The Ecological and Economic Aspects of the Multifunctional Role of Agroecosystems

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ABSTRACT

Current perceptions about agriculture-based systems are rooted in an assessment of their negative and positive externalities, as well as their tremendous influence in the cultural and religious values of communities. Among the emerging concerns is how to integrate this view of the multi-faceted nature and function of agroecosystems, not only in incentive systems but also in national, regional, and global policy guidelines. This paper documents available evidence which shows that the concept of multifunctionality can be used as the basis of agricultural policymaking.

The concept of multifunctionality is differentiated and at the same time associated with the popular concept of sustainability. It is pointed out that sustainability finds expression in a multifunctional agroecosystem; that is, multifunctionality is a sufficient condition for sustainable agricultural system but not a necessary condition. Various examples presented in this paper indicate the need to look at the multifunctionality of agricultural systems in a landscape vis-à-vis its historical, spatial and time dimensions of its biodiversity element.

The review of field studies provides evidence that ecological processes drive the relationships between the various roles of agroecosystems. The cases cited consist of: a paddy rice agricultural system in Yunnan province in China which has resulted from the interspecific enhancement of agrobiodiversity; a sustainable rice production system among the Bontocs in Northern Luzon, Philippines, where the interaction between the household and the rice agroecosystem has led to improved nutrient recycling; and the Phu Wiang watershed in Northeast Thailand where the lowland agroecosystem productivity is maintained at the expense of the uplands and upper forest areas.

The final section concludes with a list of questions that need to be addressed before an effective agri-environmental policy can be implemented within the context of developing countries. These questions hark back to the basic premise that implementing agri-environmental policies rooted within the concepts of multifunctionality involves technology or science, ecology, economics, and institutions. The multifunctional role of agroecosystems, which is just beginning to be slowly unraveled, will become an important area of research, and should prove valuable toward achieving national development as well as fulfilling certain Millennium Development Goals.

INTRODUCTION

Traditionally, agroecosystems or agricultural systems have been regarded simply as production units, and farmers, as producers of marketable goods or commodities. Thus, the focus of policy and technology, as well as other support systems, has been to correct market incentives, improve the extension system, and provide the technology that will help farmers increase the supply of consumable goods in the market. However, this prevailing perception toward agriculture-based systems has changed because of the concern not only for the negative externalities (such as soil and water pollution, adverse human health impacts, and increasing greenhouse gas emission) but also the possible positive externalities of preventing soil erosion, increased carbon sequestration, flood control, nutrient cycling enhancement, pollination, and pest and disease control. In addition, agroecosystems, especially the traditional ones, are known to have tremendous cultural and religious values that form an integral part of a community life.

An increasing awareness of the multiple facets of agriculture has also changed the traditionally perceived role of the farmer as simply a producer of marketable goods. The farmer and his farm are now being viewed, through slowly, as a producer and a source of marketable products, as well as of environmental and cultural services. Years of failure to account for these other services might have meant that agricultural systems have been sub-optimally promoted or undervalued. The main emerging concern now is how to integrate this view of the multi-faceted nature and function of agroecosystems at all hierarchical levels of society, especially among policymakers, and how it should find expression in incentive systems and national, regional, and global policy guidelines.

It is against this backdrop that this paper is written. The rest of the discussion is organized as follows. The next section talks about the concept of multifunctionality. This concept is differentiated and at the same time associated with the popular concept of sustainability. The review of field studies follows, providing evidence that ecological processes drive the relationships between the various roles of agroecosystems. The limited empirical literature also shows that non-commodity benefits have significant but varied values. This information provides the context for the succeeding analysis, which considers a simulated implementation of an agri-environmental policy. Specifically, different targeting schemes for genetic conservation payments are examined for their efficiency and equity impacts. The final section concludes with a list of questions that need to be addressed before an effective agri-¬environmental policy can be implemented within the context of developing countries.

HOW DOES THE MULTIFUNCTIONALITY OF AGROECOSYSTEM RELATE TO THE CONCEPT OF SUSTAINABILITY?

The concept of multifunctional agriculture is often called the "European model of agriculture" (Batie 2003). It is best understood by looking at the simple diagram in Figure 1.

Humans often modify natural systems to produce the needed goods and services for society. Agroecosystems, or modified natural systems, often do not happen without human intervention. These systems are honed by economic goals of production and conservation. They are crafted from natural systems by human beings to fit the needs of human society. As a consequence, the original processes and functions in the natural system such as nutrient cycling, energy storage and use patterns, and regulation of biotic diversity have been correspondingly modified. These modifications and the significant disruptions of such ecological processes, ultimately determine the long-term sustainability or lack of sustainability of agroecosystems.

However, alongside the production of commodity or marketable goods, the farm also produces, through known and unknown ecological processes, other services. These are often ecological or environmental services such as the prevention of soil erosion, climate regulation, and production of genetic resources or agro-biodiversity, among others. Appropriate modifications can also lead to opportunities for recreation and aesthetic values.

The process of modification and the traditions and beliefs that accompany them often become engrained as a way of life or become part of the "culture." Thus, we hear of farming being referred

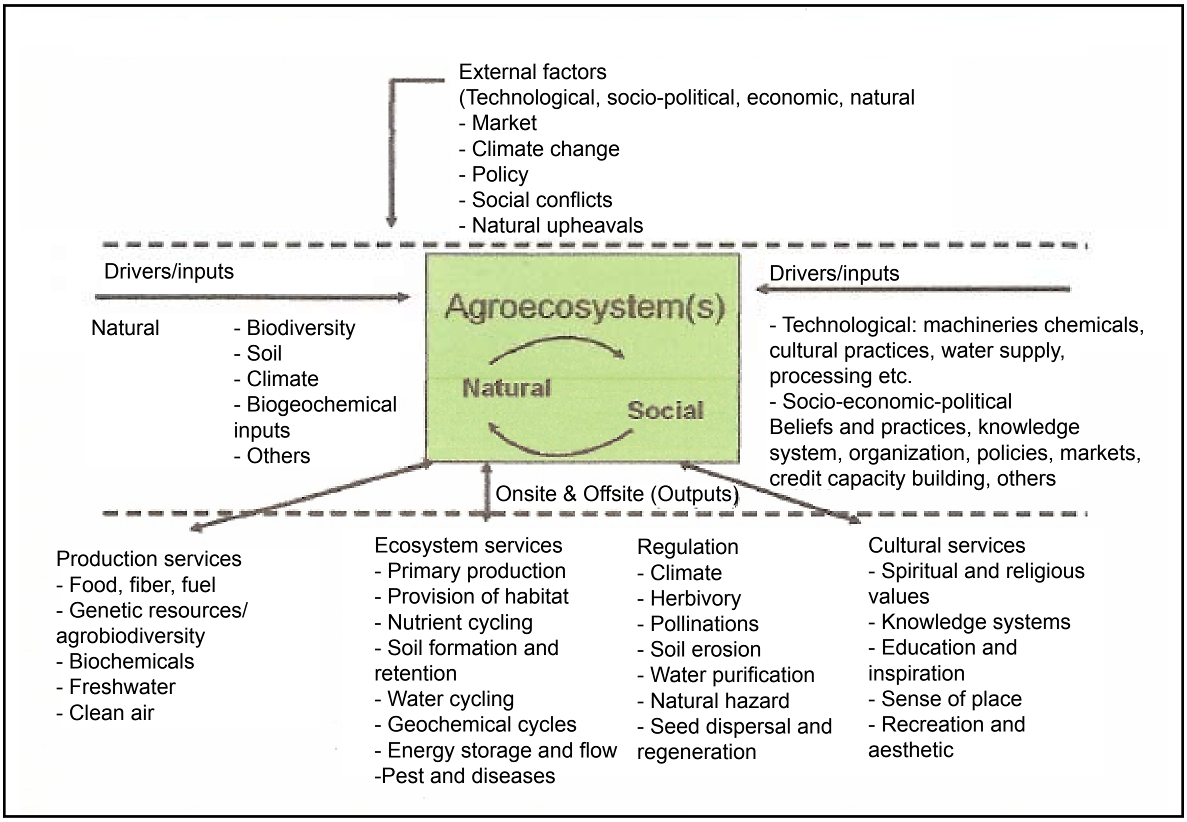

Fig. 1. Conceptual model of the multi-functional aspects of agroecosystems.

to as the "rural way" of life and nostalgia often creates a preference for preserving this "way of life." Agroecosystems can therefore be a source of cultural values. In sum, natural system modifications often lead to both commodity and non-commodity benefits. Thus, agroecosystems perform multiple functions and consequently produce different values to different people. These multifunctions and values include direct market values, indirect benefits from producing environmental goods, and cultural values.

The analysis of the multifunctionality of agriculture or agroecosystems can be approached in two ways (OECD 2001). The first views multifunctionality as an attribute or characteristic of an agricultural system or the production process. For instance, upland agriculture that employs the use of hedgerows and similar cultivation techniques results in increased biodiversity. It may also lead to reduced use of chemical inputs making it more health- and environment-friendly. Thus, a possible interpretation is that this agricultural technology has multiple attributes. In particular, it leads to the production of marketable commodities, environmental services, and cultural functions especially if the cropping pattern includes crops, which are used in cultural and religious rituals. This agroecosystem has, therefore, characteristics of biodiversity, chemical input reduction (environmental), economic properties, and cultural values.

An alternative approach to the analysis is by looking at it as a policy objective. This means that certain functions are desired and, therefore, are targeted by policy. Using this view, one can say that hedgerow technology makes agriculture more multifunctional. Thus, hedgerows technology is desired because it contributes to increased multifunctionality of the upland agroecosystem. In economic terms, the first approach is more related to a positive concept of multifunctionality, while the second is more of the normative concept of multifunctionality.

Whatever view one takes, the multifunctionality of agroecosystems gains policy relevance only when two components are present. These are:

a) the jointness of production of commodity, environmental services, and cultural values of agriculture, and b) the externalities and public good nature of these services, which result in nonexistent or thin markets for these services.

Multifunctionality is distinct from the concept of sustainability, but may be related to it, especially if the environmental and cultural functions and services are given significant values. Sustainability is essentially a goal-oriented concept (OECD 2001). If a farming system is not sustainable, then there are grounds for policy to make it sustainable. In contrast, if a system is not multifunctional, there is no imperative to make it more multifunctional unless one function is directly related to another, which then translates into sustainability. This difference is especially true if one subscribes to the positive concept of mu1tifunctionality. However, if a multifunctional agroecosystem leads to a more sustainable agroecosystem, then multifunctionality is targeted as a consequence of the goal of sustainability.

The distinction between the two concepts is even clearer when we consider the relationship between agroecosystems and the viability of rural life. Replacing traditional systems of cultivation with environmentally friendly but modem techniques sustainably modifies natural systems but may render the agroecosystem less functional. Sustainability finds expression in a multifunctional agroecosystem. That is, multifunctionality is a sufficient condition for sustainable agricultural system but not a necessary condition.

ECOLOGICAL ASPECTS OF THE MULTIFUNCTIONALITY OF AGROECOSYSTEMS

Do certain ways of modifying natural systems really produce joint products? Is there an ecological basis for the multifunctionality of agroecosystems? These questions are best answered through specific field experiences that relate agroecosystems with the ecological processes underlying them.

In a well-documented case study in Yunnan province in China, a paddy rice agricultural system—which is more productive, does not require high inputs in pesticide, and is more environmentally friendly—has resulted from the interspecific enhancement of agrobiodiversity. The traditional rice variety, which is susceptible to rice blast, has been combined with the more high-yielding rice-blast-tolerant hybrid rice (i.e., four to six rows are planted to hybrid rice for every row devoted to the traditional rice variety).

This combination creates a canopy architecture, which generates a micro environment less conducive to rice blast while at the same time increasing the income of farmers because the traditional rice commands a higher price in the market. In short, this system of paddy rice production is both environmentally friendly and economically viable. In a period of a little over six years, this system has spread out to more than half a million hectares of rice farms in Yunnan province. An important point illustrated by this case study is that enhanced ecological processes achieved by a certain way of modifying a natural system drive commodity and non-commodity outcomes.

Another case of a sustainable rice production system was documented among the Bontocs in Northern Luzon (Omengan 1981). The nutrient cycling in this rice production system has been shown to be tied up closely to the household's raising of animals whose manure revert back to the rice paddy system. The social rituals and the political structure of the village allow for synchronized planting, which reduces pest infestation. The Bontoc model shows a specific form of "coupling" of functions. It involves an interaction between the household and the rice agroecosystem, which leads to improved nutrient recycling.

A landscape analysis is also very useful in determining the multifunctional role of agroecosystems. A case study of the Phu Wiang watershed in Northeast Thailand amply illustrates this multifunctional role of agroecosystems in the landscape (SUAN-EAPI 1987). The landscape in this watershed consists of paddy rice fields in the lower portion where the human settlements are also located, a rainfed upland planted to cassava in the middle portion, and a forest area at the upper portion of the watershed. Water buffaloes, which are used for paddy rice preparation and plowing of upland cassava fields, serve as draft power source but are also allowed to graze in the paddy fields after rice harvest. However, during the paddy rice-growing period, the buffaloes are grazed in the hilly and mountainous areas in the upper part of the watershed but are brought down and kept in pens under or near the houses at night.

Accumulated animal manure is used as fertilizer for rice fields and home gardens. This kind of livestock management promotes nutrient accumulation in the lowlands while the uplands, which serve as the source of nutrients, is continuously being depleted of these soil nutrients, brought by the water buffaloes to the lowlands. This will cause a decline in upland productivity in the long run; in addition, the cassava crops planted in the upper slopes are a major source of nutrient outflow from the watershed since these are harvested and exported to Europe as animal feed. This is a case of one agroecosystem serving as source of nutrients and weeds to another agroecosystem; in this case, the lowland agroecosystem productivity is maintained at the expense of the uplands and upper forest areas.

ECONOMIC ASPECTS OF MULTIFUNCTIONAL AGROECOSYSTEMS

The Value of Non-Commodity Benefits of Agriculture-Based Systems

The previous section has shown that there is an ecological basis for the production of both commodity and non-commodity benefits from a single farm. Joint production is made possible through natural ecological processes that are modified through human intervention. The question this section wants to address is whether these functions have monetary values.

Various valuation techniques can be used to ascertain the values of these functions. In a recent unpublished case study commissioned by the Food and Agricultural Organization (FAO), Fuwa and Sajise (2006) reviewed the Asian experience in the valuation of the multifunctionality of rice paddy agriculture. Selected results from that study are shown in Table 1. The table shows that the values of various agroecosystems can be substantial—as high as $38, 000 per hectare. It also shows, however, that there are no clear dominant functions and the values of the various functions of rice paddy agriculture are very site-specific (and probably context-specific) so that there are agroecosystems that, by virtue of their kind and location in a landscape and use context in human society, can have significant monetary values.

In another study, Sajise, Harder, and Tabali (2006) also estimate the value of interspecific agrobiodiversity in selected upland farms in Sta. Fe, Nueva, Vizcaya, Philippines. Employing hedonic pricing techniques, a Box-Cox model is estimated through Maximum Likelihood techniques. The preliminary results of the analysis show that the value of interspecific agrobiodiversity ranges from P5/m2 of diversity to P16/m2. These implicit prices are sometimes higher than the prices farmers receive for selling vegetables.

Conservation Payments and its Equity Implications

The previous discussions have highlighted two important facts. First, the multifunctional roles of agriculture and the attendant values associated with it are borne out of ecological processes occurring within an agroecosystem. Second, these ecological processes often redound to significant monetary values.

The provision of non-marketed functions, however, is prohibited by the fact that most of the non-¬marketed functions are public good in nature. Common economic logic would presume that there would be under-provision of these services. What then can be done to increase the provision of these services? What are the implications of various strategies aimed at increasing the production of non¬-marketed benefits? These questions pertain to the actual implementation, through policy incentives, of the multifunctionality of agroecosystems.

If multifunctionality and its values are derived from ecological processes, its implementation is facilitated by economic and social policies. In this section, the possibility of using agri¬environmental concerns as the basis for policymaking will be looked into and the use of conservation payments to effect agrobiodiversity in rice farms in the Philippines will be in focus. Conservation payments or environmental service payments are gaining popularity among policymakers. It is purported as the first-best mechanism in implementing conservation schemes because it directly pays people to preserve and conserve the environment.

Fuwa and Sajise (2006), making use of data from agrarian reform beneficiaries, look at the implications of paying rice farmers to integrate traditional rice varieties in their farms or in-situ genetic conservation. This is complementary to the current gene banking efforts which aim to conserve genetic materials off-site. The concern is brought about by the fact that there is the possibility of loss of genetic materials due to the concentration of rice cultivation to two varieties. Ninety-eight of the rice farms in the country are now cultivating only two varieties. The study looks at various targeting schemes in achieving increased rice diversity. A treatment effects model is used to account for the fact that rice varietal choice is an endogenous variable.

The study finds that the "first-best" targeting scheme, which is a household-specific payment aimed at households who would likely incur income losses, results in the highest provision of biodiversity. However, it also results only in a minimal decrease in poverty; the poverty head count ratio declines by only 3%. A pro-poor subsidy scheme—one that pays households below the poverty line—has the largest poverty alleviation impact, namely a 35.6% reduction in the poverty head count ratio. However, this scheme also has the highest leakage, meaning, households that are not eligible because they will not incur profit losses will also receive payments. There will also be a decrease in the number of parcels planted with traditional varieties. Thus, the pro-¬poor subsidy will benefit most the poor but is less efficient than the first- best scheme. Lastly, a uniform conservation payment, which targets all households who are planting only modern varieties is considered. This targeting scheme results in lower leakages compared to the pro-poor scheme and has modest poverty impacts (28.7% reduction in the head count ratio). Comparing the three policies, the authors conclude that the uniform conservation payments seem to be the middle ground policy. It is less efficient than the first- best scheme but is more efficient than the h subsidy. However, it can reduce poverty more than the first-best scheme. Furthermore, the scheme requires less information than the first-best scheme and is administratively less costly.

Likewise, another study (Sajise, Harder, and Tabali 2006) comparing similar policies but for interspecific agrobiodiversity conservation reaches a similar conclusion. In their case, "first-best" payments often favor large landowners who are relatively well-off. Apparently, while poverty targeting is superior in terms of increasing equity, it often favors landowners where interspecific agrobiodiversity is not efficient to promote from a cost-based perspective. These results seem to be driven by the fact that economies of scope are increasing with land size.

Apart from these results, it is also evident that implementing multifunctionality within the broader goals of poverty alleviation and environmental protection may not always lead to win-win situations; thus, compromises are evident. It is something that future research must try to account for and policymakers need to grapple with. Similar trade-offs between equity and efficiency are also found in studies by Alix-Garcia et al. (2004) for the case of payment for environmental services for watershed protection in Mexican ejidos (land sharing arrangement among community people).

In many cases of rural agroecosystems, the production, environmental, and cultural functions are also closely linked. In such cases, poverty will drive the management of agroecosystems into a mainly production objective which may bring about the sacrifice of environmental functions: a case in point is the conversion of traditional diverse home gardens into purely bean production requiring high inputs of chemicals because of the market demand and the objective of increasing income. This example is a clear illustration that poverty becomes a major facilitating force in the use of traditional agroecosystems solely for their marketed benefits. Unless someone is willing to pay the farmers for their products from the traditional home gardens to include environmental services, such situations will continue to persist.

Perhaps this only shows that the implementation of multifunctionality has an added dimension in developing countries and this is the aspect of poverty alleviation. This aspect is far removed from the context by which the concept of multifunctionality originated. The poverty implication of an agri-environmental policy is not much of an issue in the European or American models of multifunctionality. In the context of developing countries there might be glaring equity-efficiency trade-offs.

Table 1. Per hectare value of 'multifunctionality' of paddy (or agricultural land) in US$ from various countries.

Scope	Mitsubishi	Mitsubishi RI, 2001		JIID, 1993	Yoshida, et al 1997	
	RI, 1991 Paddy	Ag. land and forest	(forest excluded)	Agriculture/ rural	Agriculture forest	(forest included
Flood prevention	2,879.3	746.4	4,527.9	3,475.8		
Fostering water resources/recharge	1,392.4	323.6	1,963.2	2,024.6	170.4	990.7
Prevention of soil erosion	86.5	70.8	429.4		95.5	555.4
Prevention of landslide		102.0	618.9	1,392.6		
Reduction of land subsidence						
Water purification					139.1	808.8
Processing of organic waste	10.1	2.6	15.9		0.0	0.0
Cooling air/climate		1.9	11.3		53.6	311.6
Atmosphere					105.0	610.5
Conservation of biodiversity					167.6	974.7
Conservation of landscapes					78.2	454.6
Amenity	27,763.7			10,743.32006)	0.0	
Health and recreation	6,549.2	506.8	3,074.6	3,733.2	46.0	267.4
Culture				936.2		
Community				1,603.3	22.7	131.8
Pesticide (negative health effects)						
All	38,810.2	1,754.2	10,641.2	23,909.1	877.9	5,105.5

* Not normalized by the size of the farm.
SOURCE: Fuwa and Sajise (Unpublished

CONCLUSION: CHALLENGES FOR IMPLEMENTING THE MULTIFUNCTIONALITY OF AGROECOSYSTEMS

If multifunctional agroecosystems are sufficient to achieve resilient, productive, and sustainable systems, how do we enhance the multifunctionality of agroecosystems? Within the context of developing countries, there is evidence of important ecological processes that drive the relationships between the various functions associated with agroecosystems. Furthermore, studies have shown that, although monetary values for non-commodity functions are very site- and context-specific, they can be significant. This provides an impetus to implement policies that would promote the various roles of agriculture-based systems. However, the findings of an empirical study have shown that there is a possibility of policy compromises, that is, trade-offs between poverty and environmental goals or trade-offs between efficiency and equity (Fuwa and Sajise 2006). This seems to be the unique setting by which multifunctionality is to be implemented within developing countries.

In conclusion, available evidence points to the fact that the concept of multifunctionality can be used as the basis of agricultural policymaking. In this light, a shift from agricultural to agri-environmental policymaking is now becoming apparent. Yet, to come up with effective agri-environmental policies, several questions remain. Prominent among these are:

- What are the most important driving variables influencing agroecosystems in a particular context and what are its effects on agroecosystem functions?

- How "joint" are non-commodity and commodity values? Can these functions be provided separately? That is, can biodiversity, for instance, be provided from outside of the farm and can the farmer be solely a provider of commodities?
- How does one begin to assess the multifunctionality and values of the various ecosystem functions? What are the kinds of trade-offs that can be accepted while retaining long-term capacity of the natural resource base of agroecosystems to produce needed goods and services? What policy instruments can be used to enhance these multifunctional values of agoecosystems in a landscape or how do we begin to promote sustainability?
- On the demand side, what are the functions that people are really willing to pay for?

It is one thing to encourage the continued provision of non-commodity benefits by farmers, but it is another matter to determine which among these functions would the larger public be actually willing to pay for.

- What are the key indicators of agroecosystem sustainability, given a particular kind and type of important agroecosystem(s)? What kinds of standards (natural, socio¬economic-political and technological) can be used for these indicators?
- What types and levels of agroecosystems and their interactions at the landscape level can promote overall sustainability, resiliency, equity, and productivity? What kinds of incentives and disincentives can promote or hinder these landscape agroecosystem designs?
- How does one relate the multifunctionality of agroecosystems to trade issues as well as the major concern for food, nutritional, and environmental security especially for developing countries?

These questions bring us back to the basic premise that implementing agri-environmental policies rooted within the concepts of multifunctionality involves technology or science, ecology, economics, and institutions. Thus, while sustainable development, which includes the design of agroecosystems, has been enunciated many years ago, the operational part, which involves the important recognition of the multifunctional role of agroecosystems, is just beginning to be slowly unraveled. This will become an important area of research, which will help in national development as well as the achievement of Goals I and 7 of the Millennium Development Goals in particular, and the rest of the other goals in the not-so-distant future.

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