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SUSTAINABLE AGRICULTURAL GROWTH AND ITS ECONOMIC CONDITIONS: A CASE OF CROPPING BEHAVIOR

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Agriculture is one of the few industries which were originally sustainable. This advantage, however, has been lost in the process of agricultural growth due to various economic and social factors. Declining productivity caused by soil borne diseases is a typical example. But the point we wish to emphasize is that this is the result of economic decisions reflected in cropping patterns used by farmers even though they know how to maintain sustainability by using appropriate cropping systems. This is why an economic analysis is required for sustainability issues.

The first purpose of this paper is to present a theoretical framework based on an economic analysis of cropping behavior which has not contributed to progress in this field as yet in spite of the growing importance of problems concerning sustainability. The second purpose is to present the results of an empirical analysis for the evaluation of actual cropping behavior as an example of the potential use of this framework.

1. Sustainable with what?

When we think about sustainable problems in the agricultural sector from the economic point of view, we have to distinguish between the following two cases. The first is a sustainability problem between the agricultural sector and non-agricultural sectors. The second is the problem of sustainability within the agricultural sector.

The first case sometimes becomes a controversial issue among the different sectors involved. For instance the pros and cons about the development of the rain forest in the Amazon. Cerrados development is another typical case.

The first case often tends to become political with social problems the economist can hardly deal with. For that reason, sustainable problem with non-agricultural sectors will not be discussed in this paper.

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We will focus on the second subject, which can be analysed in terms of economic behavior. The agricultural sector was originally based on sustainable systems. But social and economic conditions often result in a distortion of the original system.

How to restore sustainable systems is one of the major problems agricultural researchers are now facing. Devising sustainable production systems is crucial for the future growth of the agricultural sector. In this context we focus on cropping behavior and try to define the economic conditions which will result in sustainable land use.

2. Theoretical Framework

In the past, cropping behavior and acreage response have been analyzed as a supply response to economic variables. However, a different theoretical framework which can deal with the sustainability issue is required because the introduction of new concepts is necessary. Since a sufficient framework does not exist, let us begin with our theoretical framework for sustainable cropping behavior.

Our framework is composed of the following three major points:

First, it is necessary to give a clear economic definition of sustainability, which is usually not presented in economic terms but in ecological terms. We define sustainability as a problem of devising incentives which are compatible with personal and social rationality, and harmonize personal and social aims.

The second point is that `the cost of land use' is to be considered. It is not easily measured but is an effective conceptual apparatus for our framework. We must define the cost of land use: it is the cost that a farmer must pay for assuring sustainable land use on his own farm. The detailed explanation is to be given later.

The third point is that cropping behavior is classified under two types: rotation cropping and continuous cropping.

The differences between the two types of cropping behavior are shown in Table 1. This classification is based on whether or not the cost is included or not in the producers decision making process. When rotation cropping is used by a farmer, then the cost of land use is internalized because a sustainable cropping systems is used and the cost is borne by tha farmer. The internalized cost is not a real cost but an opportunity cost; the highest gain you could have when you use the resource for other opportunities. The following items are included in the internalized cost.

TABLE 1. Difference between continuous and rotation cropping.

Different Points	Rotation Cropping	Continuous Cropping
Cropping system	Observed	Not observad
the Cost of L.U.	Internalized	Externalized
Soil Trouble	Yes	No
I.C.	Yes	No
Sustainability	Yes	No

note: L.U. = land using, I.C. = incentive compatibility

1. The opportunity cost of green manure which is not a cash crop but planted to maintain soil fertility.
2. The opportunity cost of labor and transportation necessary to obtain manure from other farms.
3. A management cost is also counted; the extra attention required to maintain optimal land use systems.

All of these can be defined as a resource allocation cost related to the land use system as a whole.

When continuous cropping is followed, the cost is externalized and the farmer does not take into account the "land use" cost in his decision making. In the case of rotation cropping no soil troubles would occur, while continuous cropping will inevitably cause soil problems. Thus incentive compatibility is assured in the former but not in the latter. Consequently the former can maintain sustainability, but the latter cannot.

In this setting, the economic conditions necessary for sustainable cropping behavior are presented below.

For example: for the production of a vegetable θ, an economic condition for sustainable soil fertility which producer i faces with two optional behaviors is described by the following formula:

Assumption:

The future gain of rotation cropping $\geq$ future gain of continuous cropping.

This condition is equivalent to the following mathematical form:

$$\sum_{t=1} q^{s}i(p - m c^{*s}i)/(1+ r i^{*})^{t} \geq \sum_{t=1} p q^{n}i(1- \eta i)^{t} /(1+ r i^{*})^{t} \qquad (1)$$

$$q^{s}i(p - m c^{*}si)/ r i^{*} \geq p q^{n}i(1- \eta i)/(ri^{*} + \eta i) \qquad (1)$$

is obtained from (1) in reduced form.

Let,

$q^{s}i$: Yield when producer i uses rotational cropping

$q^{n}i$: Yield when producer i uses continuous cropping

$c^{s}i$: cost of land use which is internalized when producer i uses crop rotation

$m c^{s}i$: $d c^{s}i/ d q^{s}i$,

$c^{n}i$: cost of land use which is externalized when producer i uses continuous cropping

η: declining rate per year of productivity due to deteriorating soil conditions,

$0 < \eta \leq 1$

p: market price per unit

r: subjective discount rate for gain of land utilization, $0 < r \leq 1$

*: conditional value for (1)

To simplify t means period appears only in case of different period in one equation.

The first clause on the left side in (1) shows the future gain using rotational cropping. The right side shows the future gain using continuous cropping. This means that the land use cost would be internalized when rotation cropping is followed. But it would be externalized, which means that the cost is not taken into consideration in decision making process, with continuous cropping.

Consequently the latter cannot maintain sustainable productivity while the former can. The η shows declining rate per year of productivity due to adverse soil conditions such as soil borne diseases caused by the continuous cropping. Productivity will eventually fall to zero.

Thus (1) shows that future gain of crop rotation system is greater than that of continuous cropping. This means that optimal land utilization is compatible with group rationality (area) and personal rationality (individual producer), which can be termed as a condition of incentive compatibility concerning cropping behavior. In this context the optimal land use system is defined as a behavior which fulfills the conditions of (1).

These are the theoretical conditions for sustainable land use systems and cropping behavior. In real life, however, the incentive compatibility conditions of (1) are not always satisfied because continuous cropping is often used by farmers.

This situation is described as follows,

$$q^{s}i(p - m c^{s}i)/ r i^{*} < p q^{n}i(1- \eta i)/(ri^{*} + \eta i) \quad (2)$$

Reversion of the inequality from (1) to (2) is brought about by discount rates and the cost of crop rotations. Under conditions given from (1), (2)

$$r i^{*} < r i \quad (3)$$

and,

$$m c^{*s}i < mc^{s}i \quad (4)$$

$(\because d^{2} m c^{s}i/d r i^{2} > 0)$
are obtained.

(3) and (4) indicate that the subjective discount rate and the perceived cost of continuous cropping are greater than those of continuous cropping. Thus it can be shown that increasing these cost factors influence farmer cropping behavior. This is why policy intervention is necessary. This is not, however, a major theme in this paper, thus will not be treated in more detail.

3. Empirical Analysis

In this section we introduce an empirical analysis of cropping behavior by measuring the coefficient of stability of what we call cropping patterns. The method outlined requires only simple calculations using Lotus 123, one of the most widely used spreadsheets in Brazil. It does not require any special statistical knowledge.

This coefficient provides useful information independent of whether the cropping pattern is implemented under stable conditions or not because stability of cropping pattern is one of the necessary conditions for sustainable growth.

The definition of the coefficient is given as follows: coefficient of stability of cropping pattern = $CV_{Ni}/^{CV}Yi$

Let,

CV_{Ni}: The coefficient of variance for ratio of crop i among farmers not following the pattern.

^{CV}Yi: The coefficient of variance for ratio of crop i among farmers following the pattern.

The coefficient of variance is usually obtained by σ / m.

Let,

σ: standard deviation of the observation

m: mean of the observation

The sample data used in this paper are from survey data for about 100 radish producing farms in Tokachi, Japan. The aim of the analysis is to evaluate cropping behavior of farmers growing radish, whose continuous cropping often causes serious soil borne diseases which impede sustainable growth. In this area radish is a newly introduced crop so that soil borne diseases have not yet ocurred. Continuous cropping is already practiced by some farmers. Thus it is necessary to evaluate the effects of this behavior on sustainability.

The type of cropping pattern is classified according to combination of pre-and post-radish crops; various combinations are possible. To simplify the discussion only two types are shown in this paper. Table 2 shows types of cropping pattern. Type I is rotation cropping and type II is continuous cropping.

TABLE 2. Types of cropping pattern: Pre-and Post-radish crop.

Type	Pre	Post	Type of cropping behavior
I	Wheat	Beans	Rotation cropping
II	Radish	Radish	Continuous cropping

The result is shown in Table 3. To obtain this coefficient you must first calculate the ratio of each crop for every farm. Then farmers are classified according to the types of cropping pattern and CV_{Ni} / CV_{Yi} is calculated for each type. This is a simple task with Lotus 123. The lower coefficients correspond to the use of the more stable cropping pattern because variance among farmers is smaller.

TABLE 3. Coefficient of stability of cropping pattern.

Crop Ratio/Type	I	II
Bean	1.005	1.289
Beet	1.002	2.362
Wheat	0.760	1.320
Feed crop	0.690	1.000

Note: Crop ratio of i is obtained from (area of crop i)/(total area) in each farm

Table 3 shows that the coefficients of type II's are higher than type I's in every crop, indicating that stable cropping is not achieved in the case of radish continuous cropping. Beets show a much higher figure than other crops, indicating that farmers who use continuous cropping tend to cultivate beet more than farmers who use rotation cropping. Further study is needed to disclose factors responsible for higher preference for beets by these farmers but it evidently shows clear aspects of unstable continuous cropping.

4. Conclusion

In this paper we present a theoretical framework for sustainable cropping behavior from an economic perspective. We have never had an adequate theoretical framework heretofore to deal with sustainability problems. An empirical analysis for the evaluation of cropping behavior in real situations is presented using the proposed framework. The methodology presented is easy to use with the Lotus 123 spreadsheet.

In conclusion I would like to emphasize the need for researchers working with cropping systems to cooperate with biological scientists as well as social scientists and among themselves.

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