

**Land Heterogeneity, Agricultural Income Forgone and  
Environmental Benefit: An Assessment of Incentive  
Compatibility Problems in Environmental Stewardship  
Schemes**

by

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**Abstract**

This paper examines the issue of incentive-compatibility within environmental stewardship schemes where incentive payments to farmers to provide environmental goods and services are based on foregone agricultural income. The particular focus of the paper is on the role of land heterogeneity, whether in terms of agricultural value or environmental value, in leading to divergences between the actual and the socially optimal level of provision of environmental goods and services. It is shown that such goods and services are systematically over or under-provided depending on the characteristics of land heterogeneity both within and between landscape regions. It is therefore concluded that incentive payments should be based on social willingness-to pay for the provision of environmental goods and services.

## 1. Introduction

The European Union's Common Agricultural Policy (CAP) has an established history of compensating farmers for policy changes which have reduced their production income. For example, the May 1992 CAP Reform introduced the concept of Direct Payments, which were designed to compensate farmers both for reduced price support and for foregone production income on set-aside land (see Fraser, 1993; Froud et al, 1996).

More recently, agricultural policy developments in the European Union have seen farmers encouraged to provide environmental goods and services and, as with reforms to the CAP, where this provision has been at the expense of production income, then farmers have been offered associated compensation. An example of this type of policy was the UK's Countryside Stewardship Scheme, which has recently evolved into the Environmental Stewardship Scheme (Fraser and Fraser, 2005). More specifically, DEFRA (2007a) states that the Environmental Stewardship Scheme "generate(s) financial incentives for farmers to provide the public goods they would not otherwise deliver" (p6), where these "payments are based on income foregone" (p13).

From the policy design perspective this basis for payment to farmers raises the question of whether it corrects the market failure in relation to the provision of environmental goods and services, and in so doing delivers "the socially optimal level of those goods and services" (p6).

In this context Rygnestad and Fraser (1996) demonstrated a relevant problem of incentive compatibility in policy design as it related to the operation of the CAP's set-aside policy in situations of heterogeneous land quality. In particular, with set-aside premiums established with reference to average levels of production income foregone, in the presence of heterogeneous land quality it was shown that it was in farmers' best interests to set-aside the lowest quality land in terms of production income, this resulting in policy "slippage" with respect to output control.

The aim of this paper is to show that a similar problem of incentive compatibility in relation to policy design besets environmental schemes, such as the UK's Environmental Stewardship Scheme, where payments to farmers for providing environmental goods and services are based on average levels of agricultural income foregone, rather than on society's willingness-to-pay for these environmental goods and services. In particular it will be shown that with incentive payments for such environmental schemes based on average foregone production income, the presence of land heterogeneity, both in terms of agricultural value and in terms of environmental value, leads to a systematic misallocation of taxpayer funding, both within and between landscape regions.

The structure of the paper is as follows. Section 1 examines the problem of “local” land heterogeneity, demonstrating how a uniform incentive payment system based on average production income foregone within a region of similar environmental value and agricultural land use results in actual levels of provision of environmental goods and services which are both extremely sensitive to the levels of these payments, and systematically encouraging under or over-provision of environmental goods and services between farms relative to the socially optimal levels within the region. Section 2 then examines the problem of land heterogeneity between regions, where this heterogeneity can be in relation either to the level of agricultural income or to the size of environmental benefits. Once again it is shown that, with incentive payments based on agricultural income foregone, such payments will systematically misallocate taxpayer funding between regions. In particular:

- (i) there will be excess provision of environmental goods and services in regions of relatively high agricultural income and/or low environmental benefits from such goods and services:
- (ii) there will be inadequate provision of environmental goods and services in regions of relatively low agricultural income and/or high environmental benefits from such goods and services.

Moreover, such misallocation may be so extreme that the overall level of social benefit is less than the cost of taxpayer funding, thereby resulting in not just a re-distribution of income, but also a dead weight loss to society from the policy’s operation. The paper ends with a brief Conclusion in which it is suggested that the payments to farmers for the provision of environmental goods and services should be based on the associated social benefits from the provision of such goods and services.

## 2. Section 1: Local Land Heterogeneity

This section examines the problem for policy design of “local” land heterogeneity. By “local” is meant a region of farms with a landscape of similar environmental value and similar agricultural land use. From the policy perspective “local” is also used to indicate a region where the established payments for providing the same environmental goods and services are uniform across the region.

By land heterogeneity in this context is meant variation both within and between farms in terms of the agricultural productivity of land. For example, in the study of Danish cereal farms by Rygnestad and Fraser (1996), croppable land was broadly characterised as being either poor, average or good, with the maximum yields varying in each case from 5.45 to 8.45 to 10.45 tonnes/ha. Moreover, each farm was characterised by the proportion of each of these land types which it comprised. As a consequence, each farmer would respond to the introduction of compulsory set-aside by setting-aside their lowest quality land. But farms with an overall higher quality of land would experience the largest decreases in production income.

Given such land heterogeneity on-farm, when a farmer is considering the marginal cost per hectare of converting land from agricultural production to the provision of environmental goods and services, then this marginal cost will be an increasing function of the agricultural productivity of each hectare of land. This marginal cost is represented in Figure 1 (for continuous variation across the farm in agricultural productivity) by the line  $MC^o_E$ . In this situation if the established incentive payment per hectare in the region for converting land from agricultural production to the provision of environmental goods and services is given by  $OC_o$ , then the farmer will choose to convert the  $Q_o$  hectares of their land for which the agricultural income foregone is less than (or equal to) this incentive payment. Moreover if the farm in question is made up of land which is of relatively poor quality compared with the average for that region, and with incentive payments per hectare based on average levels of agricultural income foregone for the region as a whole, then this farmer may instead find that the incentive payment is such as given by  $OC_1$ , in which case the farmer will choose to convert the larger area  $Q_1$  of the farm to providing environmental goods and services. In this context, note that if the farm in question is comprised of land which is less heterogeneous in quality, such that the variation in agricultural productivity is smaller overall, then this situation would be

represented by the flatter line  $MC^1_E$  in Figure 2. Moreover, in this case it can be seen that the farmer's chosen area of converted land is more sensitive to the established level of the incentive payment (i.e.  $OC_0$  or  $OC_1$ ) with this area varying from  $Q_0$  to  $Q_2$  in the case of  $MC^1_E$  compared with the smaller variation from  $Q_0$  to  $Q_1$  in the case of  $MC^0_E$ .

Consider next the situation where the farmer's choice of converted area with respect to the incentive payment is compared with the socially optimal converted area. In this situation the socially optimal converted area is found by referring to the social (willingness-to-pay) demand curve for environmental goods and services on the farmer's land in this region. This demand curve is represented by the line  $D_S$  in Figure 3. Also represented in Figure 3 is the marginal cost curve for converting land ( $MC^0_E$ ), and the established incentive payment for converting land ( $OC_0$ ). It can be seen that the situation represented in Figure 3 has been designed to create an outcome where the farmer's actual choice of area to convert ( $Q_A$ ) is exactly equal to the socially optimal area to convert ( $Q_S$ ) – i.e. where the social willingness-to-pay for conversion is exactly equal to the farmer's marginal cost of conversion.

However, now consider a situation of two farms in the same region, so that the established incentive payments and the social willingness-to-pay for converted land are the same for both farms, but where these two farms exhibit between-farm land heterogeneity in terms of the average agricultural productivity of their land. In particular consider farm X, which has an average agricultural productivity of land which exceeds the average for the region as a whole, and farm Y, which has an average agricultural productivity of land which is below the average for the region as a whole. As a consequence, the established incentive payment per hectare for the region is below the marginal cost of conversion per hectare for most of farm X, and above this marginal cost for most of farm Y. This situation is represented in Figure 4, where both the incentive payment per hectare of converted land and the social demand curve for each hectare of converted land are unchanged from those in Figure 3 (i.e.  $OC_0$  and  $D_S$ ), but the above-average and below-average marginal cost of conversion lines are represented by  $MC^X_E$  and  $MC^Y_E$  respectively. It can be seen from figure 4 that this between-farm form of land heterogeneity results in very divergent levels of actual converted land being chosen by the two farmers (i.e.  $Q^X_A$  compared with  $Q^Y_A$ ). In addition, even though the social demand curve for converted land is the same for farms X and Y, their differing marginal costs of

conversion justifies a different socially optimal area of converted on each farm, with this area on farm Y exceeding that for farm X (i.e.  $Q_s^Y > Q_s^X$ ) to reflect farm Y's lower marginal cost of conversion. But more importantly, a comparison of the actual with the socially optimal areas of conversion for each farm shows that the uniform conversion incentive payments per hectare across the region combined with the between-farm land heterogeneity within the region results in a systematic under or over-provision of environmental goods and services by farmers relative to the social optimum for their farm. Specifically, for farms in the region which have above-average quality of agricultural land for the region (such as X), farmers will systematically choose to convert less than the socially optimal area of converted land for their farms. While for farmers in the region which have below-average quality of agricultural land for the region (such as Y), farmers will systematically choose to convert more than the socially optimal area of converted land for their farms. Therefore, even though the environmental value of land is similar across the region, the uniform incentive payments system combined with the between-farm land heterogeneity means that the provision of environmental goods and services will be concentrated in parts of the region where the agricultural value of land is below-average. Moreover, note that this intra-regional misallocation of funds will occur even when the total funding to the region for the provision of environmental goods and services within the region is similar to the socially desirable level.<sup>1</sup>

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<sup>1</sup> Note also that if instead environmental value was much higher than given by  $D_s$ , then at some level both types of farms would feature inadequate provision. Similarly, for environmental value much lower than  $D_s$ , at some level both types of farms would feature excess provision. Even so, the provision of environmental goods and services will be concentrated in parts of the region where the agricultural value of land is below-average.

## Section 2: Land Heterogeneity Between Regions

This section considers the policy design problem where regions are subject to the same environmental stewardship scheme, but feature land heterogeneity in terms of agricultural productivity and/or environmental value. The following analysis is based largely on comparing two regions which are specified as featuring only one of these aspects of land heterogeneity, although the situation where two regions differ in terms of both agricultural productivity and environmental value is considered later in this section. Note that in all cases farmers continue to be specified as facing on-farm land heterogeneity in terms of an increasing marginal cost of converting land from agricultural production to the provision of environmental goods and services. However, to simplify the intra-region specification all farms in the same region are assumed to be identical, so that the analysis for each region is based on a “representative” farm.

### 2.1 Heterogeneity in Environmental Value

In this case the two regions are specified to be equivalent in terms of agricultural productivity, such that the incentive payment per hectare for converting land to the provision of environmental goods and services is identical for the two regions. However, the two regions are heterogeneous in terms of the social value of their environmental landscape, with one region featuring greater social willingness-to-pay for environmental goods and services per hectare than the other. An example of this type of situation would be two regions with similar agricultural income per hectare, but where one region was closer to a large population centre than the other, so that the total demand for environmental goods and services was greater in the former region. This situation is represented in Figure 5. Figure 5 shows that the actual proportion of land chosen to be converted to the provision of environmental goods and services is the same for both regions ( $Q_A$ ), consistent with their identical agricultural productivity and incentive payments to convert land. However, it can also be seen that the environmental land heterogeneity between the two regions results in a systematic misallocation of the provision of environmental goods and services between the two regions. In particular, for the region of relatively high environmental value (as represented by  $D^S_2$  the actual amount of converted land is less than the socially optimal amount ( $Q^S_2$ ). While for the region of relatively low environmental value (as represented by  $D^S_1$ ), the actual amount of converted land exceeds the socially optimal amount ( $Q^S_1$ ). Therefore, it can be seen that the operation of a uniform incentive payments scheme across these two regions, which is justified in terms of the requirement for such payments to be “based on income foregone”, results in excess provision of environmental goods and services in the region of low environmental

value, and inadequate provision of environmental goods and services in the region of high environmental value.<sup>2</sup>

## 2.2 Heterogeneity in Agricultural Value

In this case the two regions are specified to be equivalent in terms of environmental value, such that the social willingness-to-pay per hectare for environmental goods and services is the same for both regions. However, the two regions are heterogeneous in terms of their agricultural productivity, such that with the agricultural income foregone from conversion higher in one region than the other, the two regions also differ in the levels of their scheme-based incentive payments for conversion. An example of this type of situation in the UK would be an arable region and a hill-farming region, where the agricultural income per hectare is higher in the arable region than in the hill-farming region, but where the total environmental value of the two regions is similar, perhaps because the hill-farming region features higher environmental value per individual user, but is more distant from a population centre than the arable region. This situation is represented in Figure 6, where the difference in incentive payments between the two regions ( $OC_1$  and  $OC_2$ ) has been specified to result in the same area of land actually converted in each region ( $Q_A$ ). By contrast, in considering the social benefit and cost of providing environmental goods and services in the two regions, it can be seen that the socially optimal amount of converted land in the region of low agricultural value exceeds that for the region of high agricultural value (i.e.  $Q^S_2 > Q^S_1$ ). Moreover, as specified in Figure 6, this situation also features excess provision of environmental goods and services in the region of high agricultural value, and inadequate provision of environmental goods and services in the region of low agricultural value.<sup>3</sup> Consequently, it can be seen that the operation of the incentive payments scheme, by differentiating the two regions on the grounds of agricultural income foregone, when in terms of environmental value they are identical, results once again in a systematic misallocation of the provision of environmental goods and services between the two regions, with a particular bias towards excess provision in the region of high agricultural value, and inadequate provision in the region of low agricultural value.

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<sup>2</sup> Note as in the previous section that for extremely divergent levels of incentive payments and social willingness-to-pay environmental goods and services could be under or over-provided in both regions. However, the extent of under or over-provision would still differ markedly between the two regions, and a bias remain towards under-provision in the region of higher environmental value, and over-provision in the region of lower environmental value.

<sup>3</sup> Note as previously that if instead environmental value was much higher than given by  $D^S$  then at some level both regions would feature inadequate provision. Similarly, for environmental value much lower than  $D^S$  at some level both regions would feature excess provision. But in both cases the relative bias in provision between regions remains the same.

### 2.3 Heterogeneity in both Agricultural and Environmental Value

This sub-section considers the case where the two regions differ in terms of both agricultural and environmental value. It should be recognised at the outset that if these differences took the form of the region of higher agricultural value also being the region of higher environmental value, then agricultural income foregone could in effect be seen as a “proxy” for social willingness-to-pay for environmental goods and services. It follows that in this case designing incentive payments for conversion based on agricultural income foregone would to some extent substitute for social values and potentially yield socially desirable outcomes in terms of the level and distribution of the provision of environmental goods and services.

However, such a positive correlation between agricultural and environmental value seems at odds with both the research evidence and casual observation. For example, Fraser and Rygnestad (1999) showed for Danish cereal growing that croppable land with relatively low agricultural productivity was also the land that offered the highest potential benefits from set-aside in terms of reduced nitrate leaching. Moreover, in the UK (and other EU countries), the so-called “Less Favoured Areas” in terms of agricultural income per hectare, are also increasingly being referred to as areas of “High Nature Value”. (EEA, 2004). As a consequence, the following numerical illustration is based on specifying a negative correlation between agricultural and environmental value, so that the region of low agricultural value also features high environmental value, and vice versa for the other region.

Note that the purpose of this numerical illustration is not just to quantify the misallocation of the provision of environmental goods and services between the two regions as was done qualitatively in the previous two sub-sections. Rather, the additional benefit of this approach is that it allows quantification of both total government spending and total consumer surplus generated by such spending on the operation of an incentive payment system for the conversion of agricultural land to the provision of environmental goods and services:

To proceed based on the framework of the previous sub-sections, let the low agricultural/high environmental value region have the following specification (where this region is denoted by “H”):

$$D_H = 120 - q$$

$$MC_H = 15 + 0.5q$$

$$OC_H = 30$$

While for the high agricultural/low environmental value region (denoted by “L”):

$$D_L = 60 - q$$

$$MC_L = 30 + 0.5q$$

$$OC_L = 70$$

On this basis Table 1 contains details of the results of the numerical illustration. As expected from the findings of 2.1 and 2.2, and given the specified negative correlation between agricultural and environmental value, there is excess provision of environmental goods and services in Region L, and inadequate provision in Region H. Moreover, given the chosen parameter values, there is greater actual governmental spending than is socially optimal, and actual consumer surplus is less than that achieved with the socially optimal provision of environmental goods and services. But the most significant quantitative finding is that while consumer surplus exceeds governmental spending in the case of the socially optimal provision (a ratio of 1.62:1) the actual provision leads to a deadweight welfare loss with total governmental spending exceeding the gains in consumer surplus (a ratio of 0.76:1). It follows that in this case the operation of the incentive payments scheme based on agricultural income foregone results not just in a redistribution of income between taxpayers and farmers, but also in an overall reduction in social welfare.

## **Conclusion**

The aim of this paper has been to assess the problems of incentive compatibility for environmental stewardship schemes which feature incentive payments to farmers to provide environmental goods and services based on agricultural income foregone. The particular focus of the paper has been on the role of land heterogeneity, in terms of both agricultural and environmental value, as a cause of design problems for such environmental policies.

Section 1 considered the problem of “local” land heterogeneity, whereby a farmer’s participation in an environmental stewardship scheme is influenced by heterogeneous agricultural productivity of land on their own farm, and where farms in the same region may differ in terms of their average agricultural productivity. Section 2 considered the problem of land heterogeneity between regions, where these regions may differ in terms of agricultural or environmental value, or both.

In Sections 1 and 2 it has shown that the operation of an incentive payment system for farmers to convert land based on agricultural income foregone leads to a misallocation of the provision of environmental goods and services, both within and between regions. In particular in Section 1 it was shown that such a system will encourage the over-provision of environmental goods and services (relative to the socially optimal level) on farms within a region that feature relatively low average quality of agricultural land. In addition, in Section 2 it was shown that such a system will encourage:

- i) the over-provision of environmental goods and services (relative to the socially optimal level) in regions of relatively high agricultural income and/or low environmental benefits from such goods and services and
- ii) the under-provision of environmental goods and services (relative to the socially optimal level) in regions of relatively low agricultural income and/or high environmental benefits from such goods and services.

Moreover, in a situation where the regions involved feature a negative correlation between agricultural and environmental value, it was shown that the misallocation of funding for the provision of environmental goods and services between regions may be so great as to result in an overall reduction in social welfare from the operation of the scheme.

As a consequence, it may be concluded that incentive payments to farmers for the provision of

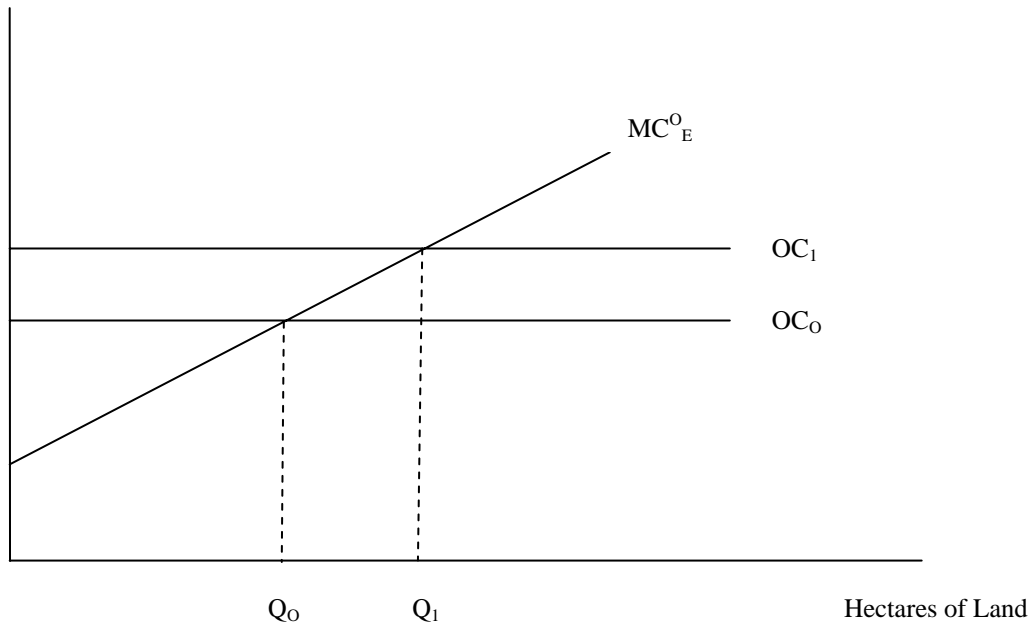
environmental goods and services should be based on the associated social benefit from the provision of such goods and services rather than on the associated agricultural income foregone. In this context it is interesting to note that although the UK's Environmental Stewardship Scheme states that it uses agricultural income foregone as the basis for determining incentive payments for the provision of environmental goods and services, that Scheme does actually contain an exception to this "rule". Specifically, within the component of this Scheme called "Higher Level Stewardship" one of the identified environmental services is "Educational Access", which provides "schools and colleges" with the opportunity to visit farms and have farmers "explain the links between farming, conservation and food production" (DEFRA, 2007b, p94). In this case the incentive payments to farmers is "per visit", and in applying to participate in the provision of "Educational Access" farmers are "expected to provide evidence of this demand" (DEFRA, 2007b, p94). Consequently, in making their decision regarding whether to provide this environmental service farmers must take account of the social benefit associated with its provision in so far as this will determine the "demand" for "Educational Access". Therefore, with this precedent for incentive payments based on social benefit already established within the UK's Environmental Stewardship Scheme, the prospects must be brighter for the broader implementation of this paper's main policy recommendation.

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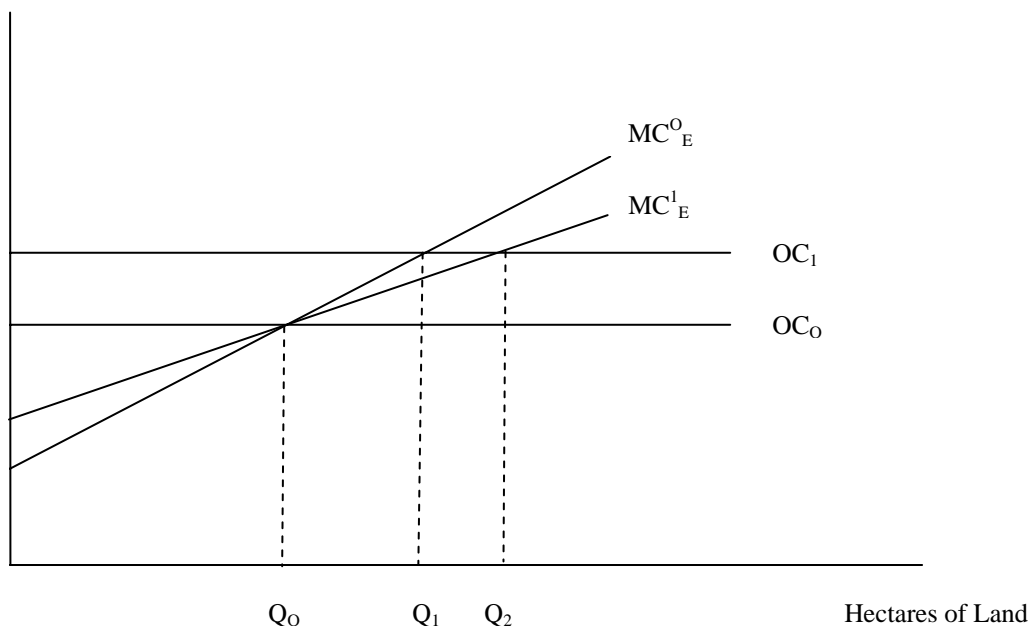
**Figure 1**

**Marginal Cost of Providing Environmental Goods and Services**



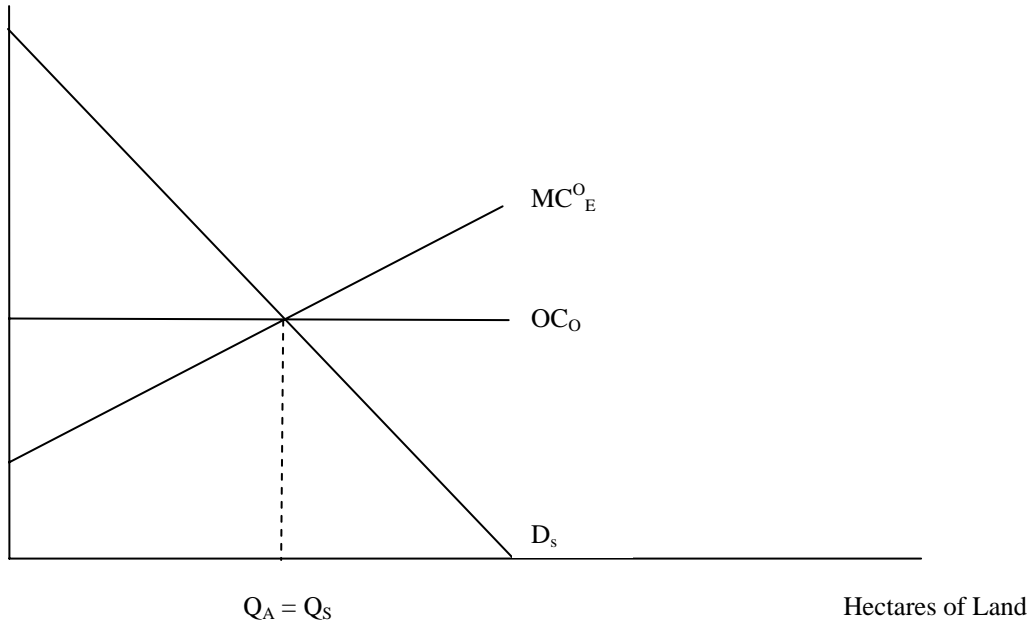
**Figure 2**

**Different Extents of Land Heterogeneity**



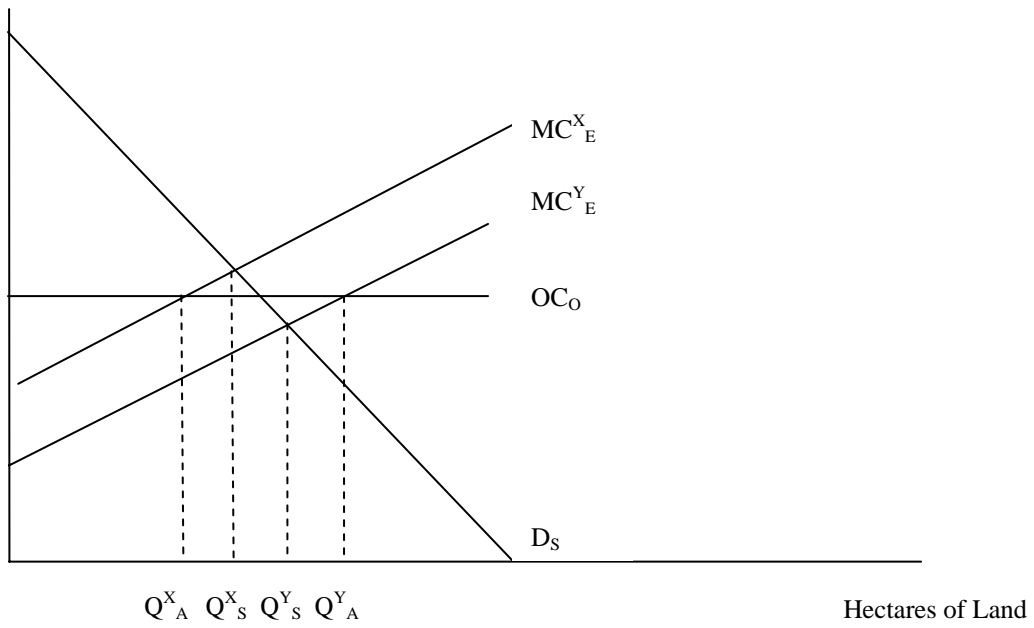
**Figure 3**

**Comparison of Actual and Socially Optimal Area of Converted Land**



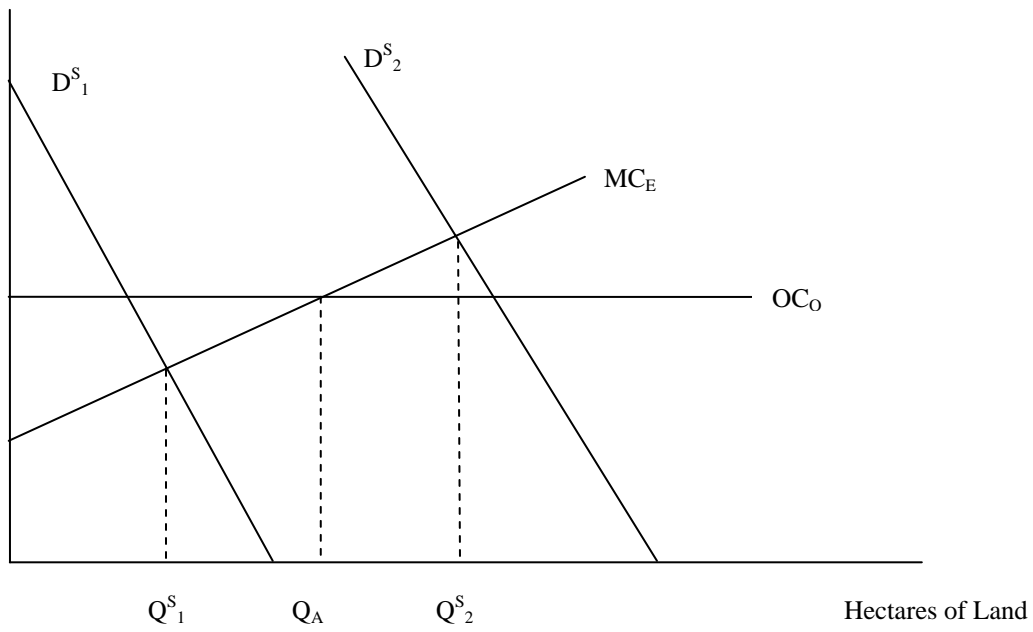
**Figure 4**

**Comparison of Actual and Socially Optimal Area of Converted Land between Farms X and Y**



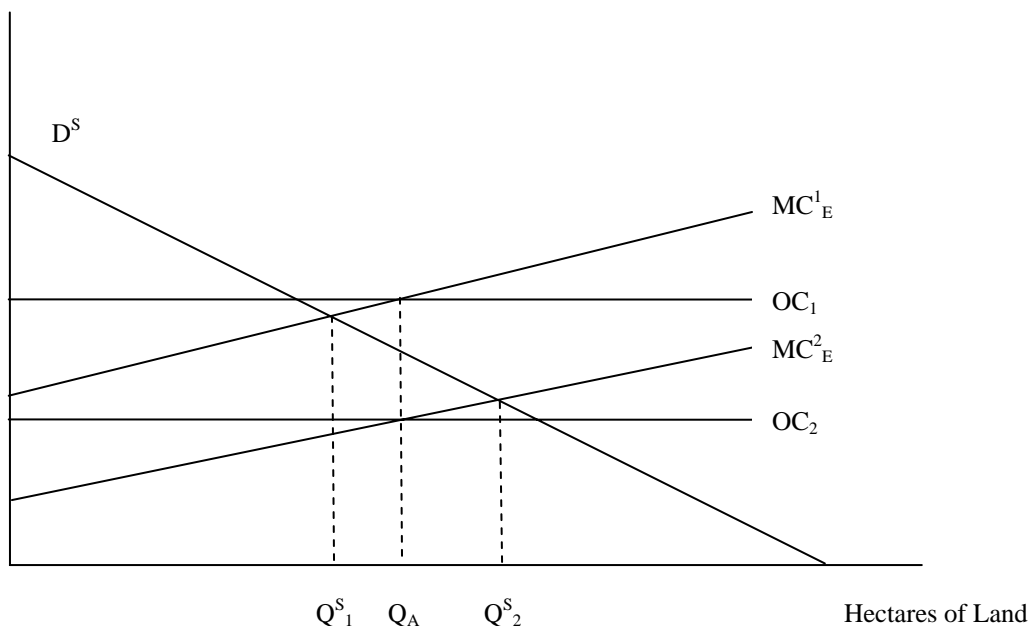
**Figure 5**

**Two Regions with Different Environmental Value**



**Figure 6**

**Two Regions with Different Agricultural Value**



**Table 1**  
**Results of the Numerical Illustration**

<u>Area Converted</u>	Region L	Region H	Total
i) Actual	80	30	110
ii) Optimal	20	70	90
<u>Governmental Spending</u>			
i) Actual	5600	900	6500
ii) Optimal	800	3500	4300
<u>Consumer Surplus</u>			
i) Actual	1800	3150	4950
ii) Optimal	1000	5950	6950