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HEAT ECONOMY OF THE WATER PLANET EARTH: AN ENTROPIC ANALYSIS AND THE WATER-SOIL MATRIX THEORY

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I. *Introduction*

In order to develop further the theory of the earth as an open steady system, the new theory founded by Atsushi Tsuchida, this paper takes up three major topics. The first task is to clarify the relationship between our open steady earth theory and the argument by Nicholas Geogescu-Roegen that the earth is a closed system. This should also contribute to a further clarification of the significance of the global water cycle and of the origin of water power. An evaluation of the heat efficiency of the earth as a huge steam engine will be made then. Second, I plan to compare the different approaches to solving similar fuel problems that occurred in both Japan and Britain in the 17th century. This has rarely been discussed by historians or economists up to now, yet it bears crucial implications for the future development of our open steady system theory. Third, in light of this theory, I shall reevaluate the concept of "water-soil matrix" *(suido)*, which occupies a unique position in the Japanese intellectual history, and shall propose its universal applicability.

II. *The Global Water Cycle and the Earth as an Open Steady System*

In the development of modern thought, there have been two points of view on how we ought to perceive the earth; one view supports a closed system and the other an open steady system approach. The former is represented in the arguments of Kenneth Boulding and Nicholas Georgescu-Roegen; the latter has recently been formulated by Atsushi Tsuchida.

Boulding has characterized the earth as the closed "spaceship earth." He maintains that the only way for human society to sustain itself is to carry out "recycling" of all its resources [Boulding (1968)]. However, his recycling theory is based on a mistaken understanding of matter and is incompatible with the law of entropy increase. For this reason, he comes under scathing criticism from Nicholas Georgescu-Roegen [Georgescu-Roegen (1977a)]. Georgescu-Roegen stresses that the laws of physics set a limit to recycling potential; for matter, just like energy, is subject to entropic degradation. However, both Boulding and Georgescu-Roegen share the view of the earth as a closed system. The latter says that the earth exchanges energy with the space outside of its system but that matter-wise it is a closed system. There is nothing wrong with this understanding itself. But simply by stipulating the earth as a closed system, one cannot explain why within that system men and all other living creatures—all of which are open steady systems—have been able to continue to exist until today.

In contrast to this, Tsuchida has investigated the process of the energy exchange that the earth carries on with its exterior environment. He has clarified the nature of the open steadiness—strictly speaking, the quasi-open steadiness—which the earth has maintained; he has also pointed out that the contemporary oil civilization is gradually destroying the basic conditions for the continuation of life [Tsuchida (1976)]. Below, I provide a simple introduction to Tsuchida's theory and supplement it by combining it with Georgescu-Roegen's theory of the earth as a closed system.

Generally speaking, of the huge amount of energy sent from the sun to the earth, the amount of energy Q remaining on the earth's surface is approximately 77 kcal/cm^2•y. This energy warms the earth's water and air and causes the vaporization of water and convection of air. Vapor and warm air, being lighter than the surrounding air, rise to higher altitudes. At these high altitudes, vapor undergoes what is called adiabatic expansion and cooling; it cools, condenses, becomes ice, and forms clouds. Warm air cools, too. At the time of this adiabatic expansion and cooling, water and air release the energy Q absorbed at the earth surface into outer space in the form of long-wave (ultrared) radiation.

The important thing here is that the earth receives remaining heat Q when the earth's surface is an average temperature T_1 of 17°C, or 290°K. When it is released outside of the global system at high altitudes, this occurs at the low temperature of about -23°C, or 250°K. Although an energy balance exists in the sense that heat Q absorbed and heat Q released are equal to each other, this difference in temperature results in a negative entropy balance. That is to say,

$$(1)\quad \Delta S=\frac{Q}{T_1}-\frac{Q}{T_2} =\frac{77}{290}-\frac{77}{250} =-0.042\ (\mathrm{kcal/deg{\cdot}cm^2{\cdot}}y).$$

Restated, through the global water cycle and convection, the earth functions as a heat engine which disposes of the entropy identified in equation (1) outside of the earth's atmospheric system. Ice and cool air formed at high altitudes return to the earth's surface as low-entropy sources in the forms of precipitation and descending air. In physics, a system which has the capacity to dispose of increasing entropy outside of itself is generally called an open steady system; in this sense the earth is a crucial kind of open steady system.

The key to how the earth is able to maintain itself in an open steady state lies, then, in its being a water planet. Where does Georgescu-Roegen's assertion of the matter-wise closedness of the earth fit in with regard to the suggestions made by Tsuchida? My interpretation is that for the very reason that the earth is matter-wise closed, water as a special kind of matter also remains within the system and is not lost outside of the atmosphere; instead, this enables the earth's system to maintain energy-wise an open steady state. Saying in another way, the earth's gravity prevents the lighter-weight vapor from being lost outside of the global system. Insofar as the strength of gravity varies in proportion to the mass of matter, and since mass is one of the basic attributes of matter, matter fills an essential role in the theory of the earth as an open steady system.

Georgescu-Roegen has argued that in discussing the problem of energy, "matter matters, too" [Georgescu-Roegen (1977b)] but unfortunately he only goes as far as to assert the importance of matter in general and fails to realize the special role of the substance water. We can see just how crucial matter is and, specifically, water is when we consider them in the context of the earth as an open steady system.

III. *A Computation of Heat Efficiency of the Water Planet Earth*

Above I have explained the characteristics of the mechanism for disposing of thermal entropy which is inherent in the global water cycle and convection. Below I would like to present a means for roughly calculating the source of energy for all the activities which the earth, as a kind of heat engine, carries out. The above argument has viewed heat and entropy balances from outside of the earth's system; now it is necessary to shift our focus on to the inside of that system. Putting aside such artificial activities as the burning of fuels (e.g., petroleum of coal) or the nuclear fission of uranium, activities like the vaporization of water and precipitation, as well as the growth, death, and regrowth of plants, repeat themselves semipermanently. There is not a complete renewability present but what may be taken as quasi-renewability. In other words, if we look at a period of one year, we observe that within that period there is almost no variation in entropy level. By modifying equation (1), we can express this renewability within the earth's system as:

$$(2) \quad \Delta S' = \frac{Q}{T_1} - \frac{Q'}{T_2} = 0. \quad (Q > Q')$$

The difference between the newly introduced Q' and the first Q is represented by A (equation (3)).

$$(3) \quad A = Q - Q' > 0.$$

From equation (2), we may say that:

$$(4) \quad Q' = \frac{T_2}{T_1} Q.$$

and, hence, we can obtain equation (5).

$$(5) \quad A = Q - \frac{T_2}{T_1} Q = \frac{T_1 - T_2}{T_1} Q,$$

or

$$(6) \quad \frac{A}{Q} = \frac{T_1 - T_2}{T_1}.$$

The right-hand side of equation (6) is the same as the familiar Carnot efficiency of a reversible engine.

The A introduced above is the energy source of the various activity and work carried out on the earth. Its size can be calculated by making $Q = 77$ kcal/cm$^2 \cdot y$, $T_1 = 290°K$, $T_2 = 250°K$. It comes out as:

(7) $A=10.6$ kcal/cm^2·y.

One of the requisite components of this A is the potential energy of the water possessed by the entire water cycle. We can represent this by W and try to estimate its size. In general, the potential energy of matter with mass m at a height h can be obtained from mgh, where g = the acceleration of gravity. That is to say,

(8) $W=mgh$.

In this case, m is the total mass of water that enters the water cycle in one year; h is the average height that vaporized water attains. Let the unit of measurement be taken in the MKS system. Since the world average annual rainfall is approximately 1,000 mm, the value of m per cm^2 on the earth's surface thus becomes:

$$m=0.1 \text{ kg/cm}^2 \cdot y.$$

Regarding h, opinion is divided as to the appropriate figure to use, but for our preliminary purposes we will let

$$h=5000 \text{ m}.$$

The acceleration of gravity, g, is a datum constant for which

$$g=9.8 \text{ m/sec}^2.$$

Therefore, when we use the Joule, which is the energy unit of measurement in the MKS system, W is calculated as follows:

$$\begin{aligned} W &= mgh \\ &= 0.1 \times 9.8 \times 5000 \text{ kg}\cdot\text{m}^2/\text{sec}^2\cdot\text{cm}^2\cdot y \\ &= 4900 \text{ kg}\cdot\text{m}^2/\text{sec}^2\cdot\text{cm}^2\cdot y \\ &= 4900\ J/\text{cm}^2\cdot y. \end{aligned}$$

By using the substitution rate of

$$1J=0.238 \text{ cal},$$

we can calculate that

(9) $W=1.17$ kcal/cm^2·y.

By referring to equation (7), we find that

$$\frac{W}{A} \fallingdotseq 0.11.$$

In other words, about 11 per cent of A is effectively transformed into water's potential energy. This is the source of "water power" on the earth's surface.

It is necessary to make one qualifying comment here. In my 1979 publication [Murota (1979)], I maintained the epoch-making significance of Tsuchida's 1976 formulation (equation 1). However, Professor Isao Kamisato has recently developed an argument which does not accept the validity of equation (1), but asserts that of equation (2) [Kamisato (1980)]. The development of the argument in equation (2) and following is dependent on Professor Kamisato's assertion. However, in the professor's article, the total $A(=Q-Q')$ is said to be transformed into water's potential energy. That is, he goes so far as to assert that

$$A=W.$$

This involves a serious error in that it attributes all the available energy on the earth solely to the water power.

One more requisite component of A is convection energy, but it is not as easily calculated as water power is. However, wind power develops on account of convection, and this wind energy results in wave energy on the seas. Since outside of these, the potential energy included in convection can be ignored, we can probably estimate the amount of convection energy as U by combining the calculations for wind energy and wave energy made by authorities of atmospheric energetics [Hubbert (1971)]. This is calculated as:

$$U=0.57 \text{ kcal/cm}^2\cdot y.$$

When we add W and U, we obtain 1.74 kcal/cm$^2\cdot$y. The ratio of this amount to A then becomes

$$\frac{W+U}{A}=\frac{1.74}{10.6}=0.16.$$

That is, 16 per cent of A is converted into water's potential energy and the kinetic energy of the atmosphere and of the oceans's surface. The amount of energy that supports the total activity of the living system is very small compared to the approximately 8.9 kcal/cm$^2\cdot y$ which constitutes the remaining 84 per cent. The major portion becomes thermal waste through friction between air and water. W and U themselves ultimately are changed into waste heat so that only the energy of $(Q'+A)$ is released outside of the global system. In amount, this is equal to the incoming energy Q. Accordingly, the energy balance is zero and the law of the conservation of energy is fulfilled.

It is topsoil which closely links the living system, including human beings, with the global water cycle. Topsoil, as the gathering place for microbes, has the capacity to decompose waste matter (e.g., excrement and the remains of plants and animals) that is created within the living system. In the process of decomposition, waste matter is changed into useless waste heat and still useful inorganic materials which can again be easily absorbed by plants. The former is absorbed by water into the water cycle; it escapes from the living system and is ultimately released into the outer space. Plants grow up again by relying on water as a low-entropy source and on inorganic matter and the sun's energy as sources of raw materials. Topsoil, along with water, is indispensible for the renewability of plants and animals.

IV. *Britain's 17th Century Fuel Problem and Its Response*

The preceding section has made it clear that the water cycle and topsoil function as the hidden keys to the earth's open steady state as well as to the renewability of numerous living systems in it. However, very because human society depletes the living systems by transgressing the limits of renewability, the continued existence of the living system is threatened. The problem of severe deforestation (i.e., wood abuse) in both 17th century Britain and Japan forced humans to confront such a crisis. This section and the next consider the respective responses to this problem.

Deforestation in 17th century England and Wales came to be a problem through a combination of several circumstances. The main fuels used for the heating of homes and for metallurgy were firewood and charcoal. With the development of handicraft industries besides metallurgy (such as the manufacture of bricks, pottery, alcohol, and bread), the demand for these fuels markedly increased. Furthermore, economic considerations in case for cattle breeding discouraged the conservation of forests. When it came to deciding whether to leave a forest intact as a firewood source, or to deforest the area and make it pastureland, the trend was to choose the latter because it promised greater economic profit [Buxton (1978)].

The most likely substitute for firewood or charcoal was coal. Coal, however, was inferior to firewood as a heating fuel because of its soot. While it was not impossible to use coal in the production of nonferrous metals, it could not be used in iron manufacture, for which charcoal was absolutely necessary.

As the relative scarcity of firewood and charcoal became more pronounced, it became necessary to use large quantities of coal for the heating of homes and the production of nonferrous metals, in spite of its inferior quality. However, as the quantity of coal produced increased, difficulties arose in its mining. Under topographically good conditions, manpower and horsepower (or, depending on the location, waterpower) could be used in coal mining. However, as coal tunnels had to be dug farther and farther below the earth's surface, they were often flooded by large amounts of underground water. This was difficult to pump out using human or horse power.

Ultimately, the 17th century British fuel problem, which involved both depleted firewood sources and a crisis in coal production, was apparently solved with the invention of the steam engine and the coke process of iron manufacture. Below I would especially like to focus on the development of the steam engine.

In the 16th century France, several technicians had realized the strength of the steam power obtained when water was heated; they were intent on devising a means to use this power to pump water from a lower to a higher place. Research on the topic done by Solomon de Caus was particularly well known and had been published in England by the mid-17th century. During the 17th century, then, in Britain as well as in France, various sorts of water-pumping devices had been built. However, their application appears to have been limited mainly to the fountains in the gardens of the nobility and does not seem to have directly affected the lives of large numbers of people.

Thomas Savery, however, working in the latter half of the 17th century, made it his goal to build a machine which, using coal for power, could be used to mine coal. What he wanted to do was to create steam by heating water with burning coal and to use that steam power to pump out the underground water which flooded the coal mines. This would thereby make coal mining at deep levels possible. Although he did build several trial machines for this purpose, it was Thomas Newcomen, also an Englishman, who actually realized Savery's goal. The steam engine he completed in 1711 ran on the power of low-quality, almost-useless soft small coal; it pumped out water from the coal mines and was a valuable contribution to the mining of high-quality coal. Because of its use in this steam engine, coal became a source of motive power at a fixed place in the process of coal mining itself.

Later, steam engines that had been improved by James Watt and others in England and in Cornwall so that they became loadable onto transportation vehicles. During the 19th century, then, coal became an important source of motive power for transportation also.

In iron manufacture, through the discoveries made in England by Abraham Darby Sr. in the 18th century and Henry Bessemer in the 19th century, the coke process removed the dependency on charcoal. Coke obtained through the dry distillation of coal was used as a reduction agent for manufacturing iron; gradually coal iron replaced charcoal iron.

In coal mining, the application of steam engines allowed coal largely to replace humans, animals, and water as sources of motive power in a fixed place. In addition, as a source of motive power for transportation, coal came to be used in a sphere which had hitherto relied on animal or wind power. Use of the coke process of iron manufacture made iron production without charcoal possible, as long as there was coal with the appropriate quality. In these ways, by the 19th century, the forest and fuel problems of England and Wales seemed to have been completely solved: but was this really the case?

As coal mining became easier, the time required to remove layers of coal from the earth became shorter. By the mid-19th century, the mining tunnels had become much deeper than those of the 17th century which had been a problem even then; newer mines, at great distances from where the coal was to be consumed, also became necessary. As a result, the cost per unit of coal produced could only be expected to rise. In addition, in America's Appalachian Mountains and elsewhere, large coal beds had been discovered where strip mining was feasible in massive scales. England's and Wales' position in coal economy was showing a drastic relative decline.

Under such circumstances, certain engineers devised various proposals for energy sources to replace coal. Responding to this, in 1865, the economist William Stanley Jevons confronted the world with his mammoth work *The Coal Question* [Jevons (1865)]. Jevons maintained that, aside from oil, there was no other energy source that could be used in place of coal and still fulfill the same roles that coal was undertaking. Water, wind, and wave power could be effective to the extent that they were applied for simple purposes suitable to them and in the appropriate locations. However, from the standpoint of potential transportability and other merits, one could not expect of them the same things that had been achieved with coal. The same could be said of either solar heat or geothermal energy.

It would be possible to build many water wheels or windmills and to use their power to pump water into a tank at a higher elevation. By allowing this water to fall down, electricity could be created. The electricity thus obtained could then be used to perform electrolysis of water, resulting in hydrogen gas. When compressed and put into containers, this hydrogen gas would become a transportable fuel. Jevons pointed out, however, that the building of large numbers of wind or water mills would require large amounts of coal, as would the procedure for compressing the hydrogen gas. Rather than obtain this heat value through such roundabout means, it would be more effective in terms of the heat value produced to burn coal directly. Through similar analyses Jevons examined one by one the supposed substitutes for coal and revealed that most of them, far from being replacements for coal, involved the wasting of coal.

The only exception was petroleum. Depending upon its use, petroleum could be a superior fuel and technologically it would be possible for petroleum to replace coal in many areas. However, Jevons recognized that globally the crude oil producing regions were geographically more dispersed than the coal-producing regions and that the crude oil supply would be subject to all sorts of uncertainties. Hence, he concluded that petroleum could not completely replace coal.

Coal was the fuel which had supported the Industrial Revolution and the subsequent development of the British economy. Although more and more problems had accumulated in the mining of coal, there was no substitute fuel. Jevons argued that Britain would be unable to continue its expansionistic economic policies and needed to devise more moderate plans for the future. Jevons' ultimate contention in *The Coal Question* was that if at least farmlands were carefully preserved, agricultural products could continue to be grown semi-permanently. Coal, however, once removed from the earth and burned, would never return to its original state.

Today, when we have already witnessed the 1973–74 OPEC oil embargo, Jevons' argument in the mid-19th century appears superbly brilliant. Talk about possible energy substitutes has become commonplace. But nuclear power, which is viewed as the chief substitute for oil, cannot be used without consuming large amounts of oil as well [Chapman (1975)]. The majority of other possible substitutes, too, will only become available to society through a significant consumption of oil. Rather than precipitously going after possible oil substitutes, it would be better to use oil and coal carefully and to devote our efforts to developing agriculture, forestry and fishery, which involve replenishable resources. Through the development of the steam engine and later the internal combustion engine, men were able to use coal and oil as an extremely effective motive power source. However, was this kind of solution to the forest depletion problem of the 17th century really desirable? In Britain, and really throughout the world, history tells a different story. The contemporary power civilization, which is based on large-scale petroleum consumption, is polluting water, promoting desertification through erosion of topsoil, and rapidly reducing forested areas. What really ought to be the approach to the deforestation problem? In the next section, I would like to consider this question by looking at 17th-century Japan's forest problem.

V. *Japan's 17th Century Fuel Problem and the "Water-Soil Matrix"*

With the decline of the nobility, who were located mainly in the capital of Heian (Kyoto), numerous regional began to flourish among the common people during Japan's middle ages. This increased activity meant increased fuel requirements; the furl which pervaded the daily lives of these people was firewood. Particularly in the Chugoku region, where the advanced technique for iron processing called *tatara* had been developed and the mass production of salt had been practiced by drying sea water, charcoal and firewood were indispensable fuels.

It was against this background that the Tokugawa administration continued the efforts by Oda Nobunaga and Toyotomi Hideyoshi to unify the nation; with the establishment of the *bakufu* government at Edo (Tokyo), the so-called Edo period began. In the Chugoku region it seems that the mountains had already been quite ravaged by indiscriminate felling of forests by the Azuchi-Momoyama and the early Edo periods (late 16th and early 17th centuries). In addition to the above-mentioned iron manufacturing (chiefly on the mountain slopes) and salt production (mainly along the Seto Inland Sea), pottery production also flourished; all of these contributed to rising demands for firewood and charcoal. Especially after the warfare of the earlier period had subsided, the demand for lumber also rose with the construction of massive temples and homes in cities all over Japan. Deforestation continued and there were many areas where reforestation became impossible. Ordinances forbidding the felling of trees were issues in some areas, but local people were forced to violate these just in order to meet their basic living needs and continued to cut trees for burning.

It was Kumazawa Banzan (1619–1691) who confronted a problem of deforestation similar to that in 17th century England and Wales. Born the son of a warrior in Kyoto, Banzan served under the administration of Ikeda Mitsumasa in Bizen country of Okayama fief. In this position, he was forced to weigh all aspects of the problem. For instance, could he somehow allow the local people to consume wood for their absolute living necessities as well as for demands that were not directly part of basic living needs? Was it all right for him to put a limit on the former type of demand? The ruination of the mountain lands through deforestation had resulted in frequent landslides, which filled in the river beds and made them shallower, and ultimately caused an increase in the scale and frequency of floods. The debilitating effects extended to the production of foodstuffs within the fief and touched the lives of all those living in the fief, both those in the mountains and those living downstream on the rivers.

Banzan, who realized this relationship between the forests, rivers, and human society, believed that it was necessary to enact an appropriate flood control policy, including tree planting, both in order to fulfill the firewood requirements of those living in the mountains and to provide stability for the lives of the people living downstream. Banzan realized that the mountain people's lives had been rich with vegetation because of the fresh running water and fertile soil they had enjoyed. His understanding of the concept of Japan's "water-soil matrix" *(suido)* included the geographical, climatic, and cultural characteristics which were part of life in the deep valleys of Japan's landscape. At a practical level, he oversaw the planting of trees and the building of small reservoirs in order to improve the earth's capacity for conserving water.

Kumazawa Banzan developed his water-soil matrix theory in many works [Taniguchi and Miyazaki eds. (1973 reprint)] which he wrote after he had left the Okayama fief until his death in Koga in Shimousa country. What I would like to stress here is that most of the intellectuals of the Edo period concentrated a great deal more on the notion of water-and-soil *(suido)* than on that of "wind-and-soil" *(fūdo)*. Recently, with just a cursory investigation, I learned that during the Edo period such works were written as: Joken Nishikawa, *Nihon Suido Kō* ("On Japan's Water-Soil Matrix"); Jyoin Shaku, *Uyō Shūhoku Suidoroku* ("Water-Soil Conditions in the Northwestern Regions"); Kyoin Ueki, *Tosa-koku Suido-kō* ("A Consideration of the Water-Soil Matrix in Tosa Country"). It appears that many people used the concept of water-soil matrix as a basis for examining problems of agriculture and forestry as well as climatology and geography.

Without relying on foreign countries for energy resources and without causing the total desertification of the landscape, Japan was able to support a population of about 30 millions for over two centuries. Furthermore, as an example of actually preventing desertification, Japan's Edo period deserves a place in world history. This was not a historical accident. A necessary ingredient was the establishment and diffusion of all of the practical applications of Banzan's and others' theories of water-soil matrix and the development of flood control techniques based on the knowledge of many agricultualists and forestry administrators.

In Japan, too, coal had been mined and used since about the 15th century—mainly in Kyushu. In the Edo period it was widely used as a heat source in salt production and tile-making there. However, Japan did not experience just a temporary solution to deforestation with the use of coal and the steam engine; rather, it pursued a course with a permanent solution, based on water-soil matrix theory, whose first requirement was tree planting.

Once it ended its policy of isolation under the pressure of American black ships loaded with coal, and after it carried out its Meiji Restoration, Japan followed the same path that Britain had taken toward becoming coal and petroleum civilizations. Japanese society has frequently ignored fundamental principles of storing rain water in the soil of the tree-rich mountains and of maintaining a steady water flow in the rivers throughout the year. Trust in Western large-scale technology has led many to believe that by building large dams and high embankments we can prevent flooding. Contrary to expectations, because the mountains have lost their ability to retain water, the strong waters during periods of heavy rain have easily gone over the high enbankments to result in wide-spread flooding. This has led to a vicious circle of building even higher embankments and then later on of even greater flooding [Tomiyama (1974)]. In the last 20 years of our petroleum civilization, the number of persons using firewood or charcoal in their homes has rapidly decreased. Even in rural mountain villages, kerosene or propane gas is used and the practice of taking care of wooded areas has declined. This is contributing further to the destruction of mountain forests.

Japan's traditional circumstances may be a bit different from those in other countries in that, historically, its society has actively tried to conserve rivers and forests by consuming firewood and charcoal within the limits of reproduction. After the petroleum assumed the position which wood had held as a fuel, the deforestation problem was not solved but, instead, speeded up [Murota (1980)].

From the Meiji period onward, the water-and-soil concept was quickly forgotten and that of wind-and-soil became predominant. It was the philosopher Watsuji Tetsurō's book *Fūdo* ("Wind-Soil Matrix") which seems to have made the concept popular [Watsuji (1935)]. Basing his work on the "klimatologie" theory developed by the 18th century German philosopher Johann Gottfried Herder, Watsuji translated "klimatologie" as "fūdo" and provided the basis for the wide acceptance of the wind-and-soil concept in modern Japan. However, today, when both Britain and Japan face unprecedented forestry problems, it seems that it is time to reconsider the significance of the water-and-soil concept.

VI. *Conclusion*

In the theory of the earth as an open steady system, first formulated by Atsushi Tsuchida, it was shown how the survival and renewability of human society, and of the larger living system of which it is but a part, are linked to conservation of water and soil. In looking at Japanese history, we find that this is by no means a novel approach, but that intellectuals of the Edo period, especially Kumazawa Banzan, put it into practice in their conservation policies for rivers and forests.

In Britain, too, Williams S. Jevons had already forecast in the mid-19th century that there would be a limit to both the coal civilization and the petroleum civilization which followed it [Jevons (1865)]. By applying his argument about round-about production to the development of nuclear power throughout the world, we realize that nuclear energy is neither a substitute for petroleum nor coal; rather, it is a technology which wastes them. The proposed new nuclear civilization which was expected to follow those of coal and petroleum will not be able to maintain itself without the help of oil and/or coal [Murota 1979)].

Ultimately, the things humans can rely on under these circumstances are water and soil. The next policy to be awaited is the further development of a theory of water-soil matrix and new discoveries for its fruitful application.

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