Sustainable management of natural capital for rural development

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Abstract

Sustainable management of natural capital is essential for rural development. The purpose of this paper is to provide several basic concepts concerning natural capital management so as to promote natural capital conservation in rural areas. As topics in the natural capital management, several original ideas are added concerning, for example, interpretation of economic value, underuse problem, catastrophe model, non-consumptive use, and others. For the standardized description, the Gordon-Schaefer model and its variants were used to explain as many cases as possible.

Keywords: conservation, Gordon-Schaefer model, natural capital, non-consumptive use, sustainability

Introduction

For sustainable rural development, both natural capital and human capital should be conserved for a long period of time. In other words, the sustainability of natural capital and quality of life (QOL) for the local residents should be maintained. As will be discussed in greater detail later, natural capital has several functions, some of which can be substituted by human-made capital but others may not be substitutable. It is often the case that the latter types of natural capital are essential for human existence. Regardless, both types of natural capitals are a must for acquiring a certain level of QOL.

It follows that for sustainable rural development, not only ecological but also economic sustainability is required to sustain both natural capital and human-made capital. However, there are many obstacles for sustainable use of these capitals. For example, because human-made capitals are derivative of natural capitals, a balance between crude natural capitals and processed natural capitals (i.e., human-made capitals) should be retained. However, it is quite difficult because of the uncertainty attributed to the use of natural capital, to socio-economic changes, and so on.

Therefore, the purpose of this paper is to point out some obstacles which are faced in natural capital management and to examine solutions to remove and/or alleviate the problems. In particular, I am interested in the natural capital conservation at the regional level, where the emphasis is on the local residents. As is well known, participatory development has been highly acclaimed around the 1990s, and various types of community-based managements are in execution. These facts indicate that local residents play a significant role in rural development.

Feasibility of natural capital conservation often relies on the local residents as the previously mentioned facts suggest. When conservation fails, problems of overuse or underuse occur. In what follows, I will review the reasons why overuse and underuse happen and examine the appropriate treatment of these issues from economic viewpoints.

2. BASIC CONCEPTS

2.1. CONSERVATION AND ECONOMIC VALUE

Preservation, protection, and conservation are similar but different concepts (Kawata, 2008). Preservation is a concept which is applied for the wilderness areas. Normally wilderness areas reach a climax vegetation, which is stable. Therefore, protection is put on sustaining wilderness areas as they are. Normally, disturbance by nature itself may not alter the region significantly, and human interventions are tightly restrained.

On the other hand, protection and conservation are concepts which are applied to secondary nature. Therefore, succession and disturbance by nature itself is assumed. The difference between protection and conservation lies in whether human invention is prohibited or not. In conservation, human intervention is presumed unless it is sustainable and rational capital is used. Conservation is the main concept in the context of economics.

Here, two topics are addressed concerning conservation. Before stating them, it is appropriate to distinguish values. Hereinafter instrumental value, indigenous value, and intrinsic value are defined here as follows. *Instrumental value* is a value which is represented by the function of the usefulness. *Indigenous value* is a value which people find necessary but may be useless. *Intrinsic value* is the value which exists for every object regardless of the necessity and/or usefulness it possesses.

First, economics aims to maximize the total net benefit represented by the economic values, where economic values are measured by the willingness to pay by the economic agents. Then it follows that even if an object is found to be useless, as long as it is required, this object has economic value. This is because someone must be willing to pay for an object which they find necessary. Normally, it is argued that only instrumental value is considered in economics, but when taking the above points into account, indigenous value is also relevant.

Second, on the other hand, intrinsic value can not be integrated in economic values. In the first place, it may be impossible to assess the total intrinsic value at least in the field of current economics. It is often the case that economics can assess only a part of intrinsic value such as existence value. In this meaning, total economic value must underestimate the value which an object has.

Two relevant notes on this second point should be mentioned. Firstly, in the field of environmental valuation, which is a branch of environmental economics, the main concern is on the marginal change of the quality of the environment. Therefore, people are interested in the change of their preference. In this context, intrinsic value may not be necessary unless it influences their preference. On the other hand, in the field of resource economics, which is also a branch of environmental economics, the optimal population size will be affected by the economic values. If intrinsic value is neglected, optimal population size may be underestimated; however, this conservative estimation is still meaningful. Suppose we could persuade some group who pursues the extermination of some wildlife. It is more persuasive when we insist on the conservation by presenting the conservative value of wildlife (excluding intrinsic value) rather than presenting ambiguous and possibly an overestimated value (including intrinsic value).

2.2. CONSERVATION LEVEL

Based on the above, in resource economics, conservative economic value is favorable, but when considering an accurate evaluation, some part of the intrinsic value should be considered. However, normally only market value is considered in economic decisions. Non-market values—in which some part of instrumental value, indigenous value, and intrinsic value are included—are normally neglected.

In what follows, I modified a normal resource economic model by incorporating some part of non-market values represented by $E(N)$, which may influence the preference of the economic agencies. Suppose that $E'(N)>0$ and $E''(N)<0$. The objective function and constraint of the modified Gordon-Schaefer model is provided as follows. In other words, the problem which social decision maker will face is;

$$\pi = \int_0^{\infty} e^{-\delta t}\{[p - c(N)]h(t) + E(N)\}dt \tag{1}$$

$$s.t. \quad \frac{dN}{dt} = r\left[1 - \frac{N}{K}\right]N - h(t) \tag{2}$$

where N, h, δ, p, r, and K and are population size, harvest rate, instantaneous discount rate, unit price, instantaneous growth rate and carrying capacity, respectively. The unit cost of harvesting activities is $c(N)=a/qN$, which is a decreasing function of N, where a is unit cost of harvesting activities, and q is harvesting efficiency. Clark and Munro (1975) provided a golden rule for the original problem, and here I develop a modified golden rule for this problem.

$$F'(N^*) + \frac{-c'(N^*)F(N^*) + E'(N^*)}{p - c(N^*)} = \delta \tag{3}$$

where N^* denotes a dynamically optimal sustainable population size, and corresponding harvest (which is dynamically optimal sustainable harvest) is denoted by h^*, which is equal to the growth rate $F(N^*)$.

2.3. WEAK AND STRONG SUSTAINABILITY

In terms of natural capital, sustainability means natural stock has been maintained at a constant level (stock can increase but must not decrease). In mathematical notation, it follows that,

$$\frac{dN}{dt} = 0 \quad \text{or} \quad r\left[1 - \frac{N}{K}\right]N = h(t) \tag{4}$$

Typically in environmental economics, weak and strong sustainability are advocated. Weak sustainability regards that natural capital and human-made capital are substitutes, while strong sustainability regards that these are complements. It follows that if weak sustainability is enough for ensuring sustainability of all inanimate and animate beings, what is required is to retain total capital (i.e., sum of natural capital and human made capital) at the constant level without degradation of the quality. However, if strong sustainability is required, we must retain each natural capital at some steady state, which is more than some critical level.

There are various standpoints and views between weak and strong sustainability. It is not easy to ascertain which is the most appropriate standpoint. However, based on the experience of the Biosphere 2 (Hawken et al., 1999), we could throw weak sustainability at least under current technological levels and other conditions. In 1991, 8 males and females started to live in a building called Biosphere 2, which is completely separated from the outside, and various ecosystems are included such as desert, tropical rainforest, savannah, wetland, agricultural land, and sea with coral reef. In the Biosphere 2, these people were required to stand on their own feet to supply food, air, water, and other materials to support their lives self-sufficiently.

Unfortunately, in this 3.15-acre experimental station, oxygen concentration decreased, and 17 months later had reached a level parallel to living at 17,500 feet. On the other hand, cockroaches had increased, but 19 out of 25 small vertebrate animals died out. This ambitious experiment suggests that it is quite difficult to support only 8 people for 2 years. It follows that it is almost impossible to replace natural capitals with human-made capitals especially those which suppose human existence.

2.4. NATURAL CAPITAL

Based on the experience of Biosphere 2, conservation of natural capital is essential for our existence. There must be various types of natural capitals at several levels. Here I classify two levels: one is single natural capital and the other is the bundle of natural capitals which may be grasped as ecosystem or landscape. For regional sustainability, the bundle of natural capitals, which interact with one another, must be stable for a long time. However, it is difficult to examine the sustainability of the bundle of the natural capital, and here I concentrate on examining a single natural capital.

Some of the single natural capital may be classified as the critical natural capital (CNC). The CNC concept is relatively new, and definition of CNC is not deterministic. As far as the author knows, there are only two series of papers which featured the CNC: one is working papers of the 'Human dimensions of environmental change making sustainability operational: Critical natural capital and the implications of a strong sustainability criterion (CRITINC)' which was carried out between 1998 and 2000 by the department of Environmental Social Science, Keele University, U.K. (Ekins, 2000). The other was published by De Groot et al. in 2003.

De Groot et al. (2003) presented two criteria for determining the CNC based on the existing researches, which states that 'the first criterion is the "importance" of natural ecosystems (ecological, social-cultural and economic), and the second is the degree of "threat" based on the quantity and quality of the (remaining) natural areas in a given region.' If at least one criterion is satisfied, that natural capital is regarded as the CNC. The CNC is the concept in the context of strong sustainability. This is because the CNC is not substitutable with human-made capital. If some natural capital can be substituted by human-made capital, it may not threaded of its existence or essentiality for humans and can not satisfy the criteria of the CNC.

Let us see an example when incorporating critical concept into our model. In order to explicitly show the critical level for the case of a certain species, I modified the Gordon-Schaefer model as follows (Kot, 2001):

$$\frac{dN}{dt} = r\left[\frac{N}{K_0} - 1\right]\left[1 - \frac{N}{K}\right]N - h(t) \qquad (5)$$

where $0 < K_0 < K$. Because annual increment takes negative values below K_0, this model is classified as the critical depensation, and once the natural capital level reached less than K_0, this species goes to extinction. Therefore, K_0 is the minimum viable population (MVP) to sustain the species. The MVP concept was proposed by Shaffer (1981) and is often referred to when considering the possibility of extinction.

The most difficult problem concerning critical issues of natural capital is the impossibility of empirical examination. Once capital is beyond the critical level, the natural capital may not recover the status where it was, and sometimes this natural capital will be lost. What is worse, there are many uncertainties in real natural capital management, one of which is catastrophe (discussed below).

2.5. CATASTROPHE

Catastrophe theory was advocated by the French mathematician René F. Thom in the 1960s (Thom, 1994). Recently, in the context of environmental issues, catastrophe has been extensively reexamined (Scheffer et al., 2001; Scheffer and Carpenter, 2003). Here we will see two examples of marine natural capitals which represent drastic change in the amount of harvest, although there is no evidence that these are catastrophic change.

The first example is the local stock of walleye pollack (*Theragra chalcogramma*) in the Nemuro strait of Hokkaido, Japan, where the average annual harvest between 1981 and 1989 was 85,541. This has decreased to less than half of that value in the early 1990s, with an average annual harvest of 24,339 between 1990 and 1999 (HKFES, 2000). Based on the description by the Okhotsk Ryu-hyo Museum, the change of seawater temperature seems to be the cause of this change. The second example is the Japanese tiger prawn (*Marsupenaeus japonicus*) in the Kii strait between Honshu and Shikoku, where annual harvests between 1977 and 1985 were 100–140 tons, but in 1986 it decreased to 54 tons, and the amount of harvest was not recovered in the following years (WFES, 2002). The reason for the drastic decrease is not known as far as the author knows.

In the rest of this section, I develop a modified Gordon-Schaefer model, which includes catastrophic dynamics, and demonstrate it by numerical simulation. The dynamic equation is described as follows:

$$\frac{dN}{dt} = r(T)\left[1-\frac{N}{K}\right]N - h(t) = \left[a + \frac{mT^p}{T^p + I^p} - bT\right]\left[1-\frac{N}{K}\right]N - h(t) \qquad (6)$$

where T is seawater temperature, and a, m, p, I, and b are constants. When setting parameter values as follows, we can demonstrate the drastic natural capital deduction which is ascribable to seawater temperature change; $K = 500, p = 500, m = 2, a = 0.001, b = 0.001, I = 0.001$, and $N = 400$. When $-5 < T < 5$, annual natural capital increment is 160. However, once the sea temperature breaks the bounds of these seawater temperatures, annual natural capital increment declines to almost zero. Although this model is simple and some modification is needed for more practical use, such a simple model is still useful for explaining catastrophic change.

Because several local populations have gathered at the fishing ground, even if some of the local populations have decreased to zero, there are still other local populations which come over to the fishing ground. In total, the size of the harvest seems drastically declined as the above two example demonstrate.

3. ISSUES OF OVERUSE

3.1. TRAGEDY OF COMMONS REVISITED

Overuse problem in the context of natural capital are often described as "the tragedy of the commons", which is descended from the name of the seminal article by the American biologist G Hardin (Hardin, 1968). Opinions on this article are somewhat complicated. Initially, Hardin presented his cherished opinion, and it seemed to be sensational and promoted further researches on commons by other scientists. One thing which should be mentioned here is the fact that his major intention seems not on the indication of tragedy of the commons itself, but on the issues, which have no technical solution such as population problem.

In the modified Gordon-Schaefer model in this paper, overuse problem is described as follows. Because open access is permitted and every economic agency hurries to fish or hunt wildlife, the result is the first-come-first-served situation. Therefore, the value that the future natural capitals have is substantially reduced, and discount rate takes a substantially high, almost infinite, value. In such a case, a modified golden rule is revised as follows:

$$N^{\infty} = \frac{a}{pq} \qquad (7)$$

where N^{∞} denotes a dynamically optimum sustainable population size when discount rate is infinite. As is easily confirmed, this condition is the same as the one which is obtained when *E(N)* is not considered. It implies that whether or not we consider part of the non-market values will influence the population size when the management has successfully proceeded, it has no influence if the open access is permitted and over-exploitation has occurred.

There are many scientists who investigated the commons of the world. They are influenced by Hardin's indication, and finally they concluded that traditional commons are often under proper management, free from the tragedy of the commons. Partha Dasgupta, a famous resource economist, critically states in his book *The Control of Resources* (Dasgupta, 1983) as he quotes some sentences of Hardin's article that 'it would be difficult to locate another passage of comparable length and fame containing as many errors as the one above'.

However, tragedy of the commons is not necessarily imaginary fears. It can be a problem in case of global commons and loose local commons. Inoue (1997) classified commons as local commons and global commons, and recently this classification has often been used. Local commons and global commons are those in which the right to access to the natural capital is limited or not limited to certain groups, respectively. Further, Inoue (1997) proposed the classification of commons based on the existence of regulation. These are called tight local commons and loose local commons, where in the former, commons discipline exists and those belong to the commons system have rights and duties to appropriate use the natural capital of the commons, but in the latter there are no discipline, right and duties, and management of the commons is not enough.

In short, tragedy of the commons is a problem which is attributed to the open access to the natural capitals. Seijo et al. (1998) state that common property (*res communis*) is a necessary condition for failure in the optimal allocation of natural capitals, and open access (*res nullius*) is the sufficient condition for over-exploitation of the natural capital. Kawata (2008) additionally states that the above discussion can be applicable for only movable natural capitals in the case of Japan.

3.2. NEW VIEWS ON THE TRAGEDY OF COMMONS

First, I provide an overview of the tragedy of the commons in the context of the game theory based on Clark (1985). Suppose two homogeneous fishing companies perform fishing activities at some area without cooperative agreement, and the government also puts no regulation on their activities. For the sake of the simplification, let the fishing cost be zero. Then, the problem for these fishing companies is as follows:

$$\pi = \int_0^\infty e^{-\delta t}\left[ph(t)\right]dt \tag{8}$$

$$s.t.\ \frac{dN}{dt} = r\left[1-\frac{N}{K}\right]N - h(t) \tag{9}$$

Modified golden rule for the problem is given as follows:

$$F'(N^*) = \delta \tag{10}$$

Suppose the initial population size of this fish $N(0)$ coincides with N^*, and suppose both companies can select one of two strategies: cooperation (conservation of the fish population) or non-cooperation (extermination of the fish population). When the other company selects cooperation, non-cooperation is the superior strategy because it brings N^* catch, whereas cooperation brings $F'(N^*)/2\delta$ catch. On the other hand, when the other company selects non-cooperation, non-cooperation is the superior strategy because it brings $N^*/2$, whereas cooperation brings zero catch. This is because we suppose the non-cooperative fishing company will catch target fish within quite a short period of time. Therefore, the payoff of non-cooperation strategy is always superior.

The above is quite a simple formulation, and more advanced formulations have been provided (Sethi and Somanathan, 1996; Hannesson, 1997). The former shows that "cooperative behavior guided by norms of restraint and punishment may be stable in a well-defined sense against invasion by narrowly self-interested behavior", whereas the latter shows that "with highly mobile fish stocks, the number of agents compatible with cooperative self-enforcing solution is not very high for reasonable values of the discount rate."

Second, we pick up the anticommons problem. Although it is an underused problem, this is something to do with commons, and it should be included in this section. Heller (1998) and Heller and Eisenberg (1998) were the very first works which pointed out the anticommons problem. The latter article states that "by contrast, a natural capital is prone to underuse in a 'tragedy of the anticommons' when multiple owners each have a right to exclude others from a scarce natural capital and no one has an effective privilege of use."

Finally, I draw the view by Sato (2004), which points out that the existence of the traditional commons (local commons) does not necessarily deny the discussion by Hardin. This is because existing commons are biased to the successful ones. If some commons suffer from the tragedy of the commons, as Hardin discussed, these commons have already disappeared because of the tragedy of the commons. This view is quite interesting, although it is almost impossible to confirm the truth.

3.3. VICIOUS CIRCLE OF ENVIRONMANTAL DEGRADATION AND POVERTY

Pinstrup-Andersen and Pandya-Lorch (1995) state that "Poverty and environmental degradation are closely linked, often in a self-perpetuating negative spiral in which poverty accelerates environmental degradation and degradation results in or exacerbates poverty." This vicious circle may also bring overuse of natural capitals especially in the rural areas of developing countries. Typically it is explained that increases in poverty and population bring overuse of natural capitals such as forests, and these clear-cut lands will be diverted to agricultural use. Because the intensive use of these land results in the desolation of the land and desertification (i.e., environmental degradation), the problems of poverty are accelerated. There are many views towards the relevancy of this vicious circle including negative opinion, and more advanced discussion may be found in the literatures of developing economics.

4. UNDERUSE ISSUES

4.1. NON-CONSUMPTIVE USE

Kawata (2007) pointed out that when the following conditions of 'decline in consumptive use', 'increase in non-consumptive use' and 'absence of predators' are satisfied, the following two problems in the management of game animals may occur (the explanations below are quoted from Kawata, 2007 with minor changes). First, as this shift occurs, the person who utilizes game animals to gain benefits (user) and the person who suffers damage (victim) may not be the same. Until recently, the hunter was primarily the user, and the farmer or forester was the victim; in addition, the possibility of the user and the victim being the same person existed (or people from the same locality). On the other hand, recently, as the primary use shifts from hunting to other non-consumptive uses such as eco-tours, the general user is not a local but a visitor to the local area. Since the damage shifts to the vegetation or landscape, with the decline of the primary industry, the victims are not limited to local farmers or foresters. Other local people—visitors to the place, and people living in other areas who have enjoyed the benefit of the place—can also be victims.

The second problem is that the utilization of game animals as beneficial animals will not alleviate the damage they cause as pests. Until recently, the use of game animals mainly entailed consumption (namely hunting), which reduced their population size. However, as non-consumptive use starts to dominate, a bigger population of game animals is required, which exacerbates the damage. On account of this change in use, the game animal population is less utilized; in addition, in the absence of predators, the severity of damage to agricultural property, forests, and vegetation increases.

I should also point out that non-consumptive use sometimes brings a lower amount of money to the local economy. For example, Frost and Bond (2008) examine the Communal Areas Management Programme for Indigenous Resources (CAMPFIRE), which started in 1989 in Zimbabwe. Based on the 1989 to 2001 data, CAMPFIRE transferred over US$20 million to the participating communities, 95.2% of which comes from safari hunting (89.5%) and sale of hides and ivory (5.7%), whereas tourism accounts for only 2.3%. These figures suggest that market value of consumptive use sometimes substantially dominates non-consumptive use, and to keep an incentive of conservation with the local people, consumptive use may play an important role. If only non-consumptive use is permitted or favored, community-based management of the natural capital may fail because of lesser allocation of wildlife conservation income and more intensive damages.

4.2. ANOTHER CRITICALITY

Extinction of the species under the intensive influence of human is often discussed as a result of overuse. However, crucial reduction of the natural capital level of some species may occur when the natural capital is underused. For example, the population size of deer may be halved once the population size approaches the carrying capacity. Kawata (2007) demonstrates this issue with the following model:

$$\frac{dN}{dt} = \left[r_1 - \frac{r_2}{P(N)}\right]\left[\frac{N}{K_0} - 1\right]\left[1 - \frac{N}{K}\right], \qquad (11)$$

where r_1 does not include the effects of the amount of plant biomass $P(N)$, and r_2 is a function of $P(N)$. Kawata (2007) supposed $P(N)$ is a convex downward quadratic equation. When values are set appropriately, this model demonstrates that the population size halved once the population size becomes close to the carrying capacity. For a different set of parameter values, there is a possibility that the population would decrease less than MVP, resulting in extinction.

DISCUSSION AND CONCLUSIONS

An overview of several topics concerning the conservation of natural capital has been presented. It is essential to manage natural capitals in the region for wholesome rural development. Sustainable management of the rural natural capitals should be performed based on the appropriate conservation level, which is determined by the balance of cost and benefit of the conservation of the natural capitals. Non-market values such as existence value are included in the benefit, which represent the total sum of willingness of the local residents to pay. Therefore, the benefit depends considerably on the consciousness of the local residents towards the conservation or preservation of the natural capitals and willingness to pay, which reveals the consciousness of local residents. In this meaning, consciousnesses of the local residents will substantially influence the sustainable management of local natural capitals.

Therefore, it is absolutely necessary to enlighten local residents for the appropriate conservation of natural capital. In addition, Natural capital managers should grasp the methods of economic analysis for the natural capitals, which have already been examined in this paper. An environmental Kuznets curve suggests that as economy grows, the quality of the environment degrades for some time, and in order to restrain the degradation, it is crucial to analyze the status of the natural capitals unfailingly.

Conservation level provided in this paper is based on an economic standpoint, and it should be used as background information in the policymaking. Moreover, in the economic analysis, the whole value of the object is not considered. However, it is not necessarily the problem. In fact, it may even be desirable because it brings conservative evaluation of the natural capital value.

There is no shortage of the failure examples of natural capital conservation. One of the reasons for the failures can be attributed to the fact that the goal of the society is put on 'growth.' However, once we replace this goal with 'development,' in the process of the development, appropriate management of the natural capital will be required, and as a result, establishment of the sustainable society will be targeted. The author hopes that several topics addressed in this paper will be a part of benchmarks of policies in pursuing such development.

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