1990 TDRI Year-End Conference on
Industrializing Thailand and Its Impact on the Environment

Land and Forest: Projecting Demand and Managing Encroachment

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Session: Natural Resources for the Future

Research Report No. 1

Land and Forest: Projecting Demand and Managing Encroachment

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Industrializing Thailand and Its Impact on the Environment

Policy research is a team effort. The names of researchers mobilized to undertake the various studies in preparation for the 1990 TDRI Year-End Conference and their respective topics of responsibility are listed below:

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Theme: **Natural Resources for the Future**

Synthesis Paper #1: Natural Resources for a Sustainable Future: Spreading the Benefits

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Research Report #1: Land and Forest: Projecting Demand and Managing Encroachment

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Synthesis Paper #3: Industrialization and Environmental Quality: Paying the Price

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Research Report #5: The Greening of Thai Industry: Producing More and Polluting Less

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Chapter 1
Introduction

Rapid deforestation in Thailand over the past two decades has fueled public alarm and concern over this diminishing resource. Ninety million rai of natural forest have been denuded in thirty years, at an average rate of three million rai per year. Less than 28 percent of the nation (about 90 million rai) is now under forest cover. To protect the existing forest, government measures such as logging bans and stricter enforcement laws have been passed to ensure that the forest will not be further encroached. These measures are enacted based on the assumption that the logging industry is the cause of deforestation.

It is undeniable that large-sized trees were initially cut down by loggers, but later villagers followed loggers' trails and cleared medium- and small-sized trees to make room for farmland. From 1960 to 1990, agricultural population increased by 14 million. During the same period, 90 million rai of forest were cleared. The problem of forest loss is no longer simply a problem of excessive logging, it is largely a problem of low-income villagers searching for agricultural land. The latest figures indicate that more than 8 million people are residing in national forest reserves. These low-income villagers are legally termed *forest encroachers*, although many had moved into the forest before it was declared forest reserve.

The environmental effects of deforestation are increasing in severity: flash floods in the South and droughts in the Northeast are well known examples. Deforestation can no longer be tolerated, yet population growth continues and more farmland is needed. The balancing of these elements is increasingly difficult and, of course, important.

Thailand currently stands at a significant turning point. The country is enjoying monumental economic expansion, and the economy is changing from a focus on agriculture to a focus on industry and services. This structural shift could have a profound impact on forest resources. If labor migration occurs, agricultural land demand may decrease, and forests could be saved from encroachment. Moreover, poverty could be alleviated through the higher income offered by the industrial and service sectors. Whether this outcome will materialized --given current social and economic conditions in Thailand-- is the point of this study.

I. RESEARCH QUESTIONS

In this study, land and forest are view as an integral resource. In the past, forests have been replaced by farmland. Therefore, instead of directly studying the forest resources, this research focuses on agricultural land and attempts to answer three crucial questions:

1. Given the demographic trends, economic growth, and structural changes, underway, what is the expected demand for agricultural land over the next 10 to 20 years?
2. What factors explain the concurrent growth of unused prime agricultural land and the advancing encroachment of marginal land?
3. In light of recurring flash floods, drought, soil erosion, and landslides related to the destruction of the forests, has the relationship between agriculture and forestry turned from one of competition to one of interdependence?

The answer to the first question the -- future land demand -- will shed light on the future pressure on the forest. If the pressure for land is lessened due to labor migration and other factors, the forest encroachment problem may prove easier to cope with. Not all the land under agricultural holding, however, is cultivated; a portion of farmland is always left unused. Even with declining cultivated land demand, further forest encroachment could persist if landowners decide to leave their land idle, while landless farmers are searching for farmland to cultivate. The second question addresses this phenomenon.

The final question regarding the competition or interdependence between agriculture and forestry is an important one. Clearing one rai of forest produces more land for agriculture, and environmental damages on existing agricultural land downstream. When forests are plentiful, the income gain from land expansion is large and the income loss from environmental damages is small. In this sense, deforestation is one solution to poverty. However, as the forest is further destroyed, the income loss starts to outweigh the income gain. The third question is raised to determine whether this turning point has been reached, in which case forest conversion to farmland might increase rather than reduce poverty over the long run.

II. RESEARCH METHODOLOGY

This study introduces quantitative analysis to the issue of land and forest resources, and uses econometric, statistical, and mathematical modeling techniques. The determination of future land demand, unused farmland, and deforestation effects are pursued through econometric modeling. Moreover, natural resource use is quantitatively linked to economic conditions and demographic trends. The introduction of quantitative analysis to the problem provides a new dimension for research in this area of study.

By using a quantitative approach, future land demand can be forecasted and policy simulations can be performed. Policy simulations provide a tool for policy makers to test a policy before implementing it, and to choose among several policy options.

III. PLAN OF STUDY

The research is presented in five chapters. Chapter 2 is a historical overview of the structural changes of the economy and the shifts in land use patterns. Chapter 3 constructs and estimates a model for the quantitative analysis of demand for cultivated land. The purpose of this analysis is to establish a quantitative relationship between the demand for cultivated land and the economic conditions, demographic trends, and other relevant factors. Forecasting of land demand up to the year 2010, and selected policy simulations are also performed. Unused agricultural land and the effects of deforestation on agricultural income are discussed in Chapter 4. The econometric models of unused land and deforestation effects are the focal points of this chapter. The findings of the study are summarized and policy recommendations are formulated in Chapter 5.

The findings of this research paper suggest that cultivated land demand will decline in the future due to: (1) labor migration to the industrial and service sectors, (2) slower population growth, (3) a shift from land-using crops to land-saving crops, (4) stagnating crop prices, and (5) higher productivity. Amidst the declining land demand, forest encroachment will prevail. Since the opportunity cost of leaving farm land idle is low (low rental fees and low land taxes), unused farmland is expected to increase. Landless farmers, therefore, will still have to encroach natural forests for farmland.

The calculations in this study show that deforestation has already produced a net social loss for the country. Prior to 1987, clearing one rai of forest generated a positive net income, that is, the income gain from land expansion was greater than the social income loss from environmental damages. Since the mid-1980s, however, this loss has outweighed the gain. It is estimated that clearing one rai of forest (in 1987) created a net loss of 150 baht. This loss grows as the forest is further denuded.

The interaction between man and natural resources is central to these findings. A natural resource policy cannot be effective if no consideration in given to the human element, and an economic policy is senseless if the natural resource and environmental aspects are not taken into account. The policy recommendations of this research paper capitalize on the interdependence between man and nature. A holistic package of natural resource management and poverty alleviation policies is recommended including the following:

- Demarcating and declaring the remaining natural forest (25 percent of the country's land area) as protected or conservation forest.
- Giving full legal land ownership to people living outside the boundary of this protected forest.
- Introducing a progressive land tax with higher tax rates for unused land.
- Boosting agricultural productivity in rainfed areas.
- Promoting non-resource-based, labor-intensive economic activities.
- Facilitating labor mobility through educational and other reforms.

Chapter 2

Changing Economic Structure and Land Use Patterns: A Historical Analysis

Forty years ago, the Kingdom of Thailand was covered with 198 million rai of tropical rain forest (approximately 62 percent of the country's total land area). Today, only 90 million rai, (about 28 percent of the total area), remain intact.

It is generally believed that the destruction of the forests is caused by the *greed* of timber traders with the help of improper logging concession policy and lax law enforcement. In reality, loggers and timber traders can only partly be blamed for the destruction of the forests. There is another important factor which causes permanent forest loss in Thailand: the increasing demand for agricultural land. In 1950 the agricultural land or farm-holding area(1) in Thailand was merely 52 million rai. The latest figures (1988) show that this farm-holding area now occupies 148 million rai or about 46 percent of the country's total land area. It can be logically concluded that the forests have been displaced by agricultural land.

The demand for agricultural land has intensified during the past decades because of (1) population pressure and (2) economic structural changes. An increase in population, especially in the farming community, means an increased demand for farmland. Also, the structural shift in the agricultural sector from subsistence farming to commercial farming (market-oriented) accelerates the demand for land. The forests have been currently losing the battle to the rising demand for farmland.

Chapter 2 demonstrates the linkages between economic factors and land-use patterns in Thailand. The historical analysis technique of these linkages is followed by a quantitative analysis in Chapter 3. Chapter 2 is comprised of five sections. In the first section, the economic evolution hypothesis is formulated. The hypothesis postulates that the economic system evolves in response to changes in relative input prices. This hypothesis will be used to explain the level of resource intensity of each stage of the

(1) *Farm-holding area* means area which is occupied for farming purposes. The area may or may not be used for farming at the time. The farm-holding area which is used for cultivation is called *cultivated area* in the context of this paper.

economy. The second section provides a historical profile of the Thai economic system and emphasizes changes within both the overall and the agricultural economy. It is followed by a landuse profile section, which is linked to economic changes in the subsequent section. The final section is a brief review of past forest policies.

I. ECONOMIC EVOLUTION HYPOTHESIS

An economic system, like a biological or political system, evolves through several stages. In the context of this paper, the evolution of the economic system is restricted to the evolution of the production process, that is, the relative intensity of use of each factor of production. Two theories, namely the production theory and the technological innovation theory, are applied to formulate the hypothesis.

Consider a production function:

OUTPUT = f(RESOURCES, LABOR, CAPITAL, TECHNOLOGY)

The facts of production or inputs of a production process consist of natural resources, labor, capital goods, and technology. Each production factor can be substituted by others. The substitutability of each factor depends on its marginal rate of technical substitution (MRTS).

By applying the optimization behavior of a producer, the combination of each input factor is selected at the point where the isocost line touches the isoquant curve (see Figure 2.1).(2)

Given the isocost line AB and the isoquant curve Q, the amount of labor and capital inputs are L_0 and K_0 respectively. When labor becomes more expensive, the isocost line AB shifts to CD, thus the optimal labor and capital inputs are now L_1 and K_1. From the production theory, one can conclude that if an input factor becomes relatively more expensive, that input factor will be substituted by other factors.

(2)The isocost line is the loci of different combinations of the use of input factors at a given budget level. The isoquant curve is the loci of different combinations of the use of input factors at a given production level.

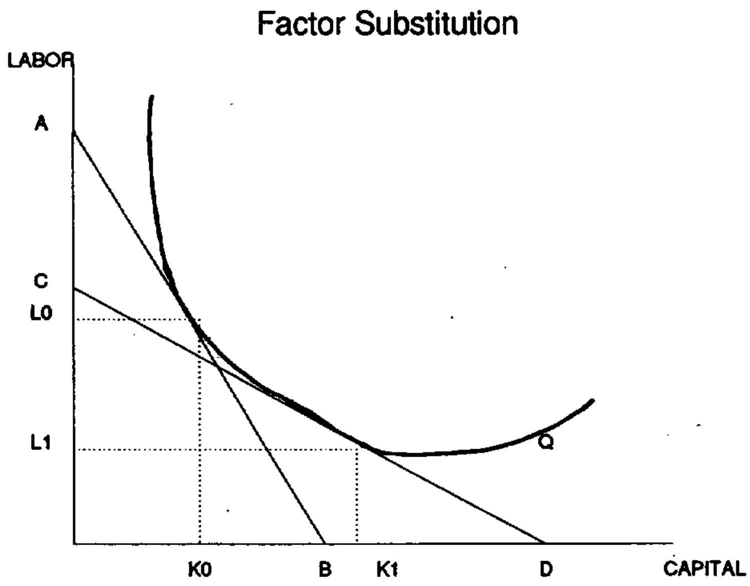


Figure 2.1

At the early stage of an economy, both technological level and capital accumulation are low, because their prices are high relative to the prices of land and labor. The production process concentrates on the use of natural resources and labor which are abundant and less costly. This type of economy could be termed a *resource-based economy.* When natural resources start to become depleted or scarce, and their price becomes relatively high, the economy replaces natural resources with other factors, namely capital and technology. Hicks (1963) and Hayami and Rattan (1971) conclude that relative factor returns are the main force determining the demand for innovation (Feeny 1982). Therefore, when the primary facts of production (resources and capital) become scarce, the economy will invest in technological innovations to partially replace these factors with input-saving technology.

Applying this theory, the economic system can be categorized as follows:

1. Resource-based Economy
   - Subsistence Agricultural Economy
   - Commercial Agricultural Economy
2. Technology-based Economy
   - Industrial Economy
     - Resource-Intensive Industries
     - High-Technology Industries
   - Service and Information Economy

The most primitive form of an economy is a subsistence agricultural economy, that is, farming enough to feed one's own family. The main production factor is land, production is labor-intensive and requires only simple technology. In a subsistence farming economy, the demand for natural resources, mainly land, varies proportionately with population growth. The barter system is the most prevalent form of marketing system at this stage.

When development economy advances, the market system expands, and the economy becomes monetized; the subsistence farming economy changes into a commercial farming economy. Farmers no longer farm only to fulfill their basic needs but also to exchange goods for money which becomes the medium of exchange. Profit maximization becomes the norm, and large-scale farming and mono-cropping a more common feature of this type of economy. The demand for land and labor accelerates during this stage, and mechanical and bio-chemical technology becomes more profitable and prevalent.

The commercial farming economy generates several by products.

1. Capital is accumulated.
2. Labor becomes more expensive.
3. Natural resources (fixed supply) become increasingly depleted.
4. The relative price of technology starts to fall.
5. Technological innovations begin to emerge.

This new factor (technology) increasingly replaces labor and natural resources and the economic system moves from being resource-based to being technology-based.

An industrial economy is the first step of the technology-based economy. The early stages of an industrial economy are still focused on the processing of natural resources such as fiber, food, and minerals. In this stage of the economy, the demand for land is less severe compared to a commercial-farming system. When the relative prices between natural resources and technology change again, the industrial economy moves from resource-intensive industries to technology-intensive industries. Technology becomes a predominant factor of production. Ultimately, an economy matures to a service or information economy that is mainly based on the application of technology and highly skilled human capital.

This process of moving from an agricultural economy to a service economy is a part of economic and human evolution and is necessary to ensure the sustainability of economic progress. When resources are abundant and the population level is low, an economy can afford to use natural resources inefficiently. However, when the population expands and resources become scarce, an economy must search for a new technology which can better use the increasingly scarce natural resources. Thus, it becomes necessary to move into an industrial age that requires less natural resources and generates higher value added from limited resource inputs. If an economy resisted moving from an agricultural to an industrial base, the supply of its natural resources would be exhausted and the economy would collapse. Every developed country has gone through this process and all industrialized economies were once based on agriculture.

Thailand is following this path, too, moving from an agriculture-based economy to commercial farming economy, to agroindustry and increasingly towards an industrialized economy. This evolutionary process does have a price. During the commercial farming stage, unless a significant change in agricultural technology (fertilizers, high-yield varieties, etc.), takes place, the expansion of the economy is based solely on the increase of land resource input, and forests are results in forestland clearing to make room for expanding farmland.

Thailand is in the process of becoming a newly industrialized country (NIC). If the above evolution hypothesis is applicable to the Thai economy, it can be projected that the demand for agricultural land should level off and begin to decline as the economy advances towards a NIC status. This hypothesis is tested in Chapter 3 by quantitatively analyzing and projecting the demand for agricultural land.

The shifting from one economic stage to another does not result in a complete and immediate abandoning of previous economic activities. During the transition period the concentration of economic activities starts to shift from one form of activities to another. For instance, a shifting from an agriculture-based economy to an industry-based economy results in decreasing economic engagement in farming and increasing engagement in manufacturing. It does not, however, mean that farmers will immediately and completely abandon their farms to become factory workers. Figure 2.2 is a diagrammatic presentation of the economic evolution hypothesis and its implications on cultivated land. The figure illustrates the relative factor intensities (land, labor, capital, and technology) in each economic stage of a developing economy.

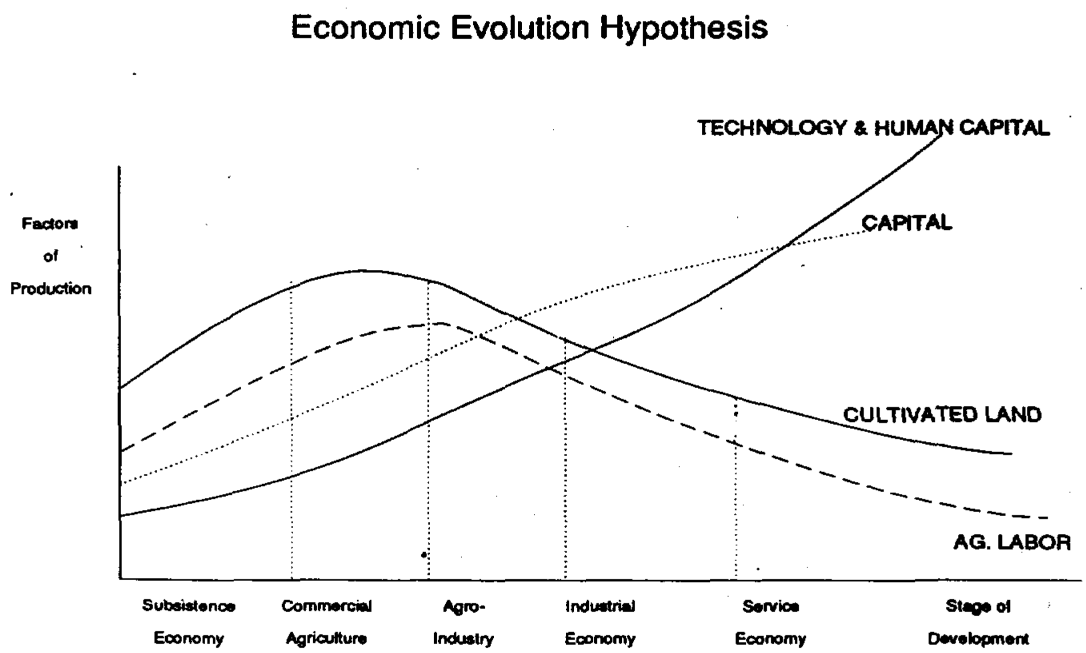


Figure 2.2

In the following section, the profile of the changing Thai economy is examined. The examination is limited to the past three decades, due to a lack of sufficient data, and focuses on the structural changes within the agricultural sector and the overall economy.

II. PROFILE OF THE CHANGING THAI ECONOMY

The previous section suggests that the economic structure evolves according to the changes in relative factor costs. The economy is heading towards an industrialized status, the percentage share of agricultural income in the gross domestic product (GDP) is declining. At present the agricultural sector's share is only 17 percent of the total GDP.

Two changes within the Thai economy are presented in this section. The first change occurs in the agricultural sector, while the second change occurs in the overall economic structure.

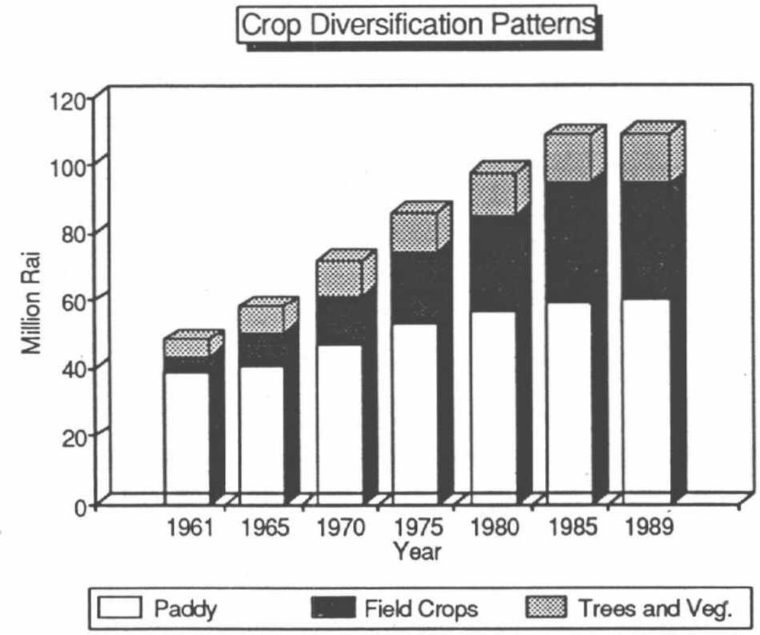
2.1 Changes Within the Agricultural Sector

The first stage in the evolutionary process of an economy is the subsistence farming economy. The next stage is the commercial farming economy where production is for the market rather than purely for subsistence. This section demonstrates that the Thai agricultural sector has already moved from the subsistence phase to a commercial or market-oriented phase. Two indicators are presented to support the evolution hypothesis. They are as follows:

1. Crop diversification
2. Crop exports

Crop diversification can be considered an indicator of the shift from subsistence farming to market-oriented agriculture. With profit incentives and the opening of foreign markets, Thai farmers have been induced to switch from their traditional crops to higher-value crops. The cropping pattern is no longer limited to traditional crops such as rice, but has diversified toward new varieties of crops such as cassava and maize.

Figure 2.3 reports the cultivated land for different types of crops, namely rice, field crops, tree crops, and vegetables. Evidently, field crops have the highest rate of expansion in terms of cultivated land area. The increasing importance of field crops and other non-traditional crops can also be measured in terms of production outputs. From 1960 to 1988, the rice output increased from 7.9 million tons to 17.9 million tons. In the same time period, the field crop output grew from 7.2 million tons to 66 million tons (see Table 2.1). On average, the annual output growth rate of rice is merely 2.98 percent compared to the annual average of 10.56 percent for field crops. The increase in the cultivated area and output of field crops reflects the diversification of the Thai agricultural system.



Source: Office of Agricultural Economics

Figure 2.3

Table 2.1 Production Output, Domestic Consumption, and Exports of Rice and Field Crops

Unit: Million Tons

Year	Rice			Field Crops		
	Output	Consump	Export	Output	Consump	Export
1960	7.87	6.97	0.91	7.21	6.30	0.90
1965	10.91	9.28	1.63	7.10	5.43	1.67
1970	13.57	12.51	1.06	12.08	8.72	3.37
1975	14.09	13.14	0.95	33.12	27.49	5.63
1980	15.41	12.61	2.80	40.86	32.59	8.27
1985	17.93	13.87	4.06	44.61	31.94	12.67
1988	17.88	12.18	5.70	65.94	54.79	11.15

Source: Office of Agricultural Economics

Another indicator of the market-oriented agricultural economy is the volume of crop exports. Rice exports increased from less than 1 million tons per year in 1960 to 5.7 million tons in 1988. Meanwhile, the exports of field crops expanded from 0.9 million tons per year in 1960 to 11.15 million tons per year in 1988 (see Table 2.1). The export figures reflect the growing trend of market-oriented farming, particularly for foreign markets.

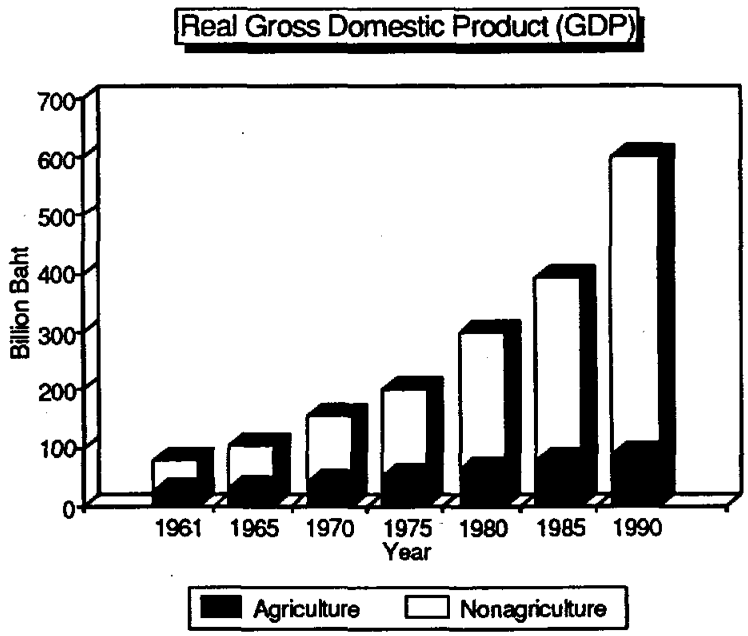
The two indicators, the crop diversification indicator and the export indicator, suggest that the agricultural sector has shifted from a subsistence farming economy to a market-oriented economy, though Table 2.1 and Figure 2.3 indicate a shift from rice to field crops. In recent years, another shift has taken place toward the intensification of fruit trees, livestock, and aquaculture. These types of agricultural activity offer higher profit margins compared to field crops and rice.

The current Thai commercial agricultural economy consists of four elements: commercialization, diversification, intensification, and specialization.

2.2 Changes Within the Overall Economy

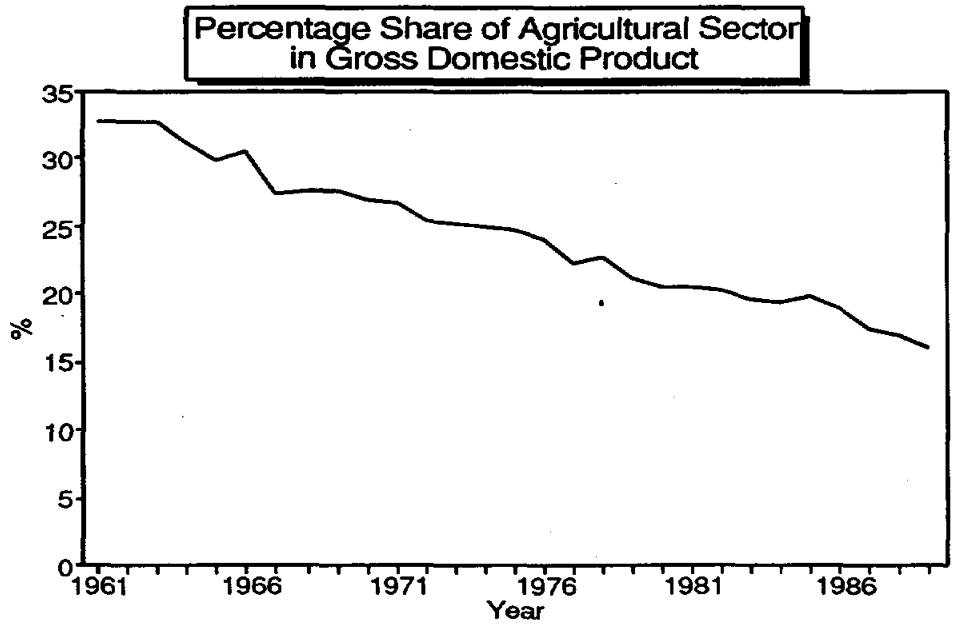
The economic evolution hypothesis implies that an economy will eventually shift from its original agricultural/resource base to an industrial/technology base. This is the case in Thailand. The growth of the nonagricultural sectors (the industrial and service sectors), measured in terms of GDP has increased at an accelerated rate, while the growth in the agricultural GDP has increased at a modest rate (see Figure 2.4).

Figure 2.5 confirms that Thailand has rapidly become industrialized: the percentage share of the nonagricultural sector's GDP has increased exponentially, and the industrial and service sectors continue to replace the once-dominant agricultural sector. The percentage share of the agricultural sector (the ratio of GDP generated from the agricultural sector to the total GDP) constantly drops. In 1961 the income from the agricultural sector accounted for one-third of the economy, but by 1988, this share was less than one-sixth of the total GDP. However, this rapid structural shift towards an industrialized economy is not equally reflected in the employment and population structure. In 1961, 77 percent of the population was in the agricultural sector. In 1989, despite the accelerated rate of industrialization, over 60 percent of the population is still engaged in agriculture.



Source: Bank of Thailand

Figure 2.4



Source: Bank of Thailand

Figure 2.5

III. LAND USE PROFILE

The previous section demonstrates the dynamics of the Thai economy. Structural changes take place both in the agricultural sector and in the overall economy. The economic evolution hypothesis developed in the first section has implications for the use of natural resource inputs. The intensity of the natural resource input varies from one economic stage to another. As the economy advances, the intensity of resource use lessens. This section demonstrates the dynamics of natural resource use -- particularly land resource use. The relationship between these two dynamics is discussed in the next section.

This section is subdivided into three parts. The first part correlates the expansion of agricultural land and the depletion of natural forests. The second part focuses on the changing agricultural landuse patterns from a concentration in rice, to upland cash crops. The third part raises the important issue of the relationship between farm-holding area and cultivated land. Although the evolution hypothesis projects a lessening of agricultural land demand as the economy becomes industrialized, the landholdings for *agriculture* need not be reduced. In other words, agricultural land could remain unused while total agricultural landholding is increased through further forest encroachment by landless farmers. The issue of unused land has significant implications for forest policy.

3.1 The Vanishing Forest

In 1950 Thailand had almost 200 million rai of natural forest, but by 1988, the forest area was down to less than 90 million rai. Pratumratana (1990) concludes that there are four possible causes of deforestation as follows:

1. Villagers: Population growth creates demand for more agricultural land, and as a result, villagers are forced to encroach on natural forests for more land. The migration of farmers especially from the Northeast into the Central Plains and other regions results in deforestation in those area.
2. Local Influential People: Influential locals persuade new migrants, mostly from the Northeast, to encroach on the forest. Trees are cut by illegal loggers, and land is sold to new migrants, or held for speculation.

3. Government Officials: An inadequate staff of forestry officials, side-payments, and influential interests make forest protection ineffective. Often trees are cut and transported without government intervention.

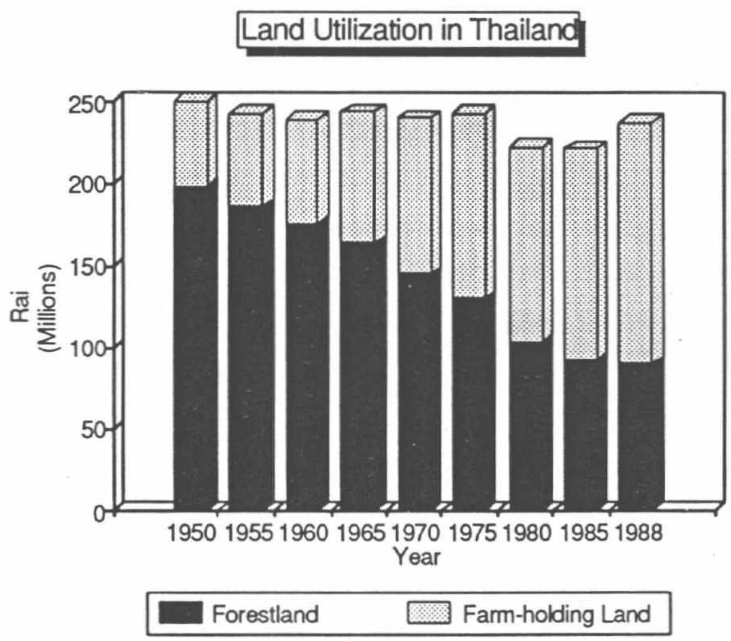
4. Government Policies: Improper logging concession policies contribute to the rapid deforestation. The past concession policy gave no incentive to loggers to properly reforest their concessions and to look after the reforested areas. The deforestation cycle occurs as follows:

Stage I: The concessionaires build roads into their concession area, and they cut large trees.

Stage II: Villagers follow the roads built by the concessionaires and cut down medium size trees for housing and fuel.

Stage III: Villagers and newcomers move into the area where the forest is almost denuded; they clear small trees and start farming.

The encroached area is finally turned into agricultural land, regardless of the initial cause of deforestation. Figure 2.6, which graphically explains the phenomenon, depicts the data of farm-holding areas and forestland. The farm-holding area *tripled* from 50 million rai in 1950 to approximately 150 million rai in 1988, while the forests are shrunk from almost 200 million rai in 1950 to 90 million rai in 1988.



Source: Office of Agricultural Economics

Figure 2.6

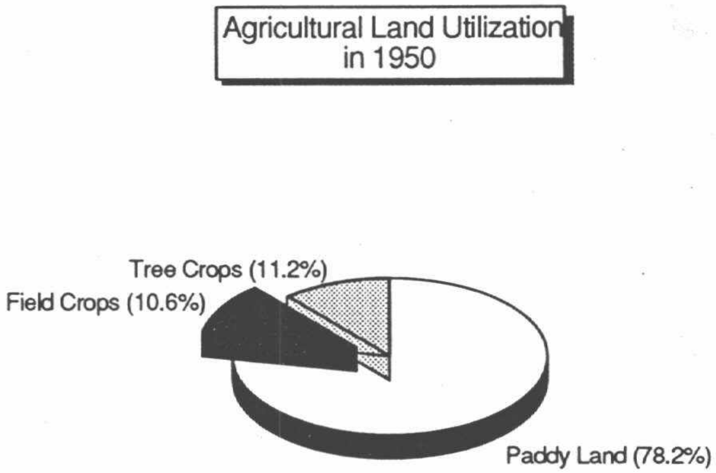
3.2 Agricultural Land Use Pattern

Rice has been and will remain Thailand's main food staple. While rice remains dominant in terms of land use, output, and labor involved, its importance is declining. As explained in Section 2.1, there has been a shift within the agricultural economy from rice to field crops. Now, there is another shift, from field crops to even higher value added activities such as fruit trees, vegetables, and aquaculture.

The expansion of agricultural land is illustrated in Figure 2.6. Although the land devoted to every crop is expanding, relative land shares are changing (see Figures 2.7 and 2.8). The proportion of landholding for rice diminished from 78 percent in 1950 to 57 percent in 1988 while the proportion of field crops tripled during the same period. The two figures shows the crop diversification trend from rice to other higher-value crops.

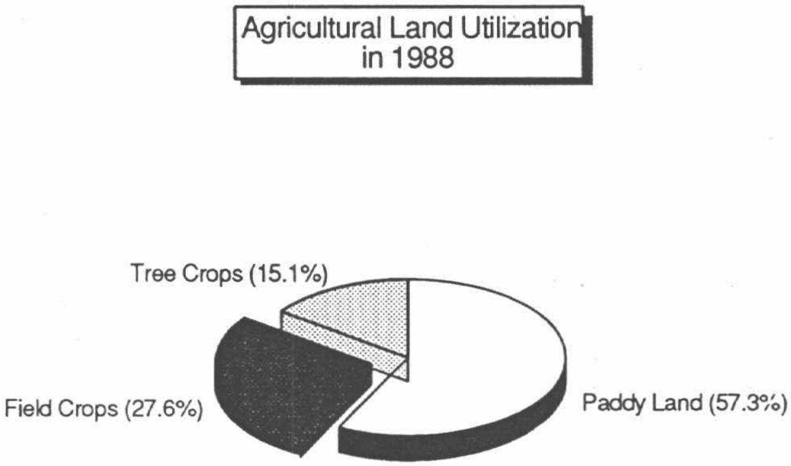
The structural shift from rice to field crops in the past three decades was due to a better return from field crops. Table 2.2 summarizes the profit from rice and selected field crops. It is evident that rice offers the lowest profit, cassava and sugarcane the highest. The profit figures for tree crops, vegetables, and other high-value crops is likely to be even higher but data are not readily available.

The shifting from rice to higher-value crops could be very significant for land and forest resource management. Since the profit margin of these crops land-saving crops is much higher than that of rice, and their requirement lower, the switching to higher-value crops will result in lower demand for agricultural land.



Source: Office of Agricultural Economics

Figure 2.7



Source: Office of Agricultural Economics

Figure 2.8

Table 2.2 Profit From Selected Crops, 1979 - 1989

Unit: Baht/Rai

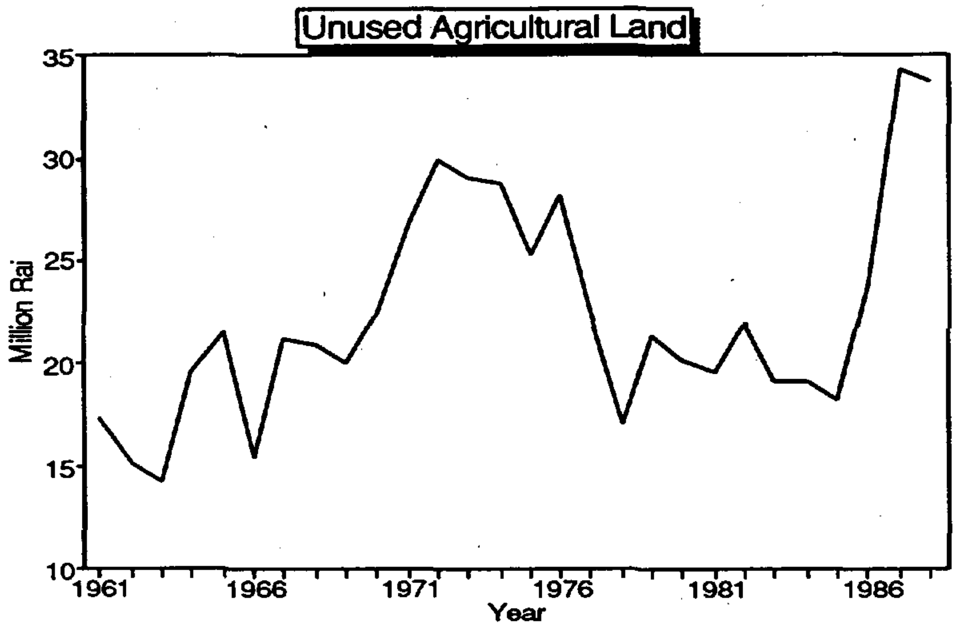
Year	Rice	Maize	Cassava	Sugarcane
1979	70.36	64.13	1047.24	268.76
1980	49.54	148.71	990.59	237.05
1981	118.92	282.43	111.30	2341.72
1982	41.99	213.54	368.62	1127.77
1983	22.33	158.25	1182.18	235.26
1984	16.78	262.13	594.22	784.34
1985	-153.25	226.86	-146.37	467.28
1986	-131.76	65.55	723.57	-126.15
1987	93.95	-61.83	1120.75	56.42
1988	320.26	132.88	487.83	655.38
1989	480.37	330.75	416.25	1090.46
Average	84.50	165.75	626.93	648.93

Source: Compiled from various issues of Agricultural Statistics of Thailand

3.3 Farmholding and Cultivated Land

Two different terms are used when referring to agricultural land use: *cultivated land* and *farm-holding* or *land-holding* (see Footnote 1). Farm-holding area is defined as the area occupied for agricultural use, regardless of whether the land is being used or not. Cultivated land is defined as the farm-holding area that is currently under cultivation. The difference between the two data indicates the amount of unused or idle farmland.

Figure 2.9 reports the trend of this unused land.(3) It should be noted that the term *unused* does not mean the land is abandoned and therefore available for landless farmers. There are always *owners* of the unused land.



Source: Calculated from data reported by the Office of Agricultural Economics

Figure 2.9

Several reasons could be cited for the nonuse of agricultural land:

1. **Soil Degradation**: A significant percentage of the farmland in Thailand is in the national forest reserves. No secure ownership is given for land in this area. Feder et al. (1988) found that owners of untitled land have less incentive to improve the quality of their land and therefore the fertility of the soil can rapidly

(3) The unused farm-holding area is calculated as:

Unused land = Farmholding area - Cultivated land - Grass land

The unused land includes fallows, walkways, housing areas, ponds, etc. All data are extracted from the annual reports of the Office of the Agricultural Economics.

decline. This leads to eventual abandonment of land for (temporarily) more fertile forestland.

2. **Low Crop Prices**: As shown in Table 2.2, the average profit margin of agricultural activities could be very small. In a year of low crop prices, land may be left unused.

3. **Labor Shortage**: Traditionally, farming is a family activity. With the shift towards a market-oriented economy, hired labor becomes a part of the agricultural activities. With the expansion of the industrial and service sectors which offer higher pay, labor migrates to the cities, and less labor is available for the agricultural sector. This leads to a labor shortage during the planting and harvesting season and a rise in wages.

4. **Lack of Irrigation**: Out of 148 million rai of farm-holding area, only 26 million rai is irrigated; the rest is under rainfed agriculture. Land could be left unused because of the lack of water.

5. **Land Speculation**: The rental fee for agricultural land is very low. The Office of Agricultural Economics reported that in 1988 the average rental fee for a farm was only 204 baht/farm. Large-scale farm holders or farm owners who do not want to be in the business, are reluctant to rent out their farms. When landowners want to convert the rented farm to other uses, it can be troublesome to retrieve the farm from the renters. Given the rising land value in recent years and minimal land taxes, landowners are likely to leave land unused, especially if they themselves are no longer engaged in agriculture.

Chapter 4 provides a quantitative analysis of unused land: a model of unused agricultural land is constructed to explain the driving factors of retirement of agricultural land.

IV. STRUCTURAL CHANGES AND LAND USE PATTERNS

The economic evolution hypothesis implies a relationship between resource use and structural change. In this section the economic data is related to the landuse patterns. Chapter 3 contains a quantitative analysis of this relationship.

Figure 2.10 relates the expansion of cultivated land with the growth of agricultural output. Real agricultural GDP is used as a proxy for agricultural output. Because little change in the real agricultural price index, the real agricultural GDP can be used to represent the agricultural production level. The figure indicates that the two variables have similar movements. The negative correlation between the expansion of the agricultural economy and the forest area is depicted in Figure 2.11 which shows that the forests recede as the agricultural sector grows.

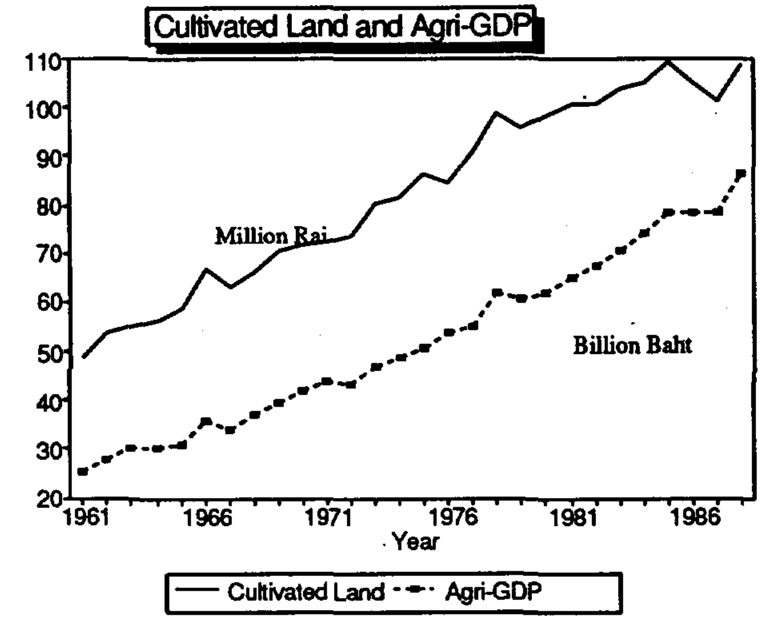


Figure 2.10

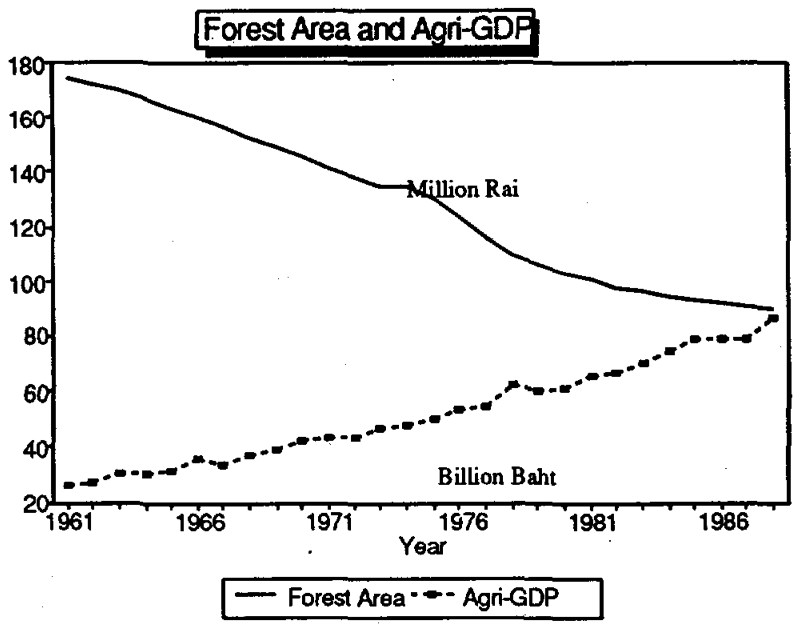


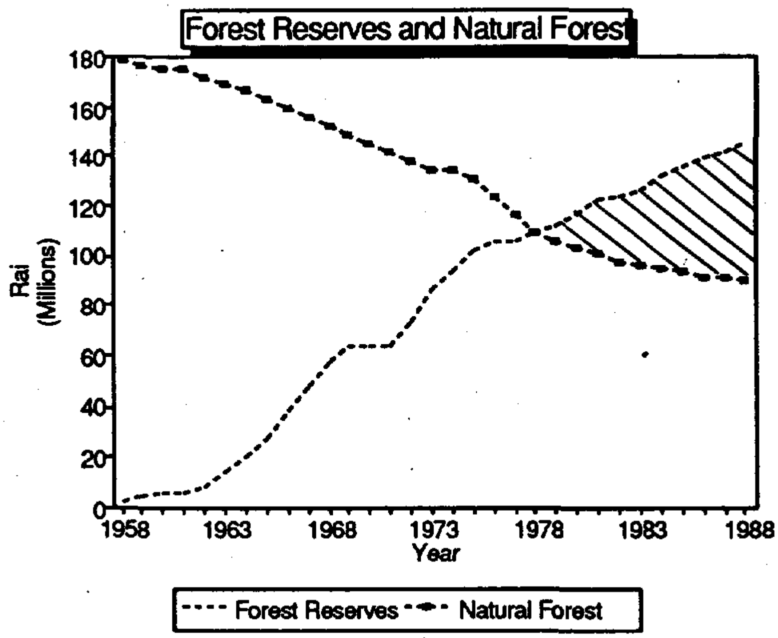
Figure 2.11

Figures 2.10 and 2.11 support the economic evolution hypothesis. The move from subsistence farming to a commercial farming economy results in an expansion of the agricultural economy. Unless agricultural productivity grows, more land is needed for cultivation, and the only source is the natural forest. It can be concluded from the graphical analysis in this section that the economic structure and land and forest resources are correlated. A quantitative analysis of the nature of this relationship is found in Chapter 3.

V. FOREST POLICIES

The government has historically been concerned with the destruction of forests and it has passed laws and measures to protect the remaining forest and to recreate those that have already vanished. The history of forest policy may be summarized as follows:

1. In 1960, the first National Economic and Social Development Plan had declared that 156 million rai of the existing 187 million rai of natural forest would be reserved as national property, and the remaining 31 million rai would be available for additional farming. In the event there were rapid population growth, this forest reserve area could be reduced to 125 million rai.
2. In 1964, the National Forest Reserve Act was passed. The main feature of the act was to prohibit the encroachment of national forest reserves. The Royal Forestry Department (RFD) was assigned the task of declaring the boundary of forest reserves. Figure 2.12 shows the cumulative legal forest reserves and the remaining natural forest for the last thirty years.
3. In 1960, the government established the National Land Classification Committee to carry out soil surveys and subsequent land classification. This committee started the implementation of land classification by establishing a center attached to the Land Department in 1961. Since 1964, this task has been handled by the Department of Land Development. During the period from 1962 to 1966, a total area of 162.2 million rai was classified as permanent forest. The permanent forests were to be gazetted by royal decree as forest reserves under the National Reserve Forest Act of 1964.



Source: Royal Forestry Department

Figure 2.12

Even with the National Forest Reserve Act in effect, the forest continued to be encroached. The shaded area in Figure 2.12 shows the amount of the *illegal* encroachment, that is, the amount of the forest reserve declared, minus the amount of natural forest that remained in that year. Since 1979, the gap between the declared forest reserves and the remaining natural forest has became wider. This *illegal* encroachment problem creates legal, social, and economic problems for those who reside inside the forest reserves.

4. A National Forest Policy was enacted in 1985. The new policy reduced the target forest area to 40 percent of the Kingdom and is subdivided it into conservation forest (15 percent of the Kingdom) and economic forest (25 percent of the Kingdom).

Past forest policies have not been successful. The 1988 figures indicate that approximately 55 million rai (see Figure 2.12) have been *illegally* encroached by some 8.7 million people (NRD2 data). Most of these inhabitants are low-income farmers. Given the current situation, there is no possible way that the government could enforce the National Forest Reserve Act of 1964 and relocate the encroaching villagers. Indeed, approximately 17 million rai, of the 55 million rai of declared forest reserves, which have been encroached, have been degazetted and allocated to various institutions including the Agricultural Land Reform Office (ALRO).

Concern over the deforestation problem should not be limited to *illegal* encroachment for several reasons: (1) some areas were legally declared as forest reserves after the forests had been cleared and settled by villagers, and (2) *physical* encroachment of natural forest has been twice as high as encroachment of legally declared forest reserves. Figure 2.13 shows that between 1960 and 1988, about 90 million rai of forestland have been denuded. In Chapter 4, it is shown that this deforestation has adverse effects on agricultural output.

In summary, the forest reserve and the permanent forest boundaries which are drawn by government agencies overlap with the agricultural domain. Figure 2.14 illustrates the overlapping of the *legal* forest boundary (162.2 million rai) and the agricultural landholding (147.8 million rai).

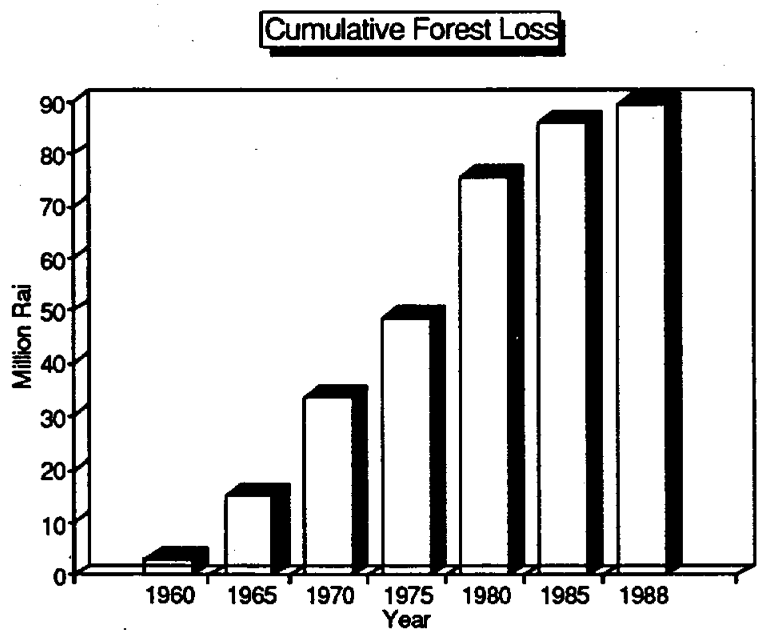


Figure 2.13

Legal Forest Boundary and

Agricultural Landholding

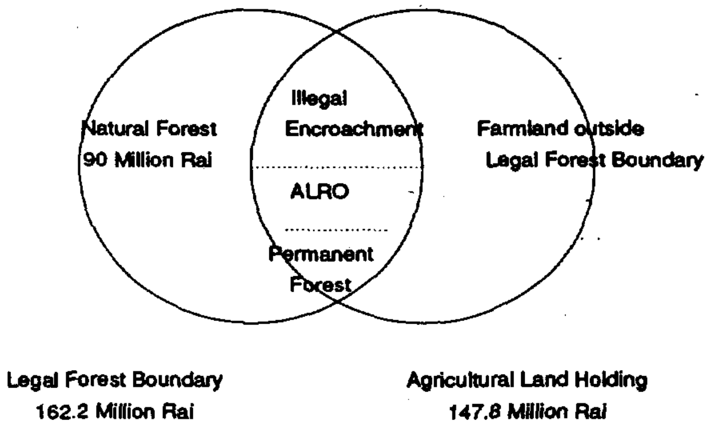


Figure 2.14

VI. SUMMARY

Chapter 2 has conceptualized the dynamics of an economy through the economic evolution hypothesis which is applied to the Thai economy in general, and the agricultural sector in particular, to determine the effects of structural changes on land and forest resources. The chapter also postulates a direct relationship between the expansion of agricultural land and the demise of natural forests. The chapter concludes with a review of past forest policies.

In summary, Chapter 2 reports what happened in the past. A successful forest policy cannot be devised without taking economic considerations into account. A quantitative analysis of the subject is found in the next chapter.

Chapter 3

Agricultural Land Demand Modeling, Forecasting, and Policy Simulation

Chapter 2 presented a historical analysis of the structural change of the Thai economy and the dynamics of land use. Its main conclusion is that the demand for agricultural land has been a major factor driving the loss of natural forest over the past 40 years. Chapter 3 serves three objectives. The first objective is to quantitatively understand the driving forces of the demand for agricultural land. An econometric model is constructed and estimated for this purpose. The second objective is to project the demand for agricultural land to the year 2010 based on the model and the projected economic and demographic data. The final objective is to simulate selected policy scenarios. The projection and simulation results will be used for policy formulation in subsequent chapters.

Past forest policies, such as the National Forest Reserve Act and National Forest Policy, were drafted without considering socioeconomic conditions and demographic trends. These policies not only fail to protect and conserve the forests, they also create legal problems for those living inside forest reserve boundaries. The National Forest Reserve Act, which prohibits the issuing of legal landownership inside forest reserves, may affect agricultural productivity, which in turn affects the villagers' level of income. Understanding the demand for agricultural land, its future projection, and the effects of government policies on land demand will provide significant tools for drafting effective and realistic forest policies.

The first section of Chapter 3 explains the land demand modeling concept, the second section describes the formulation of the land demand model and reports the estimation results. The projection of agricultural land demand (up to the year 2010) is contained in section three. The final section provides selected policy simulations.

I. THE MODELING CONCEPT

Land and forests are integral resources. The boundaries of the country are fixed, and therefore the total supply of land is fixed. Twenty-five years ago as much as 50 percent of the country was covered with forest. The expansion of urban areas, recreational land, and, most important, agricultural land have reduced the forest cover to a quarter of the total land area today. It is critical to understand the forces behind this massive deforestation. Instead of constructing a forestland model, however, an agricultural land demand model is constructed because forestland can be calculated as a residual of the agricultural and other land demands. An agricultural land demand model is chosen for two reasons. First, agriculture is the largest land user, and urban and industrial land use is relatively small by comparison. Second, the agricultural land demand, as shown in Chapter 2, is related to economic and demographic conditions. An econometric model can be constructed based on this theoretical relationship.

The section is divided into two subsections. The first subsection explains the indirect approach to the forest management problem using the agricultural land demand model. The second subsection describes the advantages of the model.

1.1 The Indirect Approach to the Forest Management Problem

The goal of this study is to determine effective, realistic, and implementable forest and land policies. The policies must not only be environmentally sound, but they must also be economically and socially beneficial and acceptable. Chapter 2 shows that a major cause of deforestation in Thailand is the expansion of agricultural land. Therefore, for a forest policy to be effective, the driving forces of agricultural land expansion must be understood.

Land (L) can be used in three ways: for forest use(L_F), for agricultural use (L_A), and for urban, industrial, and other uses (L_U). The land equation can be written as follows:

$$L = L_F + L_A + L_U$$

Diagram 3.1 summarizes the land use patterns.

(L)
Total Land

- (L_F) Forest Land
  - Protection
  - Production
- (L_A) Agricultural Land
  - Cultivated
  - Unused
- (L_U) Other Land Use
  - Urban
  - Industrial
  - Recreational
  - Infrastructure
  - Public Land
  - Etc.

Diagram 3.1

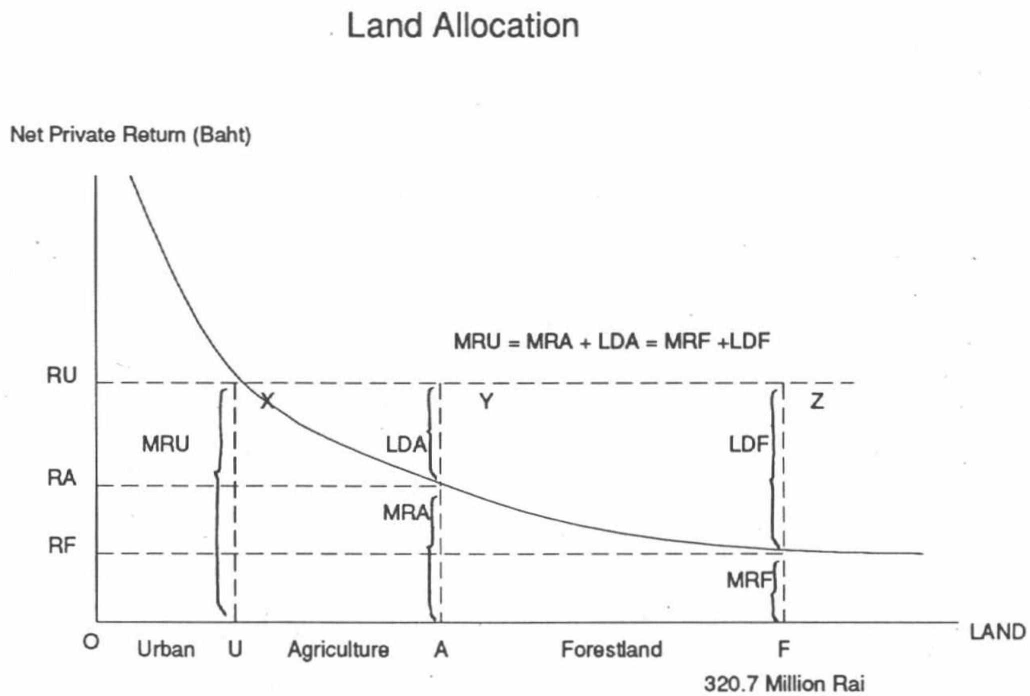
The total land area (L) in Thailand is 320.7 million rai. The utilization of land is distributed among the three uses described above. By applying the economic principle of optimization, it can be concluded that the amount of natural forest area is a residual of the demand for agricultural land and, in turn, that the amount of agricultural land is a residual of the urban and other land demand. This is because the private economic value of industrial and urban land use is far greater than that of agricultural use. Similarly, the *private* economic value of agricultural land is far greater than that of forestland.

At the margin, land is allocated among urban, agricultural, and forest uses as to maximize the total returns to this limited factor of production. This equilibrium allocation is obtained where the marginal returns are equalized:

$$MR_U = MR_A = MR_F$$

where:

MR_U is the marginal return to urban and other land use,
MR_A is the marginal return to agricultural land use, and
MR_F is the marginal return to forestland.



OU	= urban, industrial, and "other" land
UA	= agricultural land
AF	= forestland
ORU	= marginal return to urban land
ORA	= marginal return to agricultural land
ORF	= marginal (private) return to forestland
LDA	= location disadvantage of remaining agricultural land for urban use at the margin
LDF	= location (and quality) disadvantage of remaining forestland for agricultural use to the margin

Figure 3.1a

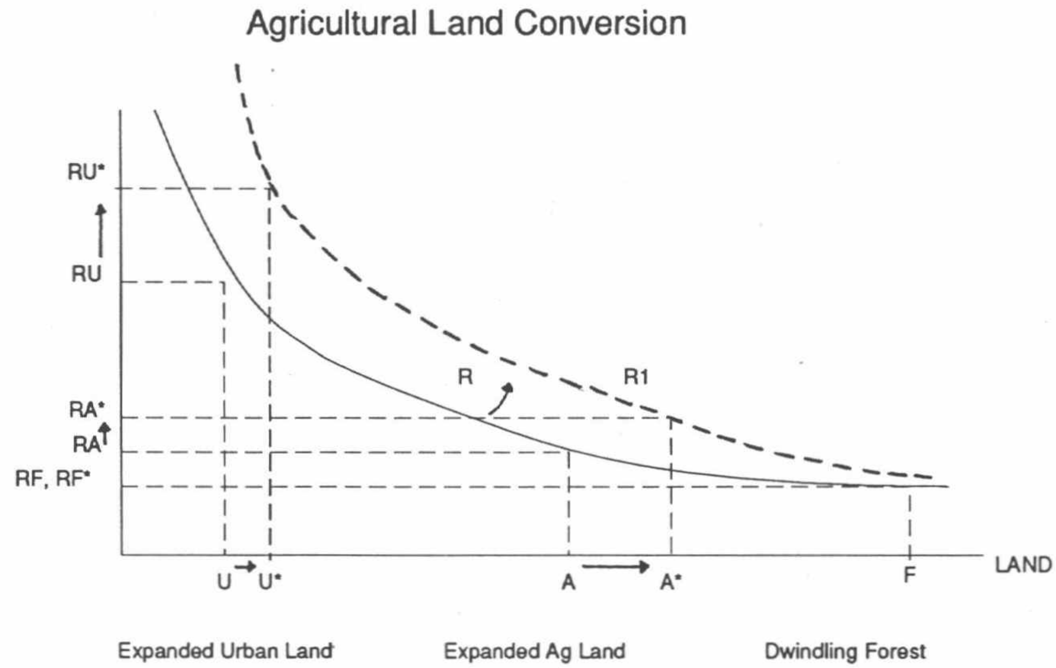
As shown in Figure 3.1a, total land available is OF. Given the marginal return curve R, the urban land price OR_U, and the agricultural land price of OR_A, at equilibrium, the land area OU is taken up by urban and other uses; land area UA is used for agriculture, and the residual, AF, remains under forest.

At point X, $MR_U = MR_A^* = MR_A + LD_A$ where LD_A is the locational disadvantage cost of agricultural land, which is due to distance, lack of infrastructure, and generally low accessibility. This locational disadvantage is equal in cost to the difference in prices between the two land uses.

At point Y, $MR_A = MR_F^* = MR_F + LD_F$ where LD_F is the locational disadvantage cost of forestland compared to agricultural land. This locational disadvantage cost includes land clearing costs, land improvement costs, risk from illegally occupying forest reserves, and transportation costs.

The locational disadvantage of agricultural land for urban use could be reduced through improvement of infrastructure, such as roads and electricity. As a result, more agricultural land could be converted to urban and other uses. Similarly, improvements in the road network or land clearing technology would lower the locational disadvantage of forest land sufficiently to make it profitable for agricultural use and sometimes profitable for urban use. An increase in the price of industrial goods and urban services relative to that of crops would also induce the conversion of agricultural land to urban use, while an increase in the crop price would induce forest encroachment and expansion of agricultural land. Because of the common property status of forest resources, an increase in the price of forest products and services, relative to the price of crops does not result in an increase in the market allocation of land to forest or even in the reduction of forest encroachment. The reverse, in fact, takes place as the increased profitability of wood and other forest products results in increased logging (legal or illegal) and harvesting of forest products without inducing tree planting. Population growth, urbanization, industrialization, and economic growth tend to raise the return to a fixed factor of production, such as land, and to change its relative return from different uses in favor of urban and industrial uses vis-a-vis agricultural and in favor of agricultural vis-a-vis forestry.

An upward (but not parallel) shift of the marginal return curve results in (1) a conversion of agricultural land, especially around the urban centers where the locational disadvantage is lowest, into urban and industrial land; and (2) forest encroachment and conversion of forestland into farmland. These two effects are shown in Figure 3.1b. The shifts result in an overall expansion of both urban and agricultural land at the expense of the forests which are pushed against a fixed land frontier.



R → R*	= shift in the marginal return curve due to industrialization, urbanization, and population and income growth
RU → RU*	= (large) increase in the return (price) of urban land
RA → RA*	= (small) increase in the return (price) of agricultural land
RF → RF*	= unchange private return (price) of forestland
U → U*	= conversion of agricultural land to urban and "other" use
A → A*	= forest encroachment due to agricultural land expansion
A*F	= dwindling natural forest

Figure 3.1b

In Thailand, urban and industrial land demand is relatively small compared to agricultural land demand. Expansion of urban and industrial land will exert a rather limited pressure on agricultural land and natural forestland. Currently, roughly 6 million rai are categorized under urban use, while approximately 148 million rai are categorized under agricultural use. The expansion of agricultural land is a more significant threat to the forest. Following this theoretical concept, determining agricultural land demand provides an indirect approach for the determination forestland.

1.2 Advantages of Model Construction

An econometric model is used to analyze agricultural land demand. This land demand refers to cultivated land, not to the total agricultural land (see Diagram 3.1). The model constructed is macroeconomic in the sense that macro data is used in the estimation process. The model provides three major benefits:

1. It determines the significant factors explaining the expansion of cultivated land and their relative importance.
2. Given projected values for the exogenous variables, future land demand is projected.
3. A number of policy scenarios are explored with the model.

The model, the projections, and the simulations are useful in policy formulation. The utilization of the model is summarized in diagram 3.2.

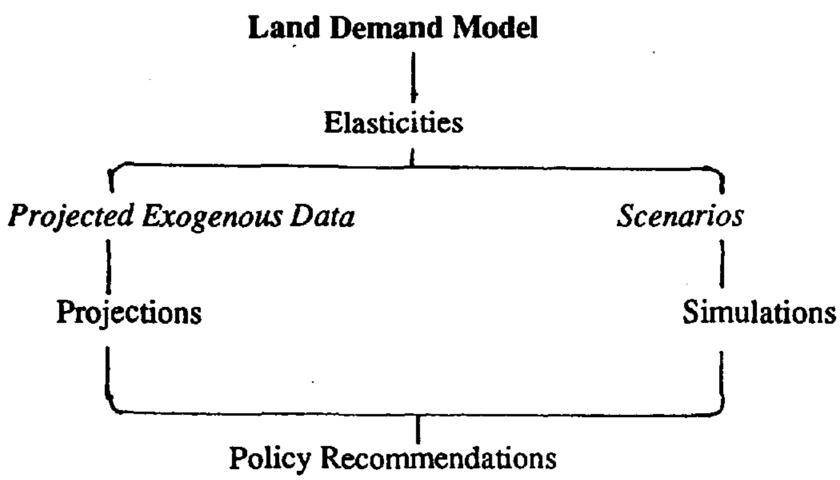


Diagram 3.2

II. AGRICULTURAL LAND DEMAND MODEL

Generally, agricultural land is demanded for two purposes:

1. As a source of food (subsistence motive).
2. As a source of income (profit maximization motive).

The single most important determinant of the demand for land to produce food is the population size, particularly the population in the agricultural sector. As the population grows, the demand for cultivated land also grows.

Crop prices and land productivity are critical determinants of the demand for land for cultivation of cash crops. Higher crop prices provide an incentive for farmers to seek more land for farming. According to the factor productivity theory, a rise in the marginal productivity of a factor will create a higher demand for that factor. Therefore, an increase in land productivity will have a positive effect on the demand for land as an input in agricultural production. However, as discussed later in this chapter, an increase in the productivity of existing farmland also negative effects on the overall land demand because it reduces the pressure for expansion of agricultural land into the forest areas. Apart from these factors, two additional factors are relevant to the demand for agricultural land: the land intensification of agriculture and the industrialization of the economy.

Table 3.1 Planted Area: Rice and Other Major Crops

Unit: Million Rai

Year	Rice	Major Crops	Total
1905	8.0	n/a	8.00
1920	15.3	0.16	15.46
1940	24.8	0.55	25.35
1960	38.6	5.70	44.30
1980	57.0	31.90	88.90
1989	60.0	35.57	95.37

Note: Major crops include maize, sugarcane, cassava, and rubber trees.
Sources: Feeny (1982) and Office of Agricultural Economics

Rice has been, and will probably continue to be, the dominant crop grown in Thailand. However, the relative importance of rice is diminishing. Table 3.1 indicates that although the rice planting area has been increasing, its share in agricultural output is falling. The planted area of cash crops, such as maize, cassava, sugarcane, and rubber trees, has been rapidly increasing during the past three decades. The crop diversification pattern is moving towards higher-value (land-saving) crops and agricultural activities, as has been explained in Chapter 2. The shifting towards higher-value crops could impact land demand because land is used more intensively by these crops.

Another significant determinant of land demand for cultivation is the industrialization rate of the economy. Industrialization provides nonfarm and off-farm employment. The two factors that determine the level of such employment are incentives and opportunities. The incentive for migration and off-farm employment is the more attractive pay in the nonagricultural sector. The employment opportunities include a high demand for labor in the nonagricultural sector. Both labor demand and the wage rate increase with the expansion of the industrial and service sectors.

Sussangkarn (1987) estimated that approximately 60 percent of rural labor (roughly 2.4 million workers) are potential migrants who actively seek jobs. The expansion of the industrial and service sectors attracts labor from the agricultural sector by offering a much higher income. The per capita income (1989 figures) in the nonagricultural sector is nine times higher than the per capita income in the agricultural sector, although, strictly speaking, they are not comparable without adjustments for non-cash income and differences in the cost of living. The farm workers that remain in the agricultural sector are those who are either not able (because of lack of skill and education) or are reluctant to migrate to the cities. The migration of farm labor into the cities results in a reduction in the demand for land.

Agricultural land demand can thus be explained by five main variables: the agricultural price, the population in the agricultural sector, the productivity of the sector, the industrialization of the economy, and the structural shift (the crop diversification or land intensification trend) within the agricultural sector. The land demand equation can be theoretically specified as:

$$LAND = f(PRICE, AGPOP, PROD, INDX, AGX)$$

where:

LAND	= cultivated land or planted area
PRICE	= real agricultural divisia price index
AGPOP	= population in the agricultural sector

PROD	= productivity of the agricultural sector
INDX	= industrialization of the economy
AGX	= crop diversification index

Because the study involves a long time series (1961 to 1989), real prices should be used instead of nominal prices. The real agricultural price index (PRICE) is obtained by deflating the nominal (divisia) price index of agricultural products with the nominal price index of nonagricultural products. The agricultural population (AGPOP) is the level of population residing in the agricultural sector. The productivity variable (PROD) represents the average agricultural productivity or average agricultural output per rai. The INDX is a proxy for the industrialization stage of the economy which reflects both incentives and opportunities for employment in the nonagricultural sector. The index is represented here as a ratio of per capita income of the two sectors: agriculture and nonagriculture. A higher INDX number reflects a wider income gap between the two sectors. The last variable, the crop diversification index (AGX), is a ratio that represents agricultural diversification or land intensification trends in the agricultural sector in response to changes in the relative returns between the land-saving and land-using crops. Land-using crops include rice, cassava, maize, sugarcane, and rubber trees. Land-saving crops include fruit trees, vegetables, and livestock.

III. THE ESTIMATION

Equation 1 is specified in double log-linear functional form and is estimated using least-square multiple regression techniques. The model is fitted with data from 1961 to 1989. The estimated model is as follows:

$$\begin{aligned} \ln LAND_t = \; & 0.081 \ln PRICE_{t-1} + 1.337 \ln AGPOP_t \\ & \quad (1.99) \qquad\qquad (12.82) \\ & - 0.279 \ln PROD_{t-1} - 0.155 \ln AGX_t \\ & \quad (-2.43) \qquad\qquad (-3.95) \\ & - 0.308 \ln INDX_t + 0.351\, DUMMY \\ & \quad (-3.37) \qquad\qquad (4.12) \end{aligned}$$

$$R^2 = 0.9905 \qquad Adj\text{-}R^2 = 0.9875 \qquad DW = 1.998$$

Detailed estimation results are given in Appendix A. The Appendix also reports the prediction accuracy test (Percentage Root Mean Square Error test) of the model.

Prices (PRICE) and farm population (AGPOP) have positive effects on the demand for land, that is, higher crop prices or larger farm population results in a higher demand for land. On the other hand, the three other variables have a negative influence on the demand for land. Higher productivity in the agricultural sector (PROD), the expansion of the industrial and service sectors (INDX), and the shift towards higher value added crops (AGX) all reduce the pressure for land expansion.

The price and productivity variables are lagged by one year, that is, last year's crop price and the last year's farm productivity levels affect this year's land demand for cultivation. Because farmers require time to prepare the land for cultivation, the current year's crop price will not have an affect on land use until next year. The same reasoning applies to the productivity variable.

Because the model is specified in double-log form, the coefficients also represent the elasticities of each variable. For instance, the coefficient of .081 of the price variable (PRICE) means that a 10 percent increase in (the previous year's) real agricultural prices will increase the demand for land by 0.8 percent. The coefficient of -0.308 of the industrialization variable (INDX) means a 10 percent increase of the per capita income difference will decrease the land demand by 3 percent.

All estimated coefficients have theoretically correct signs, that is, the effect of each variable is consistent with economic theory. Higher prices (PRICE) create incentives for farmers to obtain more land for farming (profit maximization incentive), while more farm population (AGPOP) means more land is needed for cultivation (subsistence motive). The expansion of the industrial and service sectors attracts labor from the agricultural sector which means that less labor is available for farming which, in turn, results in less demand for farmland. As explained earlier, the shift from traditional crops to higher-value crops and activities such as fruit trees, livestock, and aquaculture reduces land demand. The sign of the crop diversification variable is, as expected, negative.

An increase in farm productivity has two counteracting effects, negative and positive. To maintain a desired level of income under the subsistence motive, an increase in the productivity level reduces the necessary demand for land. An increase in the productivity level of existing land also lowers the incentive for expanding agriculture into nearby forestland or migrating to forestland of lower productivity. Under the profit maximization principle (factor productivity theory), an increase in productivity results in a higher demand for land. These two opposite effects partially offset each other. Our empirical results indicate that the negative effect of a productivity increase overpowers its positive effect. Therefore, an increase in the productivity of current farmland would reduce the demand for cultivated land.

A time dummy variable (DUMMY) is added to the system. This variable is added to absorb the time trend effects in the system. The model is also corrected for the second-order autoregressive (AR 2) problem. The Cochrane-Orcutt technique is applied for the correction.

Table 3.2 Beta Coefficients

Variable	Beta Coefficient	Ranking
AGPOP	0.7703	1
INDX	0.1914	2
PROD	0.1126	3
AGX	0.0952	4
PRICE	0.0153	5

The beta coefficient of each variable is calculated in order to assess the relative importance of each independent variable on land demand. The variable with the highest beta coefficient is the most important contributor to land demand. AGPOP with the beta coefficient value of 0.77 turns out to be the most important determinant.. The real price is the least important variable among the five independent variables in the model.

IV. THE PROJECTION

The key purpose of the estimated model was to identify and quantify the determinants of the demand for farmland for cultivation. Given projections of these determinants or exogenous variables, the model is capable of projecting the future land demand. The accuracy of the projections, however, would depend on the quality of the model and the accuracy of the projected exogenous variables.

The test statistics and the prediction accuracy test (see Appendix A) yield satisfactory outcomes. Therefore, the accuracy of the projections depend on the quality of the projected exogenous variables.

Projecting exogenous variables, particularly for a long period of time, is a difficult task. Fair (1984) points out that, in many cases, the prediction accuracy relies more on the projections of exogenous variables than the quality of the model. In this model, the independent variables are agricultural prices, agricultural population, productivity, crop diversification level, and industrialization level. These variables are projected from the year 1990 to the year 2010.

The price and productivity variables are projected using the Holt-Winters smoothing technique with multiplicative seasonal correction. This smoothing technique is similar to the time series analysis concept, that is, the projection is based on the past trend of the variable. The projections show that, from 1990 to 2010, the real agricultural price level decreases at an average of 0.5 percent per year, and the productivity level is projected to increase at an average of 0.77 percent per year. The past values and the projections of these variables are shown in Table 3.3 below.

Table 3.3 Trends and Projections of Productivity and Price Indices

Year	PROD	PRICE
1961	2.511	1.184
1965	2.470	0.996
1970	2.652	1.023
1975	2.461	1.314
1980	2.602	1.286
1985	3.133	0.882
1990	3.255	1.052
1995	3.483	0.993
2000	3.792	0.985
2005	4.013	0.926
2010	4.235	0.918

Source: Projected from Past Trends
Using the Holt-Winters Smoothing Method

Table 3.4 Growth Rates of Sectoral GDP, 1972 Prices

Unit : Percent

Year	Agriculture	Nonagriculture	Total
1960-65	4.94	8.52	7.37
1965-70	6.58	9.46	8.59
1970-75	3.87	6.25	5.62
1975-80	4.13	9.13	7.96
1980-85	4.93	5.85	5.66
1985-90	3.62	11.12	9.78
1990-95	2.46	10.57	9.51
1995-00	2.92	7.48	7.03
2000-05	2.97	6.33	6.05
2005-10	3.00	6.69	6.43

Source: TDRI Projections

The industrialization variable and the crop diversification variable are derived from the macroeconomic data projections. An econometric model is built for this task. The industrialization variable is the ratio of the nonagricultural GDP to agricultural GDP. The growth rates of the nonagricultural and agricultural GDP, actual and projected, are shown in Table 3.4. The crop diversification variable is calculated as the a ratio between the land-saving crop output and the land-using crop output. The projected output levels of both types of crops (represented here by the real GDP of that type of crop) are reported in Table 3.5.

Table 3.5 Value Added of Land-Using and Land-Saving Crops

Unit: Million 1972 Baht

Year	Land-Using Crops	Growth Rates (%)	Land-Saving Crops	Growth Rates (%)
1965	12,747	3.71	8,019	5.02
1970	16,859	6.18	12,022	8.45
1975	19,532	3.26	14,946	4.50
1980	23,144	4.02	18,852	4.85
1985	30,944	6.01	24,093	5.05
1990	35,751	3.58	31,361	5.44
1995	36,316	0.32	38,053	3.94
2000	39,458	1.67	45,860	3.80
2005	43,222	1.84	55,143	3.76
2010	47,545	1.93	66,197	3.72

Note: Land-using crops include paddy, maize, cassava, and rubber trees.
Land-saving crops include vegetables, fruits, livestock, and fisheries.
Source: TDRI Projections

The projection of the agricultural population is calculated from the Thailand Development Research Institute's (TDRI) demographic and macroeconomic projections. Income elasticities of labor demand in the industrial and service sectors are calculated from past data. Using these elasticities, and the projections of population and of the sectoral GDP, projections of the sectoral labor demand are estimated. Labor demand for the agricultural sector is then used to calculate future agricultural population. The projections are found in Table 3.6.

Table 3.6 Population and Labor Force

Unit : Millions

Year	TO-POP	AG-POP	L-IND	L-SER	L-AG
1960	27.67	21.31			
1965	31.24	24.06			
1970	36.10	27.80			
1975	41.21	29.16	1.63	3.28	13.27
1980	46.47	31.92	2.32	4.26	15.94
1985	51.36	33.90	2.82	5.36	17.67
1990	55.85	34.99	3.85	7.34	20.00
1995	59.78	35.40	5.14	9.21	20.23
2000	63.57	34.93	6.62	11.01	19.97
2005	67.17	34.03	8.14	12.64	19.45
2010	70.45	31.49	10.17	14.51	18.00

Source: TDRI Projections

Note: TO-POP and AG-POP are total population and agricultural population. L-IND, L-SER, and L-AG are labor force in the industrial, service, and agricultural sectors, respectively.

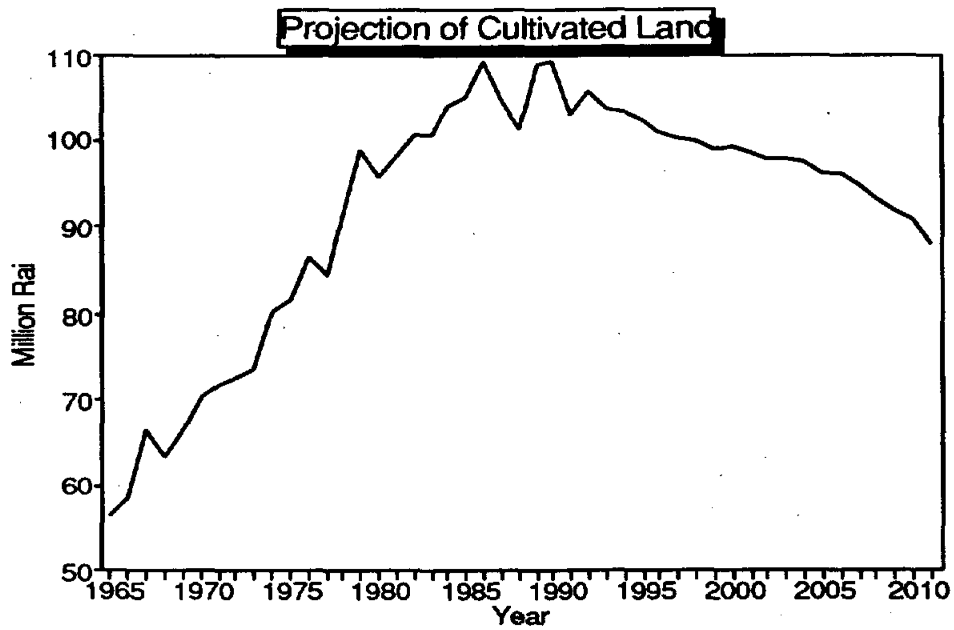


Figure 3.2

Using the projections of the independent or exogenous variables, the demand for cultivated land is estimated from 1990 to 2010. The resulting projection is graphically reported in Figure 3.2. The projection suggests that land demand begins to diminish after the year 1989. By 2010, the demand for cultivated land is projected to be 88 million rai, or approximately 19 million rai less than the current figure.

From 1990 to 2005, the land demand is projected to decrease by 0.5 percent annually. After 2005, the land demand will decrease at an annual rate of 1.75 percent. The decrease in land demand is a result of the following:

- Declining trend in real agricultural prices
- Levelling off and declining population
- Increase in productivity level
- Growth of the industrial and service sectors
- Diversification towards land-saving crops

During the period from 2005 to 2010, land demand is projected to decrease at a faster rate because the agricultural population is projected to decrease at a faster rate (see Table 3.6). As noted earlier, population is the most significant factor in the demand for agricultural land (see Table 3.2).

V. SELECTED POLICY SIMULATIONS

The cultivated land demand model can be used for policy simulations as well as for projections. Simulation can be helpful for policy formulation. Policy makers are normally faced with an array of policy options, and although the theoretical impacts of these options might be clear, often their quantitative impacts and relative effectiveness are not known. Policy simulation can help evaluate and compare alternative policies. In this section, four policy scenarios are simulated.

Scenario 1: Farm Subsidy Policy.

Crop price guarantees are common practice among developed countries. Farm subsidies, such as price or income guarantees, are given to maintain the income level of the farmers. An increasing trend towards farm price supports is anticipated in Thailand because of the growing inequality in purchasing power between the agricultural sector and the nonagricultural sector. Table 3.7 reports the projected per capita incomes of the two sectors.

Table 3.7 Projected Sectoral Per Capita Income

Unit: In Constant 1972 Baht

Year	Total	Agri	Nonagri	Nonag/Agri Ratio
1990	11,232	2,634	25,894	9.83
1995	16,522	2,990	32,332	10.81
2000	21,818	3,514	39,312	11.19
2005	27,697	4,182	46,151	11.04
2010	36,057	5,247	54,278	10.34

Source: TDRI Projections

In scenario 1, it is assumed that the government guarantees the real crop price to increase 2 percent annually, using 1989 as the base year.

Scenario 2: Productivity Increase Policy.

Productivity growth in the Thai agricultural sector is low compared to international and regional standards. Ammar et al. (1989) studied agricultural productivity (output/labor) growth in Thailand and found that education has a significant impact on productivity. A 10 percent increase in the education level (average year of schooling) will raise productivity by almost 5 percent. Feder et al. (1986) also found that secure land ownership has a significant effect on productivity. Therefore an increase in productivity could come from various sources including education, secure landownership, irrigation, etc.

In Scenario 2, it is assumed that the productivity level can be increased at 3 percent per year, using 1989 as the base year.

Scenario 3: Capital Subsidy for the Industrial Sector.

Governments normally support the expansion of industry with privileges such as machinery import tax exemptions or export subsidies. The tax-exempt status of imported machinery provides an incentive for replacing labor with machinery which lowers the labor requirement. In this case, it is assumed that the government subsidizes the use of labor-saving technology in the industrial sector. The labor requirement in the industrial sector is assumed to be 10 percent less than in the base case of Section 3. The recent reduction in the import duty on machinery for industry is likely to induce substitution of capital for labor.

Scenario 4 : Oil Crisis Simulation.

The on-going Middle East crisis (as of December 1990) has created a fear of worldwide recession. Under these conditions, the projected double-digit growth of the industrial and service sectors may not be achieved. In Scenario 4, it is assumed that the growth rate of the nonagricultural sector from 1990 to 1994 is reduced to the rates shown in Table 3.8 below.

Table 3.8 Revised Nonagricultural GDP Growth Rates

Unit: Percent

Year	Base Case	Oil Crisis
1990	10.93	9.50
1991	11.46	7.50
1992	11.39	8.00
1993	10.64	8.50
1994	10.10	9.00
1995	9.37	9.37

The simulation results are summarized in Table 3.9 below.

Table 3.9 Demand for Agricultural Land: Policy Simulation Results

Unit: Million Rai

Year	Base	Farm Subsidy	Productivity Growth	Capital Subsidy	High Oil Price
1990	103.25	103.25	103.25	103.66	103.66
1995	101.13	102.01	95.90	104.57	104.57
2000	98.69	100.84	91.37	102.05	102.05
2005	96.05	99.03	86.77	99.35	99.35
2010	87.94	91.84	77.86	90.93	90.93

Scenarios 1, 4, and 3 result in land demands higher than the base case. The price guarantee scheme (Scenario 1) provides incentives for farmers to farm more. The subsidization of labor-saving technology in industry (Scenario 3) increases the pool of agricultural labor and results in a higher demand for farmland. The same logic applies for Scenario 4, the oil crisis case, which creates recessionary effects on the economy.

With lower employment opportunities in the nonagricultural sector, the demand for land for cultivation would be higher.

The most notable case is Scenario 2 in which productivity is increased by only 3 percent annually. The land saving because of this productivity increase is clear: in the year 2010, ten million rai would be available for reforestation and other conservation uses.

VI. SUMMARY

The theoretical and historical analyses of structural changes and land use patterns from the previous chapter are quantified in Chapter 3. A cultivated land demand model is constructed. This model relates five key variables --(1) agricultural prices, (2) agricultural population, (3) productivity level, (4) industrialization, and (5) crop diversification-- to the demand for (cultivated) agricultural land. The model is also used for projecting future land demand. The projection indicates that land demand will decline in the future due to lower real crop prices, slow agricultural population growth, an increase in the productivity level, expansion of the nonagricultural sector, and the shift towards land-saving crops.

Policies such as crop price guarantees, investments in agricultural productivity , capital subsidies for industry, and lower growth rates due to higher oil prices, have been simulated. These policies may seem to be unrelated to land use patterns, but they are intrinsically linked. For example, Scenario 3 shows that a policy which makes capital relatively less costly for the industrial sector, by allowing machinery to be imported free of import tariffs, would, all other things being equal, increase the demand for land through *excess* labor supply.

The structure of the agricultural land demand model, the future demand projections, and the policy simulations will be used in policy formulation in Chapter 5.

Chapter 4

Managing Encroachment: Unused Land, Deforestation, and Productivity

The projections in Chapter 3 indicate that agricultural land demand will steadily diminish throughout the next two decades. Declining land demand is a result of industrialization, slower population growth, structural shifts within the economy, and other relevant factors. This projection of declining demand does not, however, imply that further forest encroachment will not constitute a problem.

Agricultural land is comprised of both a used portion (cultivated land) and an unused portion. In 1988 approximately 25 percent of farmland, or about 34 million rai, were unused. If landowners who no longer engage in agricultural activities prefer to leave land unused rather than rent it out to landless farmers because of low rental fees, landless farmers are forced to encroach on the forests for land. An econometric model is constructed to determine the main cause of unused land.

Yet, the environmental cost of deforestation may ultimately be higher than the income gained from opening the land. This study investigates this issue and also tests the cumulative effects of deforestation.

The adverse effects of deforestation are manifest in agricultural productivity; deforestation is known to cause soil erosion, floods, unseasonable climates, etc., all of which may have an impact on agricultural productivity. The relationship between forest and agricultural productivity is discussed in this chapter.

Chapter 4 is divided into four main sections: Section 1 explores the issue of unused farmland, Section 2 presents a procedure for estimating the effects of deforestation on farm income, Section 3 demonstrates the relationship between forest area and agricultural productivity, Section 4 is a summary.

I. UNUSED LAND AND FOREST ENCROACHMENT

In any given year, a fraction of farmholding is left unused for a variety of reasons such as poor rainfall, low prices, drops in productivity, flooding, and fallow requirements. Farmland is left unused when labor has better employment opportunities outside the agricultural sector, land is converted from farming to other uses when the expected return from such uses is higher. The percentage of unused farmland in farmholding area has ranged from a high of 29 per cent in 1972 to a low of 14 per cent in 1985. Since 1985, however, the portion of unused agricultural land rose from 14 per cent to 25 per cent in 1988. It is projected that the percentage and the area of unused land will rise further in future.

To understand the determining factors of unused farmland, an econometric model is constructed. The model is estimated with data ranging from 1961 to 1988. The detailed estimation results are listed in Appendix A. The estimated model is as follows:

$$\begin{aligned}\ln ULAND_t = & - 0.383 \ln PRICE_t - 0.627 \ln PROD_t \\ & \quad\;\; (-2.57) \qquad\qquad (-1.79) \\ & - 0.957 \ln AGPOP_t + 3.872 \ln HPOP_t \\ & \quad\;\; (-2.26) \qquad\qquad (7.08) \\ & + 0.992 \ln DIFF_t - 0.201\, DUMMY \\ & \quad\;\; (3.36) \qquad\qquad (-6.41)\end{aligned}$$

$R^2 = 0.9105 \qquad Adj\text{-}R^2 = 0.8892 \qquad DW = 2.32$

where:

PRICE	= real agricultural price index
PROD	= agricultural productivity
AGPOP	= agricultural population
HPOP	= farmholding per agricultural population
DIFF	= per capita income difference
DUMMY	= dummy for period 1979 -1985

The results indicate that the unused land area is determined by crop price, land productivity, size of the current farmholding, size of the agricultural population, the differential return between agricultural and nonagricultural activities, and a dummy variable for the oil crisis period (1979 to 1985). The estimated coefficients of the model have the following economic implications.

1. A 10 percent increase in the crop price index results in a 3.8 percent decrease in unused land area. As the crop price increases, farmers have an incentive to convert once unused farmland to cultivated land.

2. A 10 percent increase in the productivity level results in a 6.3 percent decrease in unused land. One major cause for abandoning farmland is a decrease in soil fertility from lack of proper soil maintenance, soil erosion, or insufficient water. Farmers are forced to abandon their land for more fertile areas. A rise in the soil quality or land productivity, as indicated in the model, can reduce the amount of unused farmland.

3. Agricultural population is another key determinant of unused farmland. A 10 percent increase in agricultural population results in a 9.6 percent decrease in unused land. The coefficient implies that, on average, an increase in the agricultural population by one additional person would reduce unused land by 0.74 rai. The additional land needed for cultivation will probably be obtained from forest encroachment.

4. The coefficient 3.87 of the HPOP variable means that a one percent increase in the average farmholding size will create 3.8 percent more unused land. Using this coefficient, it is calculated that a 10 rai increase in farmholding area will increase the area of unused land by 8.2 rai. It implies that the increase in farmholding is primarily for the replacement of deteriorating cultivated land or for speculation rather than to increase the cultivated land area. Out of every ten rai increase of farmholding area, two rai is used for cultivated land expansion, and eight rai goes to replace previously cultivated land.

5. Off-farm and nonfarm employment also affect the decision to leave farmland unused. With more attractive employment alternatives, farmers migrate to the cities and land is left uncultivated. In this model, the differential return (per capita income) of the agricultural and nonagricultural sectors is a proxy for the nonfarm employment opportunities. The larger the income difference between the two sectors, the more attractive nonfarm employment opportunities are. The positive coefficient of the income difference variable indicates that as the income gap widens, farmland is increasingly abandoned.

Table 4.1 Beta Coefficients

Variable	Beta Coefficient	Ranking
HPOP	1.330	1
AGPOP	0.566	2
DIFF	0.331	3
PROD	0.228	4
PRICE	0.217	5

The calculation of beta coefficients illustrates the relative importance of each variable. As shown in Table 4.1, the three most significant variables in determining unused land area are: (1) the farmholding per farmer, (2) the size of the agricultural population, and (3) the difference in return of the two sectors.

If the farmholding variable is discounted, it could be concluded that unused farmland is driven by the availability of better alternatives for labor and capital, causing migration to the nonagricultural sector. Moreover, the opportunity cost of keeping the land idle is low. The low opportunity cost of unused land is due to low returns on agricultural activities and low rental fees: the average rental fee of farmland is only 150 - 200 bath per rai. Landowners have little incentive to rent their unused area to landless farmers.

An increase in the demand for land for cultivation is satisfied by a reduction in unused farmland, the use of other land sources such as grasslands and unclassified lands, and new land clearing through forest encroachment. Since landowners are reluctant to rent out their land and converting other land to farmland is costly, landless farmers or farmers whose land has become unproductive are forced to encroach on natural forest to acquire land for cultivation.

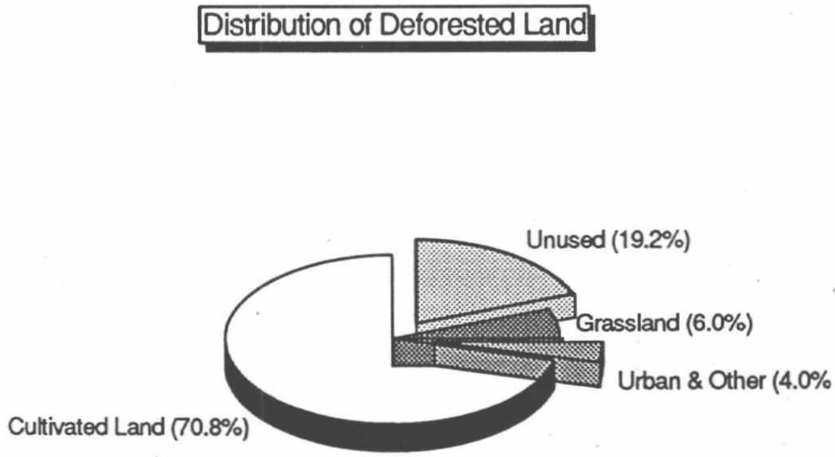


Figure 4.1

An analysis of the sources and distribution of the land supply affected by changes in land demand indicates that for every 100 rai added to cultivated land, 140 rai of forest are being cleared, with 27 rai going to replace retiring farmland that reverts to the unused land category, 7 rai going to grasslands, aquaculture etc., and 6 rai going to unclassified lands (see Appendix B). Figure 4.1 illustrates the distribution of deforested land.

The analysis of the determinants of unused farmland and the sources of new cultivated land in this section provide two important implications for the forest encroachment issue which are as follows:

1. Forests will be further encroached if a substantial portion of farmland remains unused. Landless farmers have no choice but to clear forest for land.
2. A reduction in soil fertility fuels more encroachment. The farmers who face declining productivity find that clearing forests for new, fertile land is less costly than improving the fertility of the existing land, given the lack of secure land titles and access to institutional credit.

The next section tests the hypothesis that, all other things being equal, deforestation contributes to the decline in agricultural productivity and total agricultural production. For a micro level study of deforestation, agricultural productivity, and poverty, see a study on *Deforestation and Poverty* in this series of TDRI studies (Research Paper No. 2).

II. AGRICULTURE AND FORESTRY

If forest encroachment continues while unused farmland is not reverted to forestland for economic and ecological reasons, what is the potential impact on agricultural production? Over the past 30 years, agricultural production has increased steadily through farmland expansion. Since deforestation meant more land for agriculture, the impact of deforestation on agricultural production appears to have been positive.

Is it, therefore, safe to assume that agricultural production can continue to rise with deforestation as has been historically the case? Will the conventional competitive relationship between agriculture and forestry continue until all forestland is replaced by farmland? There is accumulating evidence at the micro level that loss of forest cover especially on steep slopes and in watershed areas, leads to increased runoff, soil erosion, loss of water control, and downstream environmental impacts such as flooding and sedimentation of water bodies, and decreased availability of water during the dry season. For example, the Department of Land Development reports that 26 million rai of agricultural land under upland crops, rubber, and shifting cultivation experience from severe to very severe erosion, and lose between 20 to 967 tons of soil per rai per year, compared to a 0.01 to 5.00 tons per rai per year loss for forestland and paddies.

A study in the Northeastern provinces of Sakhon Nakhon and Kalasin showed a loss of 97 to 103 tons per rai per year from land under shifting cultivation and about 130 to 155 tons per rai per year for bare soil, compared to only 15 to 18 tons from forest. Another study indicates that a loss of 5 centimeters of topsoil results in a 22 percent drop in the yield of maize, and a loss of 15 centimeters of topsoil results in a 50 percent drop in yields. The sedimentation of reservoirs, the landslides that occurred in the South in November 1988, and the recurrent floods and droughts, all of which have some impact on agricultural production, are not unrelated to deforestation though quantitative assessments of these impacts are lacking.

In studying the effects of deforestation on agricultural output, the following approach has been employed:

1. An agricultural production function with land and cumulative deforestation as separate arguments is specified and estimated. The effects of agricultural land expansion and deforestation on agricultural output are calculated from the estimation results.

2. The output gain from land expansion and output loss from deforestation are then compared, and the net gain or loss of agricultural output from conversion of one rai of natural forestland into farmland at the margin is calculated.
3. To understand the effects of cumulative deforestation in different time periods, steps 1 and 2 are repeated for the earlier time periods of 1978, 1980, 1982, and 1984, to determine whether and when the conventional competition of agriculture and forestry for land, has turned into interdependence and complementarity.

2.1 Agricultural Production Function with a Deforestation Factor

Land has been the most important input in Thai agricultural production. The growth in agricultural output in the past decades is primarily from the expansion of agricultural land, not from an increase in the level of productivity. As agricultural land expands, the natural forest recedes. From 1961 to 1988, 85 million rai of natural forest were displaced; 82 million rai which were converted into agricultural land, although not all is being cultivated.

Land expansion (primarily from clearing natural forests) increases agricultural production. However, deforestation also produces negative effects on income. As a result of rapid deforestation, particularly in the Northeast and the South, soil erosion, unseasonable rainfall, drought, and flash flood problems have become severe and have contributed to lower agricultural output. Thailand may have reached the point where the adverse effects of deforestation on agricultural income outweigh the gains from land expansion. This section provides research into the counteracting effects of land expansion and deforestation on agricultural production.

In agricultural production, the key input factors are land, labor, and capital. Agricultural research and extension, irrigation, rainfall, fertilizer use, and education may also play a role. Of these factors, only those included in the following production function have been found to be significant in the case of Thai agriculture at the macro level.

OUTPUT = f(LAND, LABOR, CAPITAL, RES, EDUC)

where:

OUTPUT	= agricultural output (real agricultural GDP at 1972 prices)
LAND	= cultivated land
LABOR	= agricultural labor

CAPITAL	= value of capital inputs
RES	= agricultural research budget
EDUC	= average years of schooling

To study the effects of deforestation on agricultural output, a deforestation variable is added to the production function above. Because deforestation effects are cumulative, the cumulative forest loss variable (FCUM) is added to the equation rather than the annual forest loss. The new production function is written as:

OUTPUT = f(LAND, LABOR, CAPITAL, RES, EDUC, FCUM)

The equation is specified in double-log linear functional form, and is estimated with data from 1961 to 1987. The key results are reported below (detailed estimation results are located in Appendix A):

$$\begin{aligned} \ln \text{OUTPUT} = \; & 0.477 \ln \text{LAND} + 0.107 \ln \text{LABOR} \\ & \quad (3.29) \qquad\qquad (1.48) \\ & + 0.415 \ln \text{CAPITAL} + 0.072 \ln \text{RES} \\ & \quad (4.11) \qquad\qquad (2.30) \\ & + 0.637 \ln \text{EDUC} - 0.442 \ln \text{FCUM} \\ & \quad (3.46) \qquad\qquad (2.32) \end{aligned}$$

$R^2 = 0.9970$ Adj-$R^2 = 0.9962$ DW = 1.83

Since the production function is specified in the Cobb-Douglas functional form, the coefficients also represent the elasticities of each input factor. For instance, a 10 percent increase in cultivated land area will increase output by 4.77 percent, or a ten percent increase in the capital input will increase the production value by 4.15 percent.

Using the output elasticities of land and cumulative forest loss, it is calculated that: from 1962 to 1987, the average income gain from one rai of land expansion was 292 baht in 1972 prices or 990 baht in current prices, while the average income loss of one rai of accumulated deforestation is 227 baht in 1972 prices or 770 baht in 1990 prices. The calculation procedure is shown in Appendix C.

2.2 Net Gain (Loss) from Deforestation

Deforestation has three effects on agricultural production:

1. Deforestation generates more land for agriculture and, hence, it is positively related with agricultural output.
2. Newly cleared land is, on average, more marginal, more fragile, on steeper slopes, and generally has lower sustainable productivity than existing agricultural land. Thus, deforested land yields in lower agricultural production per rai than previously opened land.
3. Denuded hillsides and watersheds under shifting cultivation or upland crops, such as cassava and maize, result in increased runoff and flash floods that might accelerate nutrient reduction and soil erosion downstream, especially on lower uplands, as well as sedimentation of water bodies and flood damage.

Section 2.1 shows that one rai of land expansion generates 292 baht of income, and one rai of cumulative forest loss produces 227 baht of income loss. One rai of forest, however, does not translate into one rai of cultivated land. A portion of forest loss goes to unused land, grassland, etc. (see the explanation in Section one and in Appendix B). For the income gain and loss to be comparable, the income gain from one rai of cultivated land must be converted into income gain from one rai of forest loss, or vice versa. For example, if one rai of cultivated land expansion corresponds to 1.4 rai of forest loss, then income generated from one rai of cultivated land needs to be deflated by 1.4 to be comparable to the income generated from one rai of forest loss.

Using the 1987 conversion ratio, 1.6:1, the average output gain for one rai of forest loss is 182 baht (1972 prices). The net gain of deforestation, therefore, is negative 45 baht (1972 prices) per rai of forest loss. In other words, one rai of forest encroachment yields a net loss of 45 bath (1972 prices) or 153 baht (current prices) in agricultural output. In light of this result, farmers will be better off if they pay up to 153 baht (current prices) per rai to encroachers to slowdown forest encroachment.

2.3 Effects of Cumulative Deforestation

Section 2.2 has shown that the net effect of accumulated deforestation (until 1987) was a 45 baht per rai (1972 prices) loss in agricultural income. This result does not mean that the cost of deforestation will remain constant at 45 baht per rai of forest lost;

the deforestation effects are cumulative. Since 1950, 50 percent of Thailand's natural forests have been cleared. Clearing one additional rai of forest in 1988 created a more severe effect on agriculture than clearing one rai of forest in 1950, when more than half of the country was forested.

To study the cumulative effects of deforestation, the production equation in section 2.1 is reestimated with the data from 1962 to 1978, 1962 to 1980, and 1962 to 1984. The elasticities from these reestimations show the average effects of deforestation over the periods 1962 - 1978, 1962 - 1980, and 1962 - 1984, respectively (see Appendix A).

From the results, the net gain (loss) of deforestation is calculated and reported in Table 4.2 below.

Table 4.2 Effects of Deforestation on Agricultural Income

Unit: 1972 Baht/Rai

Gain/Loss	1962 - 1978	1962 - 1980	1962 - 1984	1962 - 1987
Gain from land expansion	213.19	186.74	174.88	182.38
Loss from deforestation	183.28	159.25	161.51	227.36
Net gain	+ 29.91	+ 27.49	+ 13.37	- 44.98

Table 4.2 indicates that the income gain from land expansion is on a declining trend which may be attributable to the fact that increasingly marginal land has been cultivated in recent years. The higher income in 1987 may have come from higher productivity, better crop prices, and a shift to higher-value crops. On the other hand, the damages from deforestation are increasing.

Table 4.2 suggests that the effects of deforestation could be worse in the future. The net income gain from clearing forest for farmland is certainly declining. In 1978 clearing one rai of forest generated a net income of 30 baht. A decade later, in 1987, clearing one rai of forest caused a 45 baht loss of agricultural income.

Section 2 shows that deforestation not only has adverse effects on agricultural income, it also creates cumulative damages. The deforestation effects increase in severity as the forest is further encroached. The adverse net effects of deforestation on agricultural production suggest that (1) agriculture and forestry are no longer competition in land from a social point of view, (2) agricultural growth through land expansion is no longer feasible, and (3) deforestation and poverty are mutually reinforcing.

In the first years of encroachment, farmers maintained a relatively high incomes by continually clearing forest for farmland. As the forest was depleted, their net income gains became smaller. As their incomes decline, farmers encroached further into the natural forests for more fertile land, but their incomes fell even further, partially due to the environmental damage caused by deforestation and partially because the newly cleared land, while temporarily fertile, was of lower sustainable productivity.

It should be noted that this calculation of the income loss from deforestation does not include other social costs such as loss of wildlife sanctuaries, loss of wilderness, and global climate change. When these costs are also considered, the net gain of deforestation could be negative in an earlier stage of the deforestation process.

III. DEFORESTATION AND PRODUCTIVITY

It has been hypothesized that deforestation has adversely affected farm income through a decline in productivity. To test this hypothesis, a simple model is constructed to explain agricultural productivity (a composite index of crop yields per rai of cultivated land). The model is specified as follows:

PROD = f(KPL, IRRL, EDUC, RAIN, FOREST)

where:

PROD	= output per rai of cultivated land
KPL	= capital per rai of cultivated land
IRRL	= share of irrigated land
EDUC	= average years of schooling
RAIN	= annual rainfall
FOREST	= forest cover

The model contains five independent variables: (1) capital per unit of cultivated land, (2) share of irrigated land, (3) average level of education attainment,(4) rainfall, and (5) forest coverage. The model is specified in double-log linear form and fitted with data from 1961 to 1987. The estimated model is reported below and detailed estimation results are located in Appendix A:

$$\begin{aligned} \ln PROD = {} & 0.113 \ln KPL + 0.330 \ln IRRL \\ & \quad (0.44) \qquad\qquad (2.45) \\ & + 0.218 \ln EDUC + 0.099 \ln RAIN \\ & \quad (1.99) \qquad\qquad (1.16) \\ & + 0.186 \ln FOREST \\ & \quad (2.56) \end{aligned}$$

$$R^2 = 0.6200 \quad Adj\text{-}R^2 = 0.5477 \quad DW = 1.43$$

The productivity equation indicates that forest cover makes statistically significant and a positive contribution to agricultural productivity. Other significant variables include education, irrigation, and rainfall.

Increased forest cover contributes to a higher level of productivity. A 10 percent increase in forestland will increase the productivity by 1.9 percent. Thus, rapid deforestation during the past two decades has indirectly resulted in a loss of productivity. This calculation is an average figure. The actual productivity loss due to deforestation could be more severe in some areas than others. These negative effects of deforestation provide a possible linkage between deforestation and agricultural income loss.

IV. SUMMARY

Chapter 2 showed that the expansion of agricultural land causes deforestation, and described how agricultural land or farmholdings are divided into cultivated land and unused farmland. Chapter 3 focused on the study of cultivated land, and projected that the demand for agricultural land will decline in the future. The decline in demand for cultivated does not, however, guarantee that forests will not be encroached.

Chapter 4 studied the unused portion of farmland. An econometric model was formulated which determined that the factors influencing unused land include crop prices, productivity growth, agricultural population, average farmholding size, and off-farm and nonfarm employment opportunities.

It is *common wisdom* that deforestation helps raise agricultural income through an expansion of farmland, but when a production function was used in combination with a deforestation variable to study the effects of land expansion and deforestation on agricultural income, the results showed that deforestation actually reduced agricultural income. The negative effects of deforestation came from a loss in soil fertility due to soil erosion, floods, lack of water, etc. It has been estimated that the effect of deforestation on agricultural income is negative. It was calculated that one rai of forest encroachment during the period of 1962 - 1987 resulted in a net loss of 150 baht in agricultural income. Chapter 4 has shown that deforestation damages are cumulative and appear to be on increasing as the forest is further encroached, while the income gains from land expansion appear to be decreasing. Thus, the net income from forest clearing which must have been positive in earlier years, has turned negative in recent years. It is projected that cumulative deforestation damages will worsen in the future.

It is further hypothesized that deforestation damages agricultural output by lowering productivity. A productivity equation was constructed to test this hypothesis and the test results indicated a positive relationship between forest area and productivity level: more forest coverage could improve farm productivity.

This study of cultivated land, unused land, deforestation damages, and productivity is used to formulate policy recommendations in Chapter 5.

Chapter 5

Conclusion and Policy Recommendations

In less than thirty years, Thailand has been transformed from a subsistence agrarian society into an industrializing economy. Forest resources have played a significant role in the industrialization and economic growth of the past decades; provided a source of income for farmers, food for industrial workers, surplus for capital accumulation, and foreign exchange for imports of capital goods. Between 1960 and 1988, roughly 90 million rai of natural forest were denuded, and more than 90 percent of the depleted forestland was converted into farmland. The agricultural growth of the past 30 years was largely a result of land expansion rather than a result of an increase in the level of agricultural productivity.

While the country's economic performance, particularly in the industrial sector, has been remarkable, the economic benefits of this growth have been unevenly distributed. Currently, more than 60 percent of the population (about 31 million people) derive most of their income from agriculture which produces 16 percent of the country's wealth. The average per capita income of the population engaged in the nonagricultural sector is nine times higher than that of those engaged in the agricultural sector. Based on projections, this income gap will widen in the future.

Farmers depend on land resources as their main source of employment, income, and food. Land resources, which could once be obtained by simply clearing forests, are becoming increasingly scarce. The cost of obtaining forestland for cultivation is rising, while the land quality is declining. Although the private benefits from forest encroachment still exceed the private costs, the social costs of deforestation have already exceeded its social benefits. If deforestation trends continue, agricultural growth may not be sustainable over the long haul unless the sources of growth shift from land expansion to productivity improvements, and effective measures are taken to contain or counter downstream environmental impacts.

This paper has carried out research on tree related areas:

1. Analysis and projection of demand for cultivated land
2. Determinants of unused farmland
3. Effects of deforestation on agricultural production and land productivity

To analyze the demand for cultivated land, an econometric model was constructed. The model consists of five independent variables including: (1) crop prices, (2) land productivity, (3) agricultural population, (4) industrialization, and (5) the structural changes in agriculture. The results show that only agricultural population and price have positive effects on land demand; the rest of the variables are negatively related to the cultivated land demand.

Cultivated land is not the only factor driving forest encroachment. If a large portion of farmland is left unused, forest encroachment could persist amidst the falling demand for cultivated land. Farmland that had been previously used might be left unused, while new land was obtained by clearing forestland. An econometric model was constructed to study this issue. It is found that land is left idle because of five factors: (1) low crop prices, (2) low soil quality, (3) agricultural population growth, (4) higher returns from the nonagricultural sector, and (5) larger average farmholding. These five factors explain approximately 90 percent of the variation of unused land.

In the past, agricultural growth was accomplished through land expansion, and forests were converted into agricultural land. The cumulative deforestation, however, has generated social costs in terms of flash floods, soil erosion, landslides, etc., which affect agricultural productivity. The private benefit from land expansion must ultimately be weighed against its social loss. As the forests recede, leaving critical watersheds denuded, the social costs grow. A point is inevitably reached at which the social costs exceed the private gain. At this point, agricultural production and income could be increased by taking land out of cultivation and reforesting it, rather than by taking land out of forestry and converting it to farmland.

The deforestation effects are estimated via an agricultural production function in which a cumulative deforestation factor is included as a parametric shifter. The estimated function is used for the calculation of the cumulative deforestation effects in various years and the analysis of the interaction between forestry and agriculture.

I. MAJOR FINDINGS

The study arrived at three major findings:

1. The demand for cultivated farmland, which grew at a rate of 3 percent over the past 30 years, is expected to level off in the early 1990s and begin to fall from the current 109 million rai to 88 million rai by the year 2010.

2. Under prevailing policies, much agricultural land will probably remain unused, while the encroachment of agriculturally marginal but ecologically critical forestland continues. This is due to the low (private) opportunity cost of unused land and the even lower (private) cost of forest encroachment, despite the fact that both may have a high social opportunity cost. The private costs of forest encroachment, adjusted for land quality, have also risen as the land frontier is being approached, but, in relative terms, encroachment is still the lowest-cost source of income for cash-strapped farmers.

3. While the social benefits from converting forestland into agricultural land in the 1960s and the 1970s were positive (considering only the impact on agricultural output) they have now become negative. The total agricultural output could increase, all other things being equal, by reducing forest encroachment and expanding the forest area.

II. POLICY RECOMMENDATIONS

Based on these findings, the following policy recommendations are offered.

1. Reclassify the Protection Forest Boundary and Create an Accurate Boundary Map

Background: The National Forest Reserve Act of 1964 gave the government the power to classify certain areas (about 50 percent of the country's total land area) as national forest reserves to protect them against encroachment. The Royal Forestry Department (RFD) was assigned the task of declaring the boundary of the forest reserves. The act failed to accomplish the goal of preserving the country's natural forests and the National Forest Policy of 1985 was enacted to set more specific and realistic targets. The new policy target was to maintain 40 percent of the country under tree cover. Fifteen percent of the land was declared preservation forest and the remaining 25 percent economic forest.

Problems: The national forest reserve boundary seems to be arbitrary and unresponsive to socioeconomic conditions. There have been cases where boundaries were drawn over well-established villages. Problems of *illegal* encroachment are omnipresent and increasingly severe. At present nearly a third of the national forest reserves is denuded and occupied by farmers.

Policy Effects: New forest boundaries should be drawn that reflect social, economic, environmental, and ecological factors. This task should include; (1) scientific demarcation of the remaining natural forest, (2) drawing of a geographically accurate forest map, and (3) degazetting of encroached forestland. The national forest policy target should shift from the current preoccupation with economic forests, which exist only on paper, to the protection of the remaining natural forests, which exist on the ground and are threatened with irreversible loss. It is recommended that all remaining natural forest (reported to cover 28 percent of the country's total area by the RFD) be clearly and undisputably demarcated. The minimum of 80 million rai or 25 percent of the country's total area should be declared as protected or conservation forests.(1) Measures should be devised for their effective protection. This recommendation is based on our finding that, even in terms of agricultural production alone, any further forest loss would impose *net* social losses. In this sense, the protected forest *is* also *the economic* forest. The growing of trees for wood production could and should be left to the market. Reforestation for environmental reasons such as the control of water flows or the rehabilitation of denuded watersheds is a public investment that should meet public investment criteria. Economic incentives can be employed to encourage the planting of a variety of tree species by farmers and other landowners.

By instituting the above policy, the *illegal* encroachment problems would be drastically reduced. The reclassification of forests, the redrawing of forest boundary, and the reform of the National Forest Policy would create a "one boundary, one map, one policy" situation for all people and agencies concerned. The remaining natural forest would be preserved as an ecological asset and a national treasure.

2. Give Secure Landownership Title to Occupants of Land Outside the Redrawn Forest Boundary

Background: The National Reserve Act of 1964 prohibits the issuing of legal land ownership documents for those residing in forest reserves. Therefore, trading and occupying this land is not recognized by the law. A large portion of the landowners in the forest reserve, however, hold Bor Por Thor 5 (Land Tax Paying) documents. Such

(1) Exceptions could be made for rich mineral-bearing lands outside national parks, wildlife sanctuaries, and watershed areas (class 1A), provided that the recommendations of the TDRI study on *Mining, Environment, and Sustainable Land Use* are adopted.

documents are not titles of ownership, but they specify that tax has been paid on a certain amount of land.

Problems: With or without documents, land within the current forest reserve boundary is actively traded. The Bor Phor Thor document, although not accepted as a legal ownership document, is normally used in land transactions. Land is also bought and sold with no documents. Without the security of ownership, landholders neglect investment to improve and maintain soil quality (Feder et al. 1988). Land productivity is essential for alleviating poverty and deterring forest encroachment.

Policy Effects: With secure landownership, land productivity would be increased through investments in proper soil maintenance and the use of fertilizer and other inputs. Forest encroachment would be reduced, and at the same time, agricultural income would be increased. For land documents to be acceptable as collateral for long-term credit, the documents must be secure, indefinite, and transferable. To allay fears that farmers might sell the land and continue encroachment, the land title could be given a certain trading time limit, for example, five years. Also, a special fee (transfer tax) could be imposed on each land the transaction. These measures would make the newly documented land less attractive to outside investors and the landowners less willing to part with their land.

3. Introduce a Progressive Land Tax to Encourage Land Distribution and Full Utilization of Land

Background: Unlike income tax rates, land tax rates are not progressively rising with the size of holdings. They are proportional to the land value, which is assessed by the Land Department (normally at levels well below market value). The average tax paid on agricultural land is also very small. The Office of Agricultural Economics' 1987 figures show that an average agricultural household paid only 4.31 baht in land taxes.

Problems: Low and nonprogressive land taxes contribute to land concentration and skewed land distribution. Moreover, low taxes mean low opportunity costs of keeping farmland idle. Instead of selling or renting their land, landholders who cease to farm prefer to keep the land unused while landless farmers are forced to search for land in the forests. The research has shown that the average farmholding size is the most crucial factor in determining unused land. A 1 percent increase in the average holding size would increase the amount of unused land by almost 4 percent.

Policy Effects: With a progressive land tax, the opportunity cost of holding excessive land would be enormously increased. Instead of finding marginal land in the forest, landless farmers would have access to prime agricultural land, which was once left idle. The problems of forest encroachment and poverty could be simultaneously improved. When monitoring capabilities improve, different tax rates could be applied to different type of plantations and farms, for example, the lowest tax could be reserved for tree plantations and the highest tax bracket could be assigned to unused land. The new tax structure would encourage environmentally beneficial land uses .

4. Facilitate Labor Migration from the Agricultural Sector to the Nonagricultural Sector

Background: In resource-poor and densely-populated regions such as the Northeast, there is an imbalance between people and resources. The degraded resource base cannot meet the demands and aspirations of a growing number of people. In short, too many people are depending in too few resources.

Problems: For many communities, off-farm and nonfarm employment offers the best, if not the only, opportunity to escape poverty. Three obstacles hinder farmers from taking up nonfarm employment or migrating to the urban and industrial centers: (1) low levels of education, (2) lack of capital to start up new occupations or new lives in the city, and (3) limited opportunities for nonagricultural employment at low-skill levels. The industrial sector requires skilled labor, but farmers are mostly unskilled.

Policy Effects: The research found that the agricultural population is the strongest determining factor of the demand for cultivated land; more agricultural population means more land is needed, and a higher demand for farmland means more forest encroachment. Three measures could be initiated to facilitate occupational and spatial mobility:

1. Increase Education and Training at the Village Level. As technology becomes more advanced more skilled labor is required, and the farmers with little education or few skills find it difficult to obtain proper jobs that pay enough to cover migration costs. Unskilled work normally offers low pay. Education not only helps migrants find jobs at a decent wage, it also benefits those who choose to remain in the village. Siamwalla et al. (1989) found that education played a vital role in increasing farm productivity and output. The findings of the present study corroborate these earlier results. Education is found to positively contribute to higher agricultural output and productivity. Tongpan et al. (1990) have also found that education level substantially improves nonfarm income.

2. Issue Secure Landownership Titles. With legal landownership, those who wish to migrate could sell or rent out land at a fair price. This would provide the necessary start-up funds for migration. Moreover, landless farmers could buy or rent unused land for cultivation, especially if our proposal for progressive land taxes that penalize unused land is adopted. The pressure to search for land in the forest would also be reduced.

3. Eliminate Implicit Capital Subsidies for the Industrial Sector. Capital subsidies induce the replacement of labor by machinery. The subsidies include no- or low-import taxes on, and low interest loans for, machinery. Other things being equal, capital subsidies reduce the demand for labor. A policy simulation scenario in Chapter 3 indicates that a reduction in labor demand by industry results in a higher demand for agricultural land.

5. Reconsider the Farm Price Subsidy Program

Background: As a country becomes industrialized, the income gap between the agricultural sector and the nonagricultural sector often widens. Governments tend to support the farming sector by guaranteeing crop prices or incomes. Price-support schemes have already been introduced in Thailand, and are expected to increase in the future.

Problems: There are two problems with the price-support scheme in Thailand. First, in practice, the majority of the farmers, especially the poor, get little or no benefit from such support (Panayotou, 1985). Second, the scheme creates inefficiency in the agricultural system. For instance, if rice is the only crop with a price-support scheme, farmers might switch from other crops to rice. A price-support policy tends to make farmers unresponsive to changes in world prices, and generates costly agricultural surpluses. Moreover, this study shows through a simulation that higher crop prices create higher demand for farmland which implies that forest would be further encroached.

Policy Effects: Other income enhancement measures should be introduced instead of the price support programs. Examples include improved irrigation systems and more relevant agricultural research. These two factors along with land titling, access to credit, and improvement of the educational system are found to be effective means of raising productivity and farm incomes.

The reversal of widening income inequality, advancing natural resource depletions, and a deteriorating environment are key challenges facing Thailand today. The choice appears to be between; natural resources and economic development, poverty and forest encroachment, and agriculture and forests. This research has established that these issues are interdependent: agriculture and forestry complement each other, poverty alleviation and forest protection are inseparable, and natural resource conservation and economic development are integral parts of a sustainable future. But the resources must be used efficiently, agricultural productivity must be increased and unused farmland must be minimized. The benefits of industrialization must be justly distributed.

The policies proposed here are designed to accomplish these goals. The recommendations are based on the qualitative and quantitative analyses of this and other studies. Researchers have taken the first step -- it is now up to policy makers to take the next.

Appendix A: Estimation Results

This appendix presents detailed estimation results for four models: cultivated land demand, unused agricultural land, deforestation and agricultural output, and deforestation and agricultural productivity.

CULTIVATED LAND DEMAND

Table A1 Cultivated Land Demand Equation, 1964 - 1989

SMPL 1964 - 1989
26 Observations
LS // Dependent Variable is LAND
Convergence achieved after 8 iterations

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
PRICE(-1)	0.0809937	0.0407042	1.9898107	0.061
AGPOP	1.3366684	0.1042579	12.820789	0.000
PROD(-1)	-0.2795222	0.1149373	-2.4319544	0.025
AGX	-0.1546830	0.0391183	-3.9542373	0.001
INDX	-0.3077879	0.0912311	-3.3737179	0.003
DUMMY	0.3517215	0.0852836	4.1241399	0.001
AR(2)	0.4372824	0.1925550	2.2709475	0.035

R-squared	0.990487	Mean of dependent var	4.444642
Adjusted R-squared	0.987483	S.D. of dependent var	0.209928
S.E. of regression	0.023486	Sum of squared resid	0.010481
Durbin-Watson stat	1.998315	F-statistic	329.7241
Log likelihood	64.71994		

Table A2 Cultivated Land Demand Equation, 1964 -1984

```
SMPL    1964  -  1984
21 Observations
LS // Dependent Variable is LAND
Convergence achieved after 7 iterations
```

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
PRICE(-1)	0.0602530	0.0649879	0.9271422	0.370
AGPOP	1.4389149	0.1407690	10.221820	0.000
PROD(-1)	-0.1984054	0.1808619	-1.0969994	0.291
AGX	-0.1547201	0.0647702	-2.3887559	0.032
INDX	-0.4181559	0.1309696	-3.1927715	0.007
DUMMY	0.2926513	0.0944644	3.0980067	0.008
AR(2)	0.3806641	0.2823153	1.3483651	0.199

R-squared	0.988594	Mean of dependent var	4.390900
Adjusted R-squared	0.983706	S.D. of dependent var	0.197730
S.E. of regression	0.025240	Sum of squared resid	0.008919
Durbin-Watson stat	1.942233	F-statistic	202.2398
Log likelihood	51.72558		

PERCENTAGE ROOT MEAN SQUARE ERROR TEST

Several testing methods, such as the percentage root mean square error test, the mean absolute error test, and the inequality coefficient test can be used to evaluate the predictive accuracy of the model (Fair 1984). The percentage root mean square error (%RMSE) test is selected for the predictive accuracy measurement of the cultivated land model. The %RMSE indicates the average the percentage deviation between the predicted value and the actual value. For instance, a %RMSE of 5 percent means that, on the average, the predicted value differs from the actual value by 5 percent. The model with %RMSE of 5 percent to 10 percent is considered acceptable.

There are two types of predictive accuracy test: the in-sample test and the out-of-sample test. The in-sample test is a test where the fitted value and the actual values of the dependent variable are compared within the sample range . The out-of-sample test, a more stringent determine where the fitted and actual values are compared outside the sample range. In this case, the model is fitted with the data from 1964 - 1984. The forecast for the cultivated land is then performed from the period from 1985 to 1989.

These forecasted values are compared with the actual land used during that period. The %RMSE tests are reported in table A3 below:

Table A3 Percentage Root Mean Square Error Test

Method	In-Sample	Out-Sample
%RMSE	1.973	2.235

Table A3 indicates that, within the sample range, the fitted values (on the average) differ from the actual value by 1.97 percent. Outside the sample, the fitted values divert from the actual value by 2.23 per cent. In other words, if the model were constructed in 1984, its prediction from 1985 to 1989 would be only 2.23 percent in error. The two tests suggest that the predictive capability of the model is extremely reliable.

UNUSED AGRICULTURAL LAND

Table A4: Unused Agricultural Land Equation, 1962 - 1984

SMPL 1962 - 1988
27 Observations
LS // Dependent Variable is ULAND

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
PRICE	-0.3832356	0.1491224	-2.5699398	0.018
PROD	-0.6286866	0.3500722	-1.7958772	0.087
AGPOP	-0.9575638	0.4230411	-2.2635245	0.034
HPOP	3.8717623	0.5464622	7.0851414	0.000
DIFF	0.9925719	0.2953244	3.3609546	0.003
DUMMY	-0.2010525	0.0401682	-5.0052653	0.000

R-squared	0.910506	Mean of dependent var	3.089125
Adjusted R-squared	0.889197	S.D. of dependent var	0.231248
S.E. of regression	0.076975	Sum of squared resid	0.124430
Durbin-Watson stat	2.322218	F-statistic	42.73030
Log likelihood	34.31664		

AGRICULTURAL OUTPUT (WITH DEFORESTATION EFFECTS)

Table A5 Deforestation Effects, 1987

SMPL 1962 - 1987
26 Observations
LS // Dependent Variable is OUTPUT

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
LAND	0.4767937	0.1448497	3.2916448	0.004
LABOR	0.1071367	0.0721667	1.4845728	0.153
CAPITAL	0.4148844	0.1009153	4.1112135	0.001
RES	0.0721589	0.0313212	2.3038374	0.032
EDUC	0.6374134	0.1840392	3.4634649	0.002
FCUM	-0.4425549	0.1909449	-2.3177096	0.031

R-squared	0.996977	Mean of dependent var	3.893979
Adjusted R-squared	0.996221	S.D. of dependent var	0.333535
S.E. of regression	0.020502	Sum of squared resid	0.008407
Durbin-Watson stat	1.826997	F-statistic	1319.275
Log likelihood	67.58606		

Table A6 Deforestation Effects, 1984

SMPL 1962 - 1984
23 Observations
LS // Dependent Variable is OUTPUT

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
LAND	0.4415551	0.1752470	2.5196160	0.022
LABOR	0.0806640	0.0818966	0.9849487	0.338
CAPITAL	0.3676712	0.1511805	2.4320019	0.026
RES	0.0737260	0.0346195	2.1296114	0.048
EDUC	0.5642450	0.2331081	2.4205292	0.027
FCUM	-0.3195122	0.2380514	-1.3421982	0.197

R-squared	0.996145	Mean of dependent var	3.832524
Adjusted R-squared	0.995011	S.D. of dependent var	0.303638
S.E. of regression	0.021448	Sum of squared resid	0.007820
Durbin-Watson stat	1.997497	F-statistic	878.4806
Log likelihood	59.20997		

Table A7 Deforestation Effects, 1980

SMPL 1962 - 1980
19 Observations
LS // Dependent Variable is OUTPUT

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
LAND	0.4816765	0.2103894	2.2894521	0.039
LABOR	0.1919983	0.1141388	1.6821478	0.116
CAPITAL	0.3044285	0.2449516	1.2428109	0.236
RES	0.1009775	0.0527368	1.9147442	0.078
EDUC	0.3263288	0.4940483	0.6605200	0.520
FCUM	-0.3179502	0.3218374	-0.9879220	0.341

R-squared	0.995107	Mean of dependent var	3.748064
Adjusted R-squared	0.993225	S.D. of dependent var	0.262434
S.E. of regression	0.021600	Sum of squared resid	0.006065
Durbin-Watson stat	2.380458	F-statistic	528.8002
Log likelihood	49.51119		

Table A8 Deforestation Effects, 1978

SMPL 1962 - 1978
17 Observations
LS // Dependent Variable is OUTPUT

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
LAND	0.4854959	0.2305519	2.1057990	0.059
LABOR	0.2104088	0.1225919	1.7163351	0.114
CAPITAL	0.3277981	0.2633125	1.2449015	0.239
RES S	0.1010699	0.0608448	1.6611099	0.125
EDUC	0.3469972	0.5516120	0.6290602	0.542
FCUM	-0.3655756	0.3574001	-1.0228749	0.328

R-squared	0.993911	Mean of dependent var	3.704926
Adjusted R-squared	0.991143	S.D. of dependent var	0.242258
S.E. of regression	0.022799	Sum of squared resid	0.005718
Durbin-Watson stat	2.377244	F-statistic	359.1147
Log likelihood	43.85612		

AGRICULTURAL PRODUCTIVITY

Table A9 Agricultural Productivity Equation

SMPL 1962 - 1987
26 Observations
LS // Dependent Variable is PROD

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
FOREST	0.1858806	0.0725421	2.5623830	0.018
EDUC	0.2183259	0.1097139	1.9899568	0.060
KPL	0.1126907	0.2551327	0.4416943	0.663
IRRL	0.3301748	0.1349350	2.4469176	0.023
RAIN	0.0989238	0.0854257	1.1580102	0.260

R-squared	0.620044	Mean of dependent var	0.982291
Adjusted R-squared	0.547671	S.D. of dependent var	0.077021
S.E. of regression	0.051800	Sum of squared resid	0.056349
Durbin-Watson stat	1.426507	F-statistic	8.567391
Log likelihood	42.85334		

Appendix B: Distribution of Deforested Land

This appendix demonstrates the calculation of the distribution of deforested land. It is recognized that not all deforested forest land is converted into cultivated land; a portion will go to idle land, urban and recreational land, and other land uses. A calculation is carried out to determine the distribution of forestland based on the land-use data in Table B1.

Table B1 Land Utilization in Thailand

(Million Rai)

YEAR	TOTAL	FOREST	Cultivate Land	Other Agri Land	Unused Agri Land	TOTAL FARM HOLDING	UNCLASS
1961	320.70	175.19	48.55	0.00	17.34	65.88	79.63
1962	320.70	172.31	53.68	0.00	15.18	68.86	79.52
1963	320.70	169.60	55.23	0.00	14.20	69.43	81.67
1964	320.70	166.70	56.57	0.00	19.48	76.06	77.94
1965	320.70	163.93	58.37	0.00	21.36	79.73	77.04
1966	320.70	160.23	66.59	0.00	15.43	82.01	78.45
1967	320.70	156.48	63.22	0.00	21.20	84.42	79.80
1968	320.70	152.80	66.43	0.00	20.80	87.23	80.67
1969	320.70	149.10	70.38	0.00	20.03	90.41	81.19
1970	320.70	145.42	71.68	0.00	22.33	94.01	81.27
1971	320.70	141.88	72.44	0.00	26.78	99.22	79.60
1972	320.70	138.32	73.53	0.00	29.85	103.37	79.00
1973	320.70	134.71	80.13	0.00	29.04	109.17	76.82
1974	320.70	134.56	81.54	0.00	28.72	110.26	75.88
1975	320.70	130.76	86.48	0.49	25.24	112.21	77.72
1976	320.70	124.01	84.44	0.49	28.18	113.11	83.57
1977	320.70	116.57	91.01	0.40	22.38	113.80	90.33
1978	320.70	109.52	98.94	0.50	17.01	116.44	94.74
1979	320.70	106.39	95.64	0.67	21.29	117.60	96.70
1980	320.70	103.42	98.14	0.68	20.17	119.00	98.28
1981	320.70	100.58	100.78	0.93	19.59	121.29	98.82
1982	320.70	97.88	100.70	0.96	21.93	123.59	99.24
1983	320.70	96.27	104.08	0.99	19.17	124.23	100.20
1984	320.70	94.70	105.15	0.98	19.18	125.31	100.69
1985	320.70	93.16	109.24	1.10	18.26	128.60	98.94
1986	320.70	91.65	104.99	1.19	23.67	129.85	99.20
1987	320.70	90.77	101.42	3.12	34.29	138.82	91.11
1988	320.70	89.88	108.98	5.09	33.73	147.80	83.02

Source: Office of Agricultural Economics

Table B2 Distribution of Deforested Land

YEAR	CULTI LAND	FOREST LAND	UNUTIL LAND	OTHER LAND	UNCLASS LAND
1961					
1962	5.13	-2.87	-2.16	0.00	-0.10
1963	1.55	-2.71	-0.98	0.00	2.14
1964	1.34	-2.90	5.28	0.00	-3.72
1965	1.80	-2.77	1.88	0.00	-0.91
1966	8.22	-3.70	-5.94	0.00	1.42
1967	-3.36	-3.75	5.77	0.00	1.34
1968	3.21	-3.68	-0.40	0.00	0.87
1969	3.95	-3.71	-0.77	0.00	0.52
1970	1.30	-3.68	2.30	0.00	0.08
1971	0.76	-3.54	4.45	0.00	-1.67
1972	1.09	-3.55	3.06	0.00	-0.60
1973	6.60	-3.61	-0.81	0.00	-2.18
1974	1.41	-0.15	-0.32	0.00	-0.94
1975	4.95	-3.80	-3.48	0.49	1.84
1976	-2.05	-6.75	2.94	0.00	5.85
1977	6.57	-7.44	-5.80	-0.09	6.75
1978	7.92	-7.06	-5.37	0.10	4.41
1979	-3.29	-3.12	4.29	0.17	1.96
1980	2.50	-2.97	-1.12	0.02	1.58
1981	2.63	-2.84	-0.59	0.25	0.54
1982	-0.07	-2.71	2.34	0.03	0.41
1983	3.38	-1.61	-2.76	0.03	0.96
1984	1.08	-1.57	0.01	0.00	0.49
1985	4.09	-1.54	-0.91	0.11	-1.75
1986	-4.25	-1.50	5.41	0.09	0.26
1987	-3.57	-0.89	10.62	1.93	-8.09
1988	7.56	-0.89	-0.56	1.97	-8.09
AVERAGE	2.24	-3.16	0.61	0.19	0.13
PER RAI	1.00	-1.41	0.27	0.08	0.06

Appendix C: Cumulative Deforestation Effects

Deforestation has two effects on agricultural output or income: (1) output gain from agricultural land expansion, and (2) output loss from environmental damages of deforestation. The calculation procedure of the deforestation effects are divided into five steps:

1. Calculate output or income gain from one rai of agricultural land expansion.
2. Convert that income gain per one rai of cultivated land to one rai of forest loss.
3. Calculate the output or income loss from one rai of deforestation.
4. Calculate the net gain of loss of one rai of deforestation is calculated.
5. Repeat step 1 to 4 for the cumulative deforestation for different time periods.

Tables C1 to C4 report the cumulative deforestation effects of four different time periods: 1987, 1984, 1980, and 1978.

Table C1 Cumulative Deforestation Effects, 1987

BENEFIT FROM ONE RAI OF CULTIVATED LAND EXPANSION

YEAR	LAND	10 %	GDP-AG	GDP GAIN	GAIN/RAI	GAIN/FRAI
1962	53.68	5.37	27,424	1307.55	243.58	152.24
1963	55.23	5.52	29,886	1424.95	258.02	161.26
1964	56.57	5.66	29,978	1429.34	252.66	157.91
1965	58.37	5.84	30,875	1472.10	252.21	157.63
1966	66.59	6.66	35,494	1692.34	254.16	158.85
1967	63.22	6.32	33,846	1613.77	255.25	159.53
1968	66.43	6.64	36,909	1759.80	264.90	165.56
1969	70.38	7.04	39,641	1890.08	268.55	167.84
1970	71.68	7.17	42,064	2005.59	279.80	174.87
1971	72.44	7.24	43,875	2091.93	288.79	180.50
1972	73.53	7.35	43,130	2056.41	279.68	174.80
1973	80.13	8.01	47,201	2250.51	280.87	175.54
1974	81.54	8.15	48,577	2316.12	284.05	177.53
1975	86.48	8.65	50,700	2417.34	279.51	174.69

1976	84.44	8.44	53,764	2563.43	303.59	189.74
1977	91.01	9.10	55,000	2622.37	288.13	180.08
1978	98.94	9.89	61,856	2949.26	298.10	186.31
1979	95.64	9.56	60,726	2895.38	302.72	189.20
1980	98.14	9.81	61,750	2944.20	300.00	187.50
1981	100.78	10.08	65,093	3103.59	307.97	192.48
1982	100.70	10.07	67,082	3198.43	317.61	198.51
1983	104.08	10.41	70,061	3340.46	320.96	200.60
1984	105.15	10.52	73,977	3527.18	335.43	209.64
1985	109.24	10.92	78,539	3744.69	342.79	214.24
1986	104.99	10.50	78,775	3755.94	357.75	223.60
1987	101.42	10.14	78,666	3750.75	369.84	231.15
AVERAGE					291.80	182.38

DAMAGED FROM ONE RAI OF FOREST LOSS

YEAR	FLOSS	10 %	GDP-AG	GDP LOSS	LOSS/RAI
1962	55.89	5.59	27,424	1213.66	217.15
1963	58.60	5.86	29,886	1322.62	225.69
1964	61.51	6.15	29,978	1326.70	215.70
1965	64.27	6.43	30,875	1366.39	212.59
1966	67.97	6.80	35,494	1570.81	231.10
1967	71.72	7.17	33,846	1497.89	208.84
1968	75.40	7.54	36,909	1633.43	216.63
1969	79.11	7.91	39,641	1754.35	221.77
1970	82.79	8.28	42,064	1861.56	224.86
1971	86.33	8.63	43,875	1941.71	224.92
1972	89.88	8.99	43,130	1908.74	212.36
1973	93.50	9.35	47,201	2088.90	223.42
1974	93.65	9.36	48,577	2149.80	229.57
1975	97.44	9.74	50,700	2243.75	230.27
1976	104.19	10.42	53,764	2379.35	228.36
1977	111.63	11.16	55,000	2434.05	218.05
1978	118.69	11.87	61,856	2737.47	230.64
1979	121.81	12.18	60,726	2687.46	220.62
1980	124.79	12.48	61,750	2732.78	219.00
1981	127.62	12.76	65,093	2880.72	225.72
1982	130.33	13.03	67,082	2968.75	227.79
1983	131.94	13.19	70,061	3100.58	235.01
1984	133.51	13.35	73,977	3273.89	245.22
1985	135.05	13.50	78,539	3475.78	257.38
1986	136.55	13.65	78,775	3486.23	255.31
1987	137.44	13.74	78,666	3481.40	253.31
AVERAGE					227.36

Table C2 Cumulative Deforestation Effects, 1984

BENEFIT FROM ONE RAI OF CULTIVATED LAND EXPANSION

YEAR	LAND	10 %	GDP-AG	GDP GAIN	GAIN/RAI	GAIN/FRAI
1962	53.68	5.37	27,424	1210.92	225.58	149.39
1963	55.23	5.52	29,886	1319.63	238.95	158.24
1964	56.57	5.66	29,978	1323.70	233.99	154.96
1965	58.37	5.84	30,875	1363.30	233.57	154.68
1966	66.59	6.66	35,494	1567.26	235.37	155.88
1967	63.22	6.32	33,846	1494.50	236.39	156.55
1968	66.43	6.64	36,909	1629.74	245.33	162.47
1969	70.38	7.04	39,641	1750.39	248.70	164.70
1970	71.68	7.17	42,064	1857.36	259.12	171.60
1971	72.44	7.24	43,875	1937.32	267.45	177.12
1972	73.53	7.35	43,130	1904.43	259.01	171.53
1973	80.13	8.01	47,201	2084.18	260.11	172.26
1974	81.54	8.15	48,577	2144.94	263.06	174.21
1975	86.48	8.65	50,700	2238.68	258.85	171.43
1976	84.44	8.44	53,764	2373.98	281.15	186.19
1977	91.01	9.10	55,000	2428.55	266.84	176.71
1978	98.94	9.89	61,856	2731.28	276.06	182.82
1979	95.64	9.56	60,726	2681.39	280.35	185.66
1980	98.14	9.81	61,750	2726.60	277.83	183.99
1981	100.78	10.08	65,093	2874.21	285.21	188.88
1982	100.70	10.07	67,082	2962.04	294.14	194.79
1983	104.08	10.41	70,061	3093.58	297.24	196.84
1984	105.15	10.52	73,977	3266.49	310.64	205.72
AVERAGE					264.06	174.88

DAMAGED FROM ONE RAI OF FOREST LOSS

YEAR	FLOSS	10 %	GDP-AG	GDP LOSS	LOSS/RAI
1962	55.89	5.59	27,424	876.23	156.78
1963	58.60	5.86	29,886	954.90	162.94
1964	61.51	6.15	29,978	957.84	155.73
1965	64.27	6.43	30,875	986.49	153.48
1966	67.97	6.80	35,494	1134.08	166.84
1967	71.72	7.17	33,846	1081.43	150.78
1968	75.40	7.54	36,909	1179.29	156.40
1969	79.11	7.91	39,641	1266.59	160.11
1970	82.79	8.28	42,064	1344.00	162.34
1971	86.33	8.63	43,875	1401.86	162.39
1972	89.88	8.99	43,130	1378.06	153.32
1973	93.50	9.35	47,201	1508.13	161.31

1974	93.65	9.36	48,577	1552.09	165.74
1975	97.44	9.74	50,700	1619.93	166.25
1976	104.19	10.42	53,764	1717.83	164.87
1977	111.63	11.16	55,000	1757.32	157.42
1978	118.69	11.87	61,856	1976.37	166.52
1979	121.81	12.18	60,726	1940.27	159.29
1980	124.79	12.48	61,750	1972.99	158.11
1981	127.62	12.76	65,093	2079.80	162.97
1982	130.33	13.03	67,082	2143.35	164.46
1983	131.94	13.19	70,061	2238.53	169.67
1984	133.51	13.35	73,977	2363.66	177.04
AVERAGE					161.51

Table C3 Cumulative Deforestation Effects, 1980

BENEFIT FROM ONE RAI OF CULTIVATED LAND EXPANSION

YEAR	LAND	10 %	GDP-AG	GDP GAIN	GAIN/RAI	GAIN/FRAI
1962	53.68	5.37	27,424	1320.94	246.07	164.05
1963	55.23	5.52	29,886	1439.54	260.66	173.77
1964	56.57	5.66	29,978	1443.98	255.25	170.17
1965	58.37	5.84	30,875	1487.17	254.80	169.86
1966	66.59	6.66	35,494	1709.67	256.76	171.17
1967	63.22	6.32	33,846	1630.30	257.86	171.91
1968	66.43	6.64	36,909	1777.82	267.62	178.41
1969	70.38	7.04	39,641	1909.44	271.30	180.87
1970	71.68	7.17	42,064	2026.12	282.66	188.44
1971	72.44	7.24	43,875	2113.36	291.75	194.50
1972	73.53	7.35	43,130	2077.47	282.55	188.37
1973	80.13	8.01	47,201	2273.56	283.75	189.16
1974	81.54	8.15	48,577	2339.84	286.96	191.31
1975	86.48	8.65	50,700	2442.10	282.37	188.25
1976	84.44	8.44	53,764	2589.69	306.70	204.46
1977	91.01	9.10	55,000	2649.22	291.08	194.06
1978	98.94	9.89	61,856	2979.46	301.15	200.77
1979	95.64	9.56	60,726	2925.03	305.82	203.88
1980	98.14	9.81	61,750	2974.35	303.07	202.05
AVERAGE					280.12	186.74

DAMAGED FROM ONE RAI OF FOREST LOSS

YEAR	FLOSS	10 %	GDP-AG	GDP LOSS	LOSS/RAI
1962	55.89	5.59	27,424	871.94	156.01
1963	58.60	5.86	29,886	950.23	162.15
1964	61.51	6.15	29,978	953.16	154.97
1965	64.27	6.43	30,875	981.67	152.73
1966	67.97	6.80	35,494	1128.54	166.03
1967	71.72	7.17	33,846	1076.14	150.04
1968	75.40	7.54	36,909	1173.52	155.64
1969	79.11	7.91	39,641	1260.40	159.33
1970	82.79	8.28	42,064	1337.43	161.55
1971	86.33	8.63	43,875	1395.01	161.60
1972	89.88	8.99	43,130	1371.32	152.57
1973	93.50	9.35	47,201	1500.76	160.52
1974	93.65	9.36	48,577	1544.51	164.93
1975	97.44	9.74	50,700	1612.01	165.43
1976	104.19	10.42	53,764	1709.43	164.06
1977	111.63	11.16	55,000	1748.73	156.65
1978	118.69	11.87	61,856	1966.71	165.70
1979	121.81	12.18	60,726	1930.78	158.51
1980	124.79	12.48	61,750	1963.34	157.34
AVERAGE					159.25

Table C4 Cumulative Deforestation Effects, 1978

BENEFIT FROM ONE RAI OF CULTIVATED LAND EXPANSION

YEAR	LAND	10 %	GDP-AG	GDP GAIN	GAIN/RAI	GAIN/FRAI
1962	53.68	5.37	27,424	1331.42	248.02	189.33
1963	55.23	5.52	29,886	1450.95	262.72	200.55
1964	56.57	5.66	29,978	1455.43	257.27	196.39
1965	58.37	5.84	30,875	1498.97	256.82	196.04
1966	66.59	6.66	35,494	1723.22	258.80	197.56
1967	63.22	6.32	33,846	1643.23	259.91	198.40
1968	66.43	6.64	36,909	1791.92	269.74	205.91
1969	70.38	7.04	39,641	1924.58	273.45	208.74
1970	71.68	7.17	42,064	2042.19	284.91	217.49
1971	72.44	7.24	43,875	2130.11	294.07	224.48
1972	73.53	7.35	43,130	2093.94	284.79	217.40
1973	80.13	8.01	47,201	2291.59	286.00	218.32
1974	81.54	8.15	48,577	2358.39	289.24	220.79
1975	86.48	8.65	50,700	2461.46	284.61	217.26

1976	84.44	8.44	53,764	2610.22	309.13	235.98
1977	91.01	9.10	55,000	2670.23	293.39	223.96
1978	98.94	9.89	61,856	3003.08	303.54	231.71
AVERAGE					279.27	213.19

DAMAGED FROM ONE RAI OF FOREST LOSS

YEAR	FLOSS	10 %	GDP-AG	GDP LOSS	LOSS/RAI
1962	55.89	5.59	27,424	1002.55	179.38
1963	58.60	5.86	29,886	1092.56	186.43
1964	61.51	6.15	29,978	1095.93	178.18
1965	64.27	6.43	30,875	1128.71	175.61
1966	67.97	6.80	35,494	1297.58	190.90
1967	71.72	7.17	33,846	1237.34	172.52
1968	75.40	7.54	36,909	1349.30	178.95
1969	79.11	7.91	39,641	1449.19	183.19
1970	82.79	8.28	42,064	1537.76	185.75
1971	86.33	8.63	43,875	1603.96	185.80
1972	89.88	8.99	43,130	1576.73	175.42
1973	93.50	9.35	47,201	1725.55	184.56
1974	93.65	9.36	48,577	1775.86	189.63
1975	97.44	9.74	50,700	1853.47	190.21
1976	104.19	10.42	53,764	1965.48	188.64
1977	111.63	11.16	55,000	2010.67	180.12
1978	118.69	11.87	61,856	2261.30	190.52
AVERAGE					183.28

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