H. 1911. *Farmers of Forty Centuries: Permanent Agriculture in China, Korea, and Japan*. Wisconsin, Democratic Printing Co.

Kiuchi, K. 1975. “Jurin no tori no shirabekata (An Observation Method of Birds in the Forests)”, in Haneda, K. (ed.) *Yachou no Seitai to Kansatsu* (*The Ecology and Observation of Birds*). Tokyo, Tsukizi Shokan.

Kurihara, Y. 1975. *Yugen no Seitaigaku (Ecology in Bounded Systems)*. Tokyo, Iwanami.

Liebig. J. von. 1840. *Organic Chemistry in Its Application to Agriculture and Physiology*. London, Taylor and Walton.

Liebig, J. von. 1843. *Familiar Letters on Chemistry, in Its Application to Commerce, Physiology, and Agriculture*. London, Taylor and Walton.

Liebig, J. von. 1859. *Letters on Modern Agriculture*. Edited by John Blyth. New York, John Wiley.

Liebig, J. von. 1972 [1863]. *Natural Laws of Husbandry*. New York, Arno Press.

Lovelock, J. 1979. *Gaia: A New Look at Life on Earth*. Oxford, Oxford University Press.

Malthus, T. R. 1959. *Population: The First Essay*. Ann Arbor, The University of Michigan Press.

Marx, K. 1936. *Capital*. Vol. 1. New York, The Modern Library.

Marx, K. 1957. *Capital*. Vol. 2. Moscow, Foreign Language Publishing House.

Marx, K. 1959. *Capital*. Vol. 3. Moscow, Foreign Language Publishing House.

Marx, K. 1977. *Critique of the Gotha Programme*. New York, International Publishers.

Maverick, L. A. 1938. “Chinese influences upon the Physiocrats”, *Economic History*, Supplement to the Economic Journal, No. 13, pp. 54-67.

Mayumi, K. 2001. *The Origins of Ecological Economics: The Bioeconomics of*

Georgescu-Roegen. London, Routledge.

Munk, W., 1950. “On the wind-driven ocean circulation”, *Journal of Meteorology*. vol. 7, pp. 79-93.

Murota, T. and Tsuchida, A. 1985. “Fundamentals in the entropy theory of watercycle, ecocycle, and human economy”, in The Conference on Man’s Coevolution with the Biosphere in the Age of Advanced Technology, York University, Toronto, Canda, January 21-25, 1985.

Nagy, K. A. 1980. “CO2 production in animals: analysis of potential errors in the doubly-labeled water method”, *American Journal of Physiology*, vol. 238, R466-R473.

Odum, E. P. 1997. *Ecology: A Bridge between Science and Society*. Sanderland, Mass., Sinauer Associates, Inc.

Oosaki, M. 1986. *Mizu to Nigen no Kyosei (Toward a Coexistence between Humans and Water)*. Tokyo, Nouzan Gyoson Bunka Kyoukai.

Parsons, H. L. 1977. *Marx and Engels on Ecology*. London, Greenwood Press.

Plato. 1977.*Timaeus and Critias*. New York, Penguin Classics.

Popper, K. 1994. *Knowledge and the Body-Mind Problem*. London, Routledge.

Schrödinger, E. 1967. *What is Life & Mind and Matter*. London, Cambridge University Press.

Schumpeter, J. A. 1954a. *Economic Doctorine and Method: An Historical Sketch*. New York, Oxford University Press.

Schumpeter, J. A. 1954b. *History of Economic Analysis*. New York, Oxford University Press.

Shibata, A. 1992. “Sake wa naze kawa wo sojou surunoka (Why salmons migrate up rivers?)”, Chuou Koron (Foreign Affairs), pp. 286-295.

Smith, A. *The Wealth of Nations*. Edited by E. Cannan. New York, The Modern Library.

Spengler, J. J. 1966. "Was Malthus right?", *Southern Economic Journal*, vol. 33, pp. 17-34.

Stommel, H., 1948. "The westward intensification of wind-driven currents", *Transactions, American Geophysical Union*, vol. 29, pp. 202-206.

Stommel, H. 1958. "The abyssal circulation", *Deep-Sea Research*, vol. 5, pp. 80-82.

Sverdrup, H. U. 1947 "Wind-Driven Currents in a Baroclinic Ocean; With Application to the Equatorial Currents of the Eastern Pacific", *Proceedings of the National Academy of Sciences*, vol. 33, NO. 11, pp. 318-326.

Tainter, J. A. 1988. *The Collapse of Complex Societies*. New York, Cambridge University Press.

Tamanoi, Y., Tsuchida, A., and Murota, T. 1984. "Toward an entropic theory of economy and ecology", Economie appliquée, vol. 37, pp. 279-294.

Taylor, O. H. 1960. *A History of Economic Thoughts*. New York, McGraw-Hill Company.

Tsuchida, A. 1985. "Seimei o fukumu kei no netsurikigaku (Thermodynamics for living systems)", (in Japanese) in S. Ono (ed.) *Entoropii (Entropy),* Tokyo, Asakura.

Walsberg, G. E. 1983. "Avian ecological energetics", in *Avian biology*, vol. 7 (D. S. Farner,. J. R. King, and K. C. Parkes, Eds.), pp. 161-220, New York, Academic Press

Wilkinson, R. G. 1973. *Poverty and Progress: An Ecological Perspective on Economic Developmen*t. New York, Praeger Publishers.

Williams, J. B. and Nagy, K. A. 1984. "Validation of the doubly labeled water technique for measuring energy metabolism in Savannah Sparrows", *Physiological*

Zoology, vol. 57: 325-328.

Wrigley, E. A. 1962. “The supply of raw materials in the Industrial Revolution”, *The Economic History Review*, Second Series, vol. 15, pp. 1-16.

Yui, M. 1988. *Mori ni Sumu Yachou no Seitaigaku* (*The Ecology of Birds Living in the Forests*). Tokyo, Soubun.