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Agricultural Expansion and Forest Depletion in Thailand, 1900-1975

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ABSTRACT

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The paper examines the extent and causes of deforestation in Thailand. A major cause of deforestation has been the expansion of the area under cultivation, especially in the post-World War II period. The reliability of the Thai agricultural statistics is assessed in order to obtain rough estimates of the area under cultivation. The data appear to capture trends much more accurately than levels. Direct evidence on the forest area and forestry production is also examined and compared to the area under cultivation estimates.

The evolution of Thai forest and conservation policy is traced. The problems associated with the open access nature of Thai forest lands and the downstream externalities caused by forest clearing are highlighted. Major institutional changes in the property rights system and forestry policy appear to be needed in order to more closely align private and social rates of return on forest activities.

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Deforestation has become an important issue in Thailand. It has been associated with soil erosion, siltation, flooding, and the depletion, and in some cases extinction, of wildlife species. Flooding in the lower Central Plain and droughts have focused attention on conditions in the northern watershed areas. Population pressure, shifting cultivation, the harvest of forest products for both domestic and international markets, opium production, and the expansion in the area in upland crops in response to new export opportunities are all said to play an important role in accounting for the depletion of forests in Thailand.

While the issue of deforestation in Thailand is timely, it is not new. In order to provide some tentative explanations of the causes and consequences of deforestation in Thailand, the paper will exploit the quantitative records on the area under cultivation and forest product production. In the process an imprecise record of the extent of deforestation over the twentieth century in Thailand will be established.

Increases in the area under cultivation have been the primary factor responsible for the growth in agricultural output and export in Thailand. This generalization appears to be valid for the nineteenth and first half of the twentieth centuries. Only recently have increases in productivity begun to play a more important role in accounting for output growth.

Output growth, thus, occurred largely through deforestation. In the first section of the paper rough estimates of the rate of expansion of the area under cultivation are derived. In the second section some of the direct evidence on forestry production is briefly described. Forestry policy and the evolution of concern about forest depletion in Thailand are examined in Section III. Finally conclusions are provided in Section IV.

Section I: Estimates of the Growth in the Area Under Cultivation

Because most of the area currently under cultivation in Thailand was once covered by forests, especially outside of the lower Central Plain, one approach to measuring the extent of forest cover in Thailand is to measure the rate of expansion of the area under crops. Thus the reliability and completeness of the Thai agricultural statistics need to be assessed.

A description of the methods of collection and assessment of the Thai agricultural statistics is provided in the Appendix. The rice balance sheet estimates provided there point to a significant underestimation of the area under paddy cultivation over the 1906-55 period. It is likely that underestimation of the area in other crops was even more substantial. This conclusion, when combined with the omission of area estimates for many crops (see Appendix), indicates that the major crop area series presented in Table A1 significantly understates the area under cultivation in Thailand. The trend in the area under cultivation is, however, likely to have been captured in a roughly accurate way. Even though the degree of under-reporting of the crops included probably decreased somewhat over time, the overall trend is basically reliable, even if the levels are not. Behrman reached much the same conclusion in his analysis of the Ministry of Agriculture production data for the 1937-63 period. He states that the rice estimates are probably the most reliable and that "the estimates generally are much better indicators of trends than of absolute levels."[1]

Table 1 presents various estimates of the rate of growth of

the area under cultivation for the 1906-55 period and selected sub-periods. It would appear as if the area under cultivation grew at roughly 3 percent per year over this period. Much of the expansion of the area under cultivation outside of the Chao Phya river delta occurred through deforestation. As for the delta itself, while much of its vegetation was already secondary, the expansion of the area under cultivation still resulted in forest and shrub clearing.[2] Slash and burn cultivation was often practiced by new settlers to provide initial subsistence and clear the land in order to make it suitable for broadcast paddy cultivation or other crops.[3]

"Table 1 about here"

For the period since 1950, data on the cropped area for a number of crops is available. Furthermore, there are multiple sources of data including Ministry of Agriculture reports, the agricultural censuses, and the National Statistical Office crop-cutting surveys. More recently aerial photography and satellite imagery surveys have been conducted. A number of observers have examined the quality of the data and established adjustments to the official Ministry of Agriculture series that correct for some of the major discrepancies.

While the quality of the data for the more recent period is improved, there is still substantial disagreement among the major sources. Ministry of Agriculture estimates of the area under crops are consistently below estimates derived from surveys of agricultural holdings which in turn appear to underestimate the "true" area in use. Satellite imagery and aerial photography survey estimates in turn consistently exceed those given by the other two methods, but also tend

to overestimate the area in use.[4]

Table 2 presents data on the total (harvested) area and harvested paddy area for the 1950 through 1975 period. The data are taken from Damrongsak and have the advantage of incorporating a number of reasonable adjustments to the official data designed to remove known inaccuracies. In his growth accounting study of Thai agricultural change over this period Damrongsak concluded that technical progress accounted for between 26.8 and 38.2 percent of output growth over the 1950 through 1976 period, depending on the method of estimation used to estimate the aggregate agricultural production function.[5] The technical progress variable captures technical progress as well as the effects of improvements in input quality, management, irrigation, education, extension, and the regional specialization and diversification trends which were important over this period. If technical progress accounted for 26.8 percent of output growth, then the growth of land, labor, and capital would have accounted for 25.0, 27.4, and 20.8 percent respectively. Similarly, if technical progress accounted for as much as 38.2 percent of output growth, then land, labor, and capital input growth accounted for 20.1, 21.4, and 20.4 percent respectively. Thus, unlike the earlier period, the growth of output is not primarily accounted for by the growth of land and labor inputs. Whereas in the earlier period (see Table 1) area grew faster than output, in the 1950 to 1976 period, the reverse was true.

"Table 2 about here"

The rate of growth of the total area under cultivation was, however, approximately as rapid as in the 1906-1955 period, around 3

percent per year (see Table 3). Splicing together the relatively more complete coverage for the period since 1950 with the less complete earlier coverage, the total area under cultivation appears to have grown at roughly 3.4 percent per year (see Table 3). This figure tends to overestimate the area growth because the degree of coverage increased over time.[6] Thus it may be regarded as an upper bound estimate. Perhaps the roughly 3 per cent per year figure is more reliable for the whole period.

"Table 3 about here"

In the post-World War II period the dominance of paddy cultivation in Thai agriculture has declined and the relative importance of new export crops such as maize, kenaf, cassava, and other crops has grown. Much of the growth in the production of these upland crops has come at the direct expense of forest land. While a significant portion of the rapid expansion in the area under paddy cultivation in the pre-World War II period was concentrated in the lowland areas of the Central Plain that were less heavily forested, much of the expansion in the post-World War II period took place in formerly wooded areas.[7] As in the past, abundant land and favorable external markets have been the source of much of the growth in agricultural output. Growth by clearing continues into the present.

Forest depletion has, thus, largely occurred as a result of the clearing of land for cultivation in response to economic incentives for commercial agriculture and/or subsistence production. Favorable prices and population growth underwrote the rapid expansion of paddy production in the nineteenth and first half of the twentieth centuries.

The favorable markets for upland crops and even more rapid rates of population growth underwrote a continuation of the process of forest clearing for agricultural cultivation in the post-World War II period. Malaria eradication programs further contributed to forest depletion by making previously infested areas safer for cultivation and augmenting the rate of growth of population, thus leading to more clearing for both commercial and subsistence production. Commercial forestry as well as harvesting for local use (to be discussed below) have further contributed to forest depletion.

Section II: Evidence on Forest Area and Production

The estimates of the expansion of the area under cultivation presented in Section I are indirect evidence on the rate of forest clearing. Fragmentary data are also available on the forested area, timber cutting, timber exports, the production of major forest products, the export of forest products, and government timber royalty revenues. We will focus on the first three.

A very rough idea of the rate of forest clearing can also be obtained by piecing together various estimates of the percent of the total area of Thailand (modern boundaries) covered by forests. Some of the estimates are based on land-use surveys, some on more systematic aerial photography or satellite imagery surveys, and a number are just guesses made by well-informed observers. A sample of the estimates is presented in Table 4. It appears that in the early part of this century, forests covered around 70 percent of Thailand, but that the proportion had fallen to 50 or 60 percent by the 1960s and to roughly 40 percent by the mid-1970s. Today less than 30 percent of the area remains in forests. Depending on the benchmark estimate accepted for 1974 or 1975, the area under forests has declined by 1.43 to 1.18 percent per year in the 1930 through 1974 or 1975 period.

"Table 4 about here"

The changes in the area under forests are compared to the changes in the area under crops in Table 5. It appears that increases in the area under cultivation account for an increasing proportion of the decline in the forested area over time. This result is consistent with the increasing importance of upland crops and concentration of the

expansion in the area under cultivation in areas outside of the lowlands of the Central Plain.

"Table 5 about here"

The longest time series data on timber cutting are for teak which is produced in northern Thailand (see Table 6). Incompleteness due to illegal cutting is a serious deficiency in the timber cutting data and one that is especially important for a valuable species like teak. A stump inventory conducted in six northern provinces covering the 1937 to 1956 period concluded that illegal cutting was 148.6 percent of the legal cut in those provinces.[8] Other observers indicate that the total teak cut is three times the legal cut.[9] Teak production data problems are further confounded by the fact that some of the production is floated to market via the Salween river, some via the Mekong river, and some via the Chao Phya river, the most popular route and the one for which the data is the most accurate and complete.[10] Because the first two routes become much less important over time, the data presumably become more complete and accurate.

"Table 6 about here"

While the industry was initially export-oriented, over time production has increasingly been destined for domestic use. The quantity of teak exports peaked in 1905-1909 and since then teak exports have declined in absolute terms and as a share of the value of total exports. Teak also accounts for a declining fraction of the volume of recorded timber production, falling from roughly 34 percent in 1932-1936 to around 11 percent by 1970-1973 and less than 7 percent in 1974-1978.

Teak production grew rapidly with the entry of European

companies after the closure of the upper Burma forests in 1885.[11] Timber stocks were rapidly depleted and in 1896 the Royal Forest Department was created specifically to regulate teak cutting. Experiments with teak plantations were begun as early as 1906 and the taungya method was introduced in 1942. Starting in the immediate post-World War II period efforts to replace foreign timber companies with indigenous firms and the government's own Forest Industry Organization were begun. After 1952 no new leases were issued to foreign firms and by 1960 the foreign concessionaires had been eliminated. The continued depletion of teak stocks led to an increase in the export duty on teak from 10 percent to 40 percent and lowering of the import duties on timber to 10 percent in the mid-1960s. A teak export ban in late 1977 followed alarming stock estimates based on satellite images.[12]

Because teak grows in isolated pockets in the forest, its production trends are not an accurate proxy for deforestation resulting from overall forestry production. Fortunately, Royal Forest Department data on non-teak timber and other forest product production are available for the period from 1932 to the present (see Table 6). The data are clearly incomplete, omitting a large amount of illegal cutting and the harvesting of timber and other forest products for home use. Use surveys indicate that overall forest production is probably three to four times the level indicated in the official estimates. Thus it is likely that, as in the case of teak, the official production estimates significantly understate the actual level.

Traditionally Thai farmers have collected timber for construction, firewood, and other forest products from nearby forests.

Production for home-use is undercounted in the official estimates. The Royal Forest Department firewood and charcoal estimates shown in Table 6 primarily reflect production for use by the major commercial consumers of these products, the railway and the tobacco curing and ceramics industries.

In addition to the production of teak, firewood, and charcoal, Thai forest production includes yang wood, yang oil, rosewood, boxwood, sapanwood, ebony, other woods, rattan canes, bamboo, cardamons, sticklac, resins, gambodge, attap palm, tanning bark, wood oils, and pulp.[13] The two major forest types are mixed deciduous and evergreen.[14]

Section III: The Evolution of Thai Forest Conservation Policy

Modern Thai forestry policy begins with the commercial exploitation of the northern teak forests in the late nineteenth century. The creation of the Royal Forest Department in 1896 and passage of the Forest Protection Act of 1897 resulted from the commercialization. While the conservation of timber stocks helped to motivate the creation of the forest department, the introduction of controls also involved a transfer of the administration of the northern forests from the local Lao chiefs to the central government in Bangkok and an enhancement of the central government's revenue base.[15] The Royal Forest Department gradually introduced and tightened regulations on leases, felling cycles, minimum girth requirements, and replanting. The focus was on the regulation of commercial exploitation and the approach was patterned after that taken by the forest departments in India and Burma from which the Thai government recruited foreign experts to help in the creation of its forest service. The impact of British policy and practice was further enhanced because many Thai foresters in the pre-World War II period attended forestry colleges in India or Burma.

Under a 1913-14 decree forest species were divided into reserved and unreserved.[16] Reserved species (such as teak and yang) could only be legally cut if a license had been obtained and fee paid. The decree did, however, allow for free permits for cutting for home or charitable use. Under provisions of a 1948 act, households residing near forest areas were allowed to cut up to 26 m^3 per person for use in construction of their homes. Not unexpectedly, many farmers in northern

Thailand regularly built sturdy houses with extra-large house posts and then sold the house to timber merchants and started all over again after several years had passed. While the 1960 Forest Act repealed that provision, a "loophole" in the 1941 and 1960 Forest Acts allows households to legally possess up to $0.2m^3$ of lumber destined for domestic use. Harvesting for domestic and even commercial purposes has continued through this provision of the law.

The importance of such home-use production is evident in data collected by the 1953 farm survey. For the whole kingdom, 89.9 percent of farm families cut wood for home use, 3.6 percent earned income through the sale of wood, and the value of fuel wood cut for home use represented 8.1 percent of the value of total farm production.[17]

While the Forest Protection Act of 1897 and the 1913-14 decree focused on the regulation of commercial forestry, conservation issues were discussed within official circles as early as the 1910s. In 1916 the forestry department first proposed that national forest reserves be created in Thailand as they already had been in a number of other countries.[18] In the 1920s Graham argued that conservation was still not adequately appreciated and that forestry policy concentrated too heavily on exploitation.[19]

In the 1930s Thai forest legislation began to reflect a broader concern with the conservation of forests that extended beyond the regulation of teak cutting. The Forest Reservation Act of 1936/37 allowed the government to designate reserve and protected forests.[20] Additional legislation in 1939, 1941, 1944, 1948, 1951, 1953, and 1954 further enhanced the ability of the government to preserve forest and

watershed areas.[21] (These acts were later replaced by the National Reserved Forest Act of 1964). Writing in 1941 Thompson concluded that, "Siam is just beginning to appreciate the importance of permanent forests in relation to climate and rainfall."[22]

By the early 1950s a goal of at least 50 percent of the area of Thailand as forest reserves had been set. While there was little discussion of exactly how the specific target was decided upon, the general motivation was the desire to preserve basic soil, water, and wildlife resources.[23] The target was incorporated into the 1959 World Bank report on Thailand and the First Five Year Plan (1961-66).[24] Continued deforestation resulted in a downward revision of the target. The goal reported in the Fourth Plan (1977-1981) was 37 percent.[25]

Wildlife preservation legislation began with the Wildlife Elephant Preservation Act of 1900 and a subsequent 1921 law on wild elephants. In 1933 a wildlife preservation act was drafted but enactment was delayed for 27 years.[26] 1942 and 1953 decrees were designed to protect bird nesting sites. Finally, in 1950 the Association for the Conservation of Wildlife was formed and in 1960 and 1964 major legislation on wildlife conservation was passed.[27]

Conservation provisions were also contained in the 1901 Mining Act (and its 1967 replacement). Other relevant conservation provisions were contained in land settlement legislation. The National Park Act was passed in 1961.

In sum, the scope of Thai forest and related conservation legislation gradually evolved from an initial narrow focus on the regulation of commercial teak cutting to a broader concern with

conservation issues that became evident over the period from the 1930s through the 1950s. By the early 1960s the earlier concerns culminated in the passage of more comprehensive legislation on forest, park, and wildlife preservation.

Under the forest legislation briefly described above virtually all forests in Thailand are publicly owned and their exploitation is supposed to be regulated by permits issued by the Royal Forest Department. In spite of the provisions for obtaining permits for domestic use, there is considerable tension between the traditional Thai villager's view of forests and forest products as common property resources and official government policy.[28] Villagers resent the cumbersome procedures and expenses (both formal and informal) involved in obtaining permits to legally harvest timber and often circumvent them. Circumvention is especially common in officially reserved forest areas where villagers frequently harvest timber and clear land for cultivation. These activities are often in fact accommodated after the fact by the local administration officials of the Ministry of Interior who issue land registration documents and provide social services in the newly settled areas. Reportedly villagers tend to avoid encroachments on officially unreserved forest areas, feeling that they are the "property" of influential persons and therefore violations will be detected and violators punished.[29] Several observers have called for the creation of small forests managed by local governments for local use and the promotion of private woodlots.[30]

The conservation of forests and preservation of important watershed areas have been frequently articulated goals in Thailand over

the last several decades. Observers argue that forests protect soil fertility, reduce erosion, regulate the water supply, retard salination, reduce silting and flooding, and preserve groundwater supplies.[31] The forest destruction of the last fifty years has resulted in a serious deterioration in basic soil, forest, and water resources as well as a depletion of wildlife.[32] Many observers have been critical of government efforts to restrict forest cutting and curtail swidden cultivation.[33] Strict enforcement of forestry department production quotas would lower production from over 2 million cubic meters per year to 1.6 million.[34]

Increasing concern over the effects of swidden cultivation on soil, water, and forest resources has also been expressed. The problem is especially acute in northern Thailand where hill tribesmen and lowland Thais compete for the use of hill slopes.[35] The Asian Development Bank estimates that roughly 1.5 million people in Thailand (especially in the north, west, and northeast) depend regularly on swidden cultivation, clearing 500,000 ha each year.[36] Swidden cultivation results in a destruction of primary forests and interruption of secondary growth, often resulting in the growth of grasslands, soil erosion, flooding, and groundwater shortages. Watershed planning and bans on swidden cultivation at middle elevations and on virgin forest land have been proposed. A broad range of solutions including research on forestry and alternate uplands crops, plantations and wage labor opportunities, and developments in the property rights system are needed to bring swidden cultivation in Thailand under control and integrate it with sound national land-use policy.[37]

The discussions of the importance of forest conservation are,

however, not new. Discussions and recommendations made in the pre-World War II period are very similar to those made more recently. By the 1930s irrigations officials were already concerned over the effects of swidden cultivation in the hill districts on siltation, flooding, and the regulation of water flows.[38] As in the cases of irrigation and agricultural research policy debates in Thailand, there is a great deal of continuity between the interwar and post-World War II periods.[39] Concern over deforestation and other environmental problems has, however, become much more widespread in Thailand, especially in the last decade.

While there has been a marked change in Thai conservation policy and in the awareness of ecological and environmental problems, there appear to have been relatively few serious examinations of the socially optimal use of land in Thailand. In addition, while the major and minor causes of forest depletion may be enumerated and their consequences discussed, it is not possible on the basis of the shaky evidence available to partition the historical pattern of forest depletion among its causes and decide how much of the depletion is due to each factor and the interactions among them.

Forest depletion in Thailand has occurred because it was privately profitable. Private returns to land clearing for commercial and/or subsistence production were sufficient to underwrite a large expansion in the area under cultivation. The expansion was, of course, in part fueled by rapid rates of population growth. Private returns drove clearing in both lowland and upland areas, both for settled and shifting cultivation. Growth in domestic and foreign demand

(decreasingly important over time) made timber cutting and the harvesting of forest products privately profitable, especially when public forest resources could be exploited for only nominal fees (formal and/or informal). These processes were facilitated by lax enforcement of the existing legislation, the exemptions and provisions in the legislation itself, and the inefficiencies inherent in the administration of forest lands in Thailand.[40]

From a contemporary perspective it now appears that forest depletion in Thailand has probably gone too far or at least far enough. That conclusion is, however, impressionistic and is not based on comprehensive or rigorous evidence. But in the earlier periods during which Thailand was a land abundant, forest abundant, and labor scarce country, growth through clearing was quite reasonable and contributed significantly to the impressive growth in per capita Thai incomes experienced by virtually all classes. Land was being converted from forest cover to higher value uses.

The crucial issues today are the optimal rate of exploitation of timber and the optimal path and extent of the conversion of forest land to other uses. In contemporary Thailand the impressionistic evidence indicates that timber is typically harvested at a rate that exceeds the socially optimal rate of exploitation and that some forest land which should not be converted to other uses is in fact rapidly being converted.

These trends occur because there are two sets of divergences between the private profitability of land clearing and forest production and the social rate of return on those activities. First there is a

divergence caused by the open and free access resource nature of Thai public lands and their management. Second there is a divergence arising because some of the costs of clearing and harvesting are not borne by the agents who reap the direct benefits, causing them to overexploit the resource from the socially optimal point of view.

While the legislation described above indicates that forests are public property subject to regulation by the forestry department, the actual pattern of practices admits many exceptions, both legal and illegal. Under the 1954 Land Code all areas not claimed within 180 days of the passage of that act became property of the government. Provincial governors, however, have the power to allow villagers to continue to file claims for newly cleared areas and have routinely continued to do so. Thus local administration officials who are under the Ministry of Interior have allowed local practice to override national conservation policy. Timber cutting by villagers is another example; because villagers do not own the forest and cannot exclude others from using it, they have little incentive to conserve and every incentive to capture the gains from cutting before someone else does. In addition there is widespread evasion of forestry regulations. Both large and small scale commercial operators exploit publicly managed forest resources for private gain. In all of these cases deficiencies in the property rights system and its administration and enforcement mean that private parties have incentives to overuse the forest resource.

The second divergence arises through a set of negative externalities. Part of the costs of land clearing are borne downstream

through erosion, silting, and flooding. As population density downstream has risen and the number of people affected by flooding has increased, the marginal social cost of the clearing of forest lands has risen over time. The costs of land clearing or forest production also include the depletion of the genetic pool as various flora and fauna become increasingly rare. An intergenerational externality may arise in that the current population may insufficiently take into account the interests of future generations. An externality also arises because forests are also valued for aesthetic and recreational uses as well as for income generation purposes.

In contemporary Thailand the erosion and flooding externality is probably the most important one, although we lack rigorous evidence on the magnitude of any of these externalities. In spite of the depletion of forests that has accompanied the increasing population density, it still may be true that the highest social value of land use in Thailand is crop cultivation rather than forest cover, except for the ridge tops and steepest slopes. The rise in population density increases the relative scarcity of both forest and crop lands.[41]

Four policy implications follow. First, institutional changes are needed to redesign the property rights system and its application to reduce (subject to transaction cost) the first divergence. Second, institutional changes are needed to alter private incentives so that private parties are faced with returns that better approximate the social returns. Third, because clearing occurs because it is privately profitable, the generation of more lucrative opportunities in intensified agriculture and industrial employment is crucial in reducing

the rate of forest depletion.[42] Both the carrot and the stick are needed. Finally, once legislation and institutions reflect a careful consideration of the factors that determine the socially optimal rate of forest use, more efficient and effective enforcement mechanisms will be needed. The probability of detecting violations will have to be high enough and penalties heavy enough to discourage socially suboptimal illegal uses. Charlermrath has suggested that one agency (a merger of various forestry, police, and other agencies concerned with land use), a Ministry of Natural Resources and Environmental Protection, be established to create the bureaucratic incentives for vigorous enforcement.[43]

Section IV: Conclusions

The clearing of land for cultivation, the cutting of forests for timber, and the collection of forest products all contribute significantly to forest depletion in all regions in Thailand. The relative importance of the factors does, however, vary considerably across the regions. In the North legal and illegal forest cutting, the extension of the area under cultivation, and shifting the cultivation all seriously threaten the forest ecology. In the Northeast the extension of the area under cultivation may play a relatively more important role with forest cutting contributing significantly as well. In the South rubber cultivation and mining activities appear to play the leading roles. There is considerable regional diversity and an examination of the trends and causes within each region is an important item for the research agenda.

In Thailand the conservation problems posed by the harvesting of forest products by rural dwellers for their own use are exacerbated by the even more serious deforestation problems posed by shifting cultivation, illegal commercial timber operations, and land clearing for the extension of the area under cultivation. These processes often interact and have been intensified through the expansion of the highway network. Land on which illegal timber operations have been conducted is often further cleared through the gathering of firewood and timber by the local population and finally completely cleared for cultivation. Intensification of the cultivation of already cleared areas, the enhancement of the economic incentives for more intensive cultivation, research on improved agricultural practices (especially for rain-fed areas), institutional changes to improve the efficiency of the irrigation system and further intensify cultivation, the promotion of replanting, the more rapid issuing of title deeds on legally cleared land, the privatization of some forest lands, restrictions of the growth in the capacity of the sawmilling industry, the promotion of taungya plantations in hill areas, the promotion of conservation education, tighter enforcement of existing legislation, the simplification of existing forestry regulations that apply to villagers, the curtailment of the cultivation of opium and swidden cultivation, more intensive forest management, and the development of a realistic comprehensive forestry policy have all been suggested as steps towards solving Thailand's increasingly serious conservation problems.[44]

In sum, a primary source of the growth in Thai agricultural output has been an expansion of the area under cultivation. Growth by

clearing was especially important in the 1900-1950 period, but continues to play a very important role. As a result, large forest areas have been cleared and forest, soil, and water resources have been depleted. The problem is especially acute in northern Thailand.

Awareness of conservation problems has been apparent for over 60 years and has grown over time. Deficiencies in policy, management, and enforcement, however, have persisted and are likely to continue to persist. Forests in Thailand are often treated as an open and free access resource; overexploitation has been the result.

Notes

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1. Behrman (1968, p. 208).
2. Ministry of Commerce (1930, pp. 27-28) and Dusit (1962).
3. See Hanks (1972) and Feeny (1982) for descriptions of the settlement patterns which accompanied the expansion of the area under cultivation.
4. Because cloud cover is at its minimum in the dry season, aerial photography and satellite image surveys are generally conducted in that season. Given that much of the cropping in Thailand is rainfed, it is difficult in the dry season to distinguish between areas that were cropped in the previous wet season and areas that were fallow; thus the tendency for these surveys to overestimate the area under cultivation.
5. Damrongsak (1978).
6. While the more complete coverage should bias our estimate of the rate of increase of the area under cultivation upwards, a downward bias is also imparted by using harvested rather than planted area for the later period.
7. According to Ministry of Agriculture data, as a percent of the area under major crops in the whole kingdom, the Central Plain major crop area was 61 percent in 1911/12, 56 in 1921/22, 54 in 1931/32,

50 in 1938/39, 45 in 1950-1952, 44 in 1958-1960, and 46 in 1965-1967; see Feeny (1982, pp. 138, 141) and Ingram (1971, p. 238).

8. See Dusit (1978, p. 56).

9. See Area Handbook for Thailand, 1971, p. 15 and Donner (1978, p. 141).

10. For the 1900-1930 period teak logs floated via the Chao Phya river represented 75 percent of total extractions, logs floated via the Salween represented 17.5 percent, and logs floated via the Mekong accounted for 7.6 percent of the total; see Ministry of Commerce (1930, p. 130). The Salween route was probably relatively more important in the late nineteenth century period than in the 1900-1930 period.

11. For general discussions of the Thai teak industry and its history, see Ingram (1971), Dickson (1908), Dusit (1962), Thompson (1967), Graham (1924), ADB (1969), Ministry of Commerce (1930), Mahaphol (1954), Wilson (1983), and Kunstadter, Chapman, and Sabhasri (1978).

12. The ban was partially lifted later to allow for the export of teak planks and boards.

13. See Thompson (1967), Area Handbook for Thailand, 1971, and Ingram (1971).

14. See Krit (1966). Ministry of Commerce (1930) and Sukhum (1955) list the major species found in the Thai forests.

15. The integration of northern Thailand into the Bangkok dominated government and the role of forestry policy in that integration are

carefully analyzed in Ramsay (1971). Chatthip and Suthy (1977, pp. 4-9) provide a translated copy of a 1903 report found in the Thai National Archives describing the changes in forestry policy instituted in northern Thailand in the late nineteenth and early twentieth century period.

16. Ministry of Commerce (1930, p. 128). Under Thai law permits are required for the harvesting of all timber on public property which includes virtually all forests except for the coastal mangrove forests; for a discussion of the mangrove forests see Taylor (1982). Timber cutting on private land is legal unless the species is a reserved one (such as teak or yang), in which case a permit is required.

17. Pendleton (1962, p. 217).

18. Charlermrath (1972, p. 50).

19. See Graham (1924, 1925).

20. Sukhum (1955, p. 34).

21. See Sukhum (1955), Royal Forest Department (1954), Gienty (1967), Kunstadter, Chapman, and Sabhasri (1978), Charlermrath (1972), and Thompson (1967).

22. Thompson (1967, p. 341).

23. Sukhum (1955, p. 24). Krit (1957, p. 23) reports that 27 million ha was the goal set by a FAO expert in his 1948 survey in Thailand. See also Charlermrath (1972).

24. See International Bank for Reconstruction and Development (1959, pp. 82-84) and Krit (1966, p. 9). The Asian Develoment Bank (1969, p. 465) suggests a goal of 25 million ha in forest

reserves.

25. National Economic and Social Development Board (1977, p. 151).

26. Chote and Dheb (1968, p. 332) and Charlermrath (1972, p. 51).

27. See Boonsong (1968, p. 267), Krit (1966), Gienty (1967), and Charlermrath (1972).

28. See Gienty (1967) and Hafner (1973).

29. Charlermrath (1972, p. 147).

30. See Sukhum (1955) and Gienty (1967).

31. See ADB (1969, pp. 476-480), Hattori and Kyuma (1978, p. 199), Charlermrath (1972), and Kunstadter, Chapman, and Sabhasri (1978).

32. Kunstadter (1978, p. 306), Charlermrath (1972), Dusit (1978, p. 55), and NESDB (1981).

33. IBRD (1959, pp. 82-84), Charlermrath (1972), Donner (1978), Silcock (1967, pp. 297-298), ADB (1969), Tsujii (1980) and Kunstadter, Chapman, and Sabhasri (1978).

34. ADB (1969, p. 465).

35. See Kunstadter, Chapman, and Sabhasri (1978).

36. ADB (1969, p. 479).

37. Thiem (1978, pp. 66-69).

38. Thompson (1967, pp. 472-473). See also Pendleton (1939, 1943).

39. See Feeny (1979, 1982).

40. The informal mechanisms for evading forest regulations and the legal "loopholes" have already been briefly discussed. Administrative inefficiencies in forest regulation arise in part because the responsibility for that regulation is shared by both the Ministry of the Interior (through its provincial and district

officials) and the Royal Forest Department (a part of the Ministry of Agriculture since 1956). While the RFD is in charge of technical matters, the provincial and district level forest officers are under the command of local administration officials and are reluctant to enforce forestry policies that are opposed by those officials. The Forest Police Division (created in 1960) is also under the control of the Ministry of the Interior, although for budgetary purposes it is under the RFD. For more on these issues see Gienty (1967) and Charlermrath (1972). Numerous observers have suggested administrative reforms.

41. Issues of optimal land use in the context of tropical development are discussed in Evenson (1981).

42. In the context of Thai agricultural and industrial development policy, the reform of existing policies which reduce the incentives for the intensification of cultivation and the expansion of labor-intensive manufacturing appear to be desirable for a variety of reasons. It is being argued here that reductions in the rate of forest depletion provide an additional, even if marginal, justification for these policy reforms.

43. Charlermrath (1972, p. 128).

44. See Kunstadter, Chapman, and Sabhasri (1978), Charlermrath (1972), Gienty (1967), Talbot and Talbot (1968), Sukhum (1955), Krit (1966), Mahaphol (1954), Eckholm (1976), Tsujii (1979), NESDB (1977, 1981), and Ives, Sanga, and Pisit (1980).

Appendix: The Reliability of Thai Agricultural Statistics and Rice Balance Sheet Estimates

As argued in the main text, it is important to assess the reliability of the Thai agricultural statistics. The traditional system of data collection for area, production, and yield statistics for major crops in Thailand involves initial reporting by the village headman (who is not an employee of the central government). The reports are channeled through the commune leader to the district officer (who is a central government employee), who in turn passes them onto provincial officials who forward the results to Bangkok. In this system, there are few incentives for accurate or complete reporting. Thus in the early 1950s the Rice Department (Ministry of Agriculture) instituted procedures in compiling the reports that ensured at least minimal checks for internal consistency in the reports on paddy production, yields, and area.[1]

The 1963 agricultural census conducted by the National Statistical Office (NSO) generated production estimates for non-rice crops that differed sharply from those published by the Ministry of Agriculture. Starting in 1966 the NSO began conducting crop cutting surveys. In general the estimates differed significantly from those made by the Rice Department. Because the NSO rice production estimates generally exceeded the Rice Department estimates and rice balance sheet estimates (see below) also indicated that the Rice Department consistently underestimated rice production, a number of observers, including the national income accountants, have routinely adjusted the

Rice Department figures upwards accordingly.

Thus, even in the post-World War II period, the data for the most important crop, paddy, are far from totally reliable. The margin of error for other crops or at more disaggregated levels is probably greater.

Crop reporting by village headman was the system relied upon in the pre-World War II period and thus there is every reason to be skeptical about the accuracy of the data. Official estimates of the major crop area, paddy area, paddy output, and paddy yields are shown in Table A1. For the period prior to 1927-28 the area under major crops includes paddy, tobacco, pepper, maize, cotton, peas, and sesame; for the period from 1927-28 through 1955 the area under coconuts is also included. Paddy area dominates, always accounting for over 90 per cent of the total estimated cropped area.[2]

"Table A1 about here"

The official estimates undoubtedly overstate the dominance of rice. The degree of understatement of the area under cultivation was likely to have been greater for crops other than rice. Some increasingly important crops like rubber were omitted from the official estimates because of a lack of reliable information. Alternate estimates that combine the official cropped area estimates with separate estimates of the area in rubber are presented in Table A2. Paddy accounts for at least 85 percent of this total area estimate.

"Table A2 about here"

Information from a more comprehensive land-use survey conducted in the interwar period indicates that paddy accounted for 60

percent of the total area utilized, tobacco, maize, cotton, peas, sesame, and pepper together accounted for 0.6 percent, and homesteads, gardens, fruit, and other small crops accounted for the remaining 39.4 percent.[3] The official major crop area data omit homesteads, gardens, and most fruits; even when they are included the dominance of paddy is clear.

Thus, in order to assess the overall reliability of the cropped area estimates, we need to examine the paddy area and output series in some detail. The decline in paddy yields evident over the 1920 through mid-1950s period (see Table A1) was reflected in contemporary discussion of the need for investments in rice research and irrigation. The level of paddy yields reflected in the official estimates roughly corresponds to the scattered evidence available on the yields obtained by farmers in various regions.[4] Most of the observations available are for individual farms, villages, or districts in the Central Plain, a region in which yields generally exceed the national average. These observations tend to indicate that the official whole kingdom yield estimates may be a bit low, but the extent of the bias, if any, is not clear.

Under the assumption that the yield data are roughly accurate, the reliability of the area and output data can be assessed by constructing a rice balance sheet which takes into account exports, human consumption, seed, feed, and losses in milling and storage and compares estimated production based on usage to the official estimates. Each component of the rice balance sheet will be discussed.

Data on rice exports are readily available from the foreign

trade series. Nearly all rice exports flowed through the port of Bangkok, the port for which the trade data are the most complete and reliable. Thus this component of the rice balance sheet estimate is probably accurately measured.[5]

Time series on per capita rice consumption are unavailable. We do, however, have a number of benchmark estimates and observations on consumption per person at the village level and informed contemporary estimates of aggregate per capita consumption.[6] The rice balance sheet estimates will be constructed assuming two different constant levels of per capita consumption, 170 kg and 144 kg. The former implies a daily caloric intake from rice of 1709 which if combined with the 1962 Household Expenditure Survey estimates which revealed that rice accounted for 85 percent of the total caloric intake, implies a total daily consumption of 2011 calories.[7] Supanee and Wagner, using the FAO method, estimate a daily per capita caloric intake requirement of 1932. Thus the 170 kg of rice per person per year consumption figure implies an essentially well nourished population, which is consistent with both contemporary accounts and the rapid rate of natural increase experienced over the period. The 144 kg per person per year estimate was used to test the sensitivity of the results and also corresponds to the assumed consumption level used by Ministry of Agriculture officials in 1950 when the first rice balance sheet estimates were constructed. The appropriateness of assuming a constant rate of per capita consumption will be examined below.

Assuming a rate of per capita rice consumption, total consumption estimates can be constructed by multiplying that rate by

estimates of the population. Unfortunately population estimates for this period are not totally reliable and there is some controversy over which set of estimates is the most accurate. Skinner provides the most comprehensive and probably most reliable set of estimates (for 1825-1955). Sternstein disputes Skinner's gradual acceleration in the rate of growth of the Thai population over the nineteenth century and instead argues that the rate of growth of the Thai population was slower in the nineteenth century, but more rapid in the twentieth. Finally, Bourgeois-Pichat argues that Skinner underestimated the degree of under-enumeration in the 1929 census and presents alternate estimates for the 1919 through 1956 period that largely agree with the pattern of change reflected in the Skinner series. Caldwell has reviewed the debate over the pre-World War II population estimates and concludes that the evidence tends to favor Skinner rather than Sternstein.[8]

All three series will be used to construct the rice balance sheet estimates. Unfortunately the Bourgeois-Pichat and Sternstein series had to be interpolated over the 1906-1919 and 1906-1920 periods respectively.[9] Given that the Bourgeois-Pichat series is basically similar to the Skinner series, and that Caldwell concluded that the evidence favored Skinner with respect to Sternstein, and given that there is no need to interpolate the early twentieth century population estimates for the Skinner series, that series should provide the most reliable population estimates for use in the rice balance sheet estimates. Each population series along with the census figures are shown in Table A3. Rate of growth of population estimates are shown in Table A4.

"Tables A3 and A4 about here"

Two paddy seed rates in kg per hectare were used, 125 and 100. Each of these figures is in broad agreement with contemporary observations on seed use and reflect the higher rate of seed use under broadcast cultivation which accounted for the majority of the area under paddy cultivation in this period.[10] A slight overestimate of seed use may result from the use of these rates.

The Thai national income accountants estimate that 3 percent of the paddy crop is accounted for as animal feed and losses. The milling rate (weight of milled rice as a percent of the weight of paddy) was assumed to be 60 percent, a lower bound figure reflecting performance rates under hand-milling and small upcountry mills. The results are not particularly sensitive to either of these assumed parameter values.

The rice balance sheet estimates were constructed according to equation (1)

$$(1) \quad [(X1.POP_t + EX_{t+1})/0.6 + X2.AREA_t]1.03093 = OUTPUT_t$$

where X1 = per capita rice consumption, 170 or 144 kg,

POP_t = population in year t,

EX_{t+1} = rice exports in the following year, t + 1,

X2 = the seeding rate in kg per hectare, 125 or 100,

$AREA_t$ = the area planted to paddy in hectares in year t,

and $OUTPUT_t$ = rice balance sheet estimate of paddy production in year t.

Estimates were constructed for the 1906-1940 and 1906-1955 periods. The rice balance sheet estimates were then compared to the official estimates. The mean, variance, and range of the rice balance sheet estimates as a percent of the official estimates are presented in Table A5.

"Table A5 about here"

Clearly, there appears to have been a significant tendency for the official production estimates to understate production. If, as was argued above, the yield per hectare data are roughly accurate, this conclusion implies a consistent understatement of both area and production in the official figures.

The conclusion which applies to the 1906-1955 period (and various sub-periods) is consistent with the results obtained by the National Accounts Office when they examined the Rice Department's estimates versus rice balance sheet estimates for the 1951 through 1966 period.[11] They concluded that cumulative paddy use over that period exceeded the Rice Department estimates by 21.36 percent. Using an alternate set of assumptions that differed slightly, Ingram found that his rice balance sheet estimates exceeded the Rice Department estimates by 13.4 percent over the 1958 through 1965 period, but were in close agreement with the Rice Department for the 1966-1968 period.[12] Thus, the conclusion that official estimates understate production in the pre-1960s period does not appear to be sensitive to the particular parameter values chosen in constructing a rice balance sheet.

It is natural to expect that the degree of understatement was reduced over time as coverage became more complete. Regression results

presented in Table A6 give limited support to that hypothesis. The ratio of the rice balance sheet estimate to the official estimate was regressed on time. For the 1906-1940 period for the Skinner (probably the most reliable) and Bourgeois-Pichat population series, the coefficient on time was seldom significant. For the Sternstein series, the coefficient was positive and significant, but as in the other cases, the coefficient of determination was very low.

"Table A6 about here"

When the time period is expanded to 1906-1955, the coefficient on time is negative and significant for the Skinner and Bourgeois-Pichat series, but the coefficient of determination is still very low. In examining the time path of the ratio of the two estimates, the ratio appears to generally be quite high over the 1930s, suggesting that the constant rate of per capita consumption assumed in the rice balance sheet estimates may overstate actual consumption in the depression period. Thus separate regressions were run for the 1906-29 and 1942-55 period and the 1930-41 period. In the former period for the Skinner and Bourgeois-Pichat series, the coefficient on time is negative and significant and the coefficient of determination is improved, but still low. The 1930-41 period results suggest no significant time trend. F-tests performed on the structural stability of the relationship for the two periods (for the Skinner and Bourgeois-Pichat series) suggest structural instability.

Thus, one is left with the conclusion that there has been some slight degree of reduction in the degree of under-reporting of paddy production over the years, but that the trends reflected in the overall

official series are probably roughly reliable.[13] If one takes the estimated coefficient on time seriously (for Skinner, 170/125 case), the mean ratio of the rice balance sheet to the official estimate would be reduced from 1.3589 to 1.2054 over a 38 year period.[14] Revisions in data collection and processing procedures used by the Rice Department in the late 1960s have reduced this apparent underestimation of rice production.[15]

Notes to Appendix

1. See Behrman (1968, pp. 200-218); for additional detail see Ingram (1971, pp. 240-243) and Asian Development Bank (1969), p. 691).
2. For the 1950-1955 period paddy accounted for more than 85 percent of the total area in a more comprehensive list of crops in which rubber, kenaf, oil seeds, cassava, garden crops, and other fruits were also included; see Silcock (1970, p. 54).
3. Zimmerman (1937, p. 386); recent data from the Division of Agricultural Economics in Thailand for 1975 indicates that for the whole kingdom 63.1 percent of the area of farm holdings is accounted for by paddy, 18.2 percent by other major field crops, and 18.7 percent by homesteads, gardens, fruit trees, tree crops, woodlots, and other. Relative to the 1930s non-paddy field crops have become more important but paddy has basically retained its primacy.
4. See Feeny (1982).
5. Controls on the export of rice were instituted both during World War II and in the 1945-1949 postwar period. From 1947 through 1955 rice exporting was subject to an implicit tax through the operation of a multiple exchange rate system and after 1955 to a rice export tax and the rice premium (a specific export tax). During the 1945-1949 period there was a significant amount of rice smuggled out of the country. In the period since 1955 rice smuggling may have been important in periods when the rice premium was set at very high levels and world rice prices were also high. Thus of-

ficial export data for the 1945-1949 and some portions of the 1949-1955 periods may understate the true level of exports. Overall the results for the rice balance sheet analysis of the 1906-1955 period are unlikely to be sensitive to these data problems.

6. See Feeny (1982).

7. See Feeny (1982) and Supanee and Wagner (1969).

8. See Skinner (1957), Sternstein (1965), Bourgeois-Pichat (1959), and Caldwell (1967). Thai population statistics are further discussed in Feeny (1982) and Thomlinson (1972).

9. Bourgeois-Pichat presents estimates for the 1919 through 1956 period; the rate of growth of the Thai population taken from census data for the 1911 through 1919 period was used to interpolate over the 1906-1919 period. For Sternstein the 1906 estimate was interpolated from a graph, because the figure was not given in a table.

10. See Feeny (1982, Table AI-19, p. 150).

11. National Income of Thailand 1968-69 Edition, pp. 191-192. These rice balance sheet estimates assumed a per capita annual consumption of 155 kg of rice, a milling rate of 60.3 percent for small mills and 64.4 percent for large mills, 3 percent losses, and seeding rates of 50 kg/ha for transplanted paddy and 100 kg/ha for broadcast paddy.

12. Ingram (1971, pp. 241-243); Ingram assumed 150 kg per person for rice consumption, a milling rate of 66 percent, and a seeding rate of 60 kg/ha. Behrman (1968) made similar assumptions about

domestic non-human consumption and computed human consumption as a residual after accounting for exports and other uses. For the 1947-1962 period, consumption averaged 181 kg per person per year, a figure which he did not consider to be excessive.

13. One additional caveat to this conclusion needs to be discussed, but given the sensitivity tests that have been performed and the congruence of the results with those arrived at by others, the validity of the overall conclusion still stands. A better method of constructing the rice balance sheets would be to multiply age-sex specific per capita consumption rates by the number of persons in each of the categories. The method used here may marginally overestimate consumption over time in that as the population age structure became younger (through the rapid rate of natural increase), the national average per capita consumption rate should have fallen as an increasing share of the population was in younger age groups with lower rates of per capita consumption. Unfortunately we lack the precise information on the age-sex specific consumption rates needed to construct these more accurate consumption estimates.

14. Similarly using the Bourgeois-Pichat population series, a consumption rate of 170 kg, and a seeding rate of 125 kg/ha, the mean of the ratio would fall from 1.3835 to 1.1804 over a 38 year period.

15. The underestimation by the Rice Department that was apparent when rice balance sheet estimates were constructed and the discrepancies between Rice Department estimates and census and crop-cutting survey figures led the Rice Department to abandon their traditional system in 1968.

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Table 1: Average Annual Rates of Change of Cropped Area, Paddy Area, Paddy Production, Paddy Yield, and Population in percent per year, 1905-1955

Period	Average Annual Rate of Change in:					
	Major Crop Area	Major Crop Area, including rubber	Paddy Area Planted	Paddy Production	Paddy Yield	Population, Skinner series
1905/06-1955	-	-	3.06	-	-	1.95
1906/07-1955	-	-	2.95	2.11	-0.82	1.96
1911/12-1955	3.11	-	3.00	2.11	-0.87	2.04
1913/14-1955	2.50	2.70	2.36	2.23	-0.13	2.06

Source: See Tables A1-A2 and A3.

Table 2: Paddy Area Harvested and Total Cropped Area Harvested, 1950-1975

Year	Paddy Area Harvested in 000 ha	Total area Harvested in 000 ha
1950	5824.00	8191.84
1951	6309.76	8698.08
1952	5643.20	8124.64
1953	6524.00	9074.08
1954	4976.16	7639.20
1955	5913.28	8657.92
1956	6338.24	9214.72
1957	4715.68	7695.04
1958	5685.92	8772.32
1959	5789.12	9078.08
1960	6207.52	9847.84
1961	6221.44	9925.12
1962	6499.84	10279.36
1963	6672.16	11610.24
1964	6567.52	10839.04
1965	6555.52	11143.52
1966	7701.60	12712.32
1967	6388.16	11446.40
1968	6937.92	12146.40
1969	7985.12	13595.68
1970	7539.68	13569.44
1971	7805.12	14193.76
1972	7457.92	14196.64
1973	8357.28	15828.00
1974	8066.56	15687.36
1975	9203.52	16960.16

Source: Damrongsak (1978, p. 146).

Table 3: Average Annual Rates of Change in Cropped Area, 1911-1976

Period	Total Area	Total Area, including rubber[2]	Paddy Area Planted	Agricultural Output in Constant Prices	Agricultural Capital in Constant Prices	Agricultural Labor Force
1950-1976	3.03	-	-	4.00	5.22	2.28
1950-1975	2.95	-	1.91	-	-	-
1955-1975	3.41	-	2.19	-	-	-
1911-1975	3.75	-	2.75	-	-	-
1912-1975	3.45	-	2.42	-	-	-
1913-1975	3.36	3.34	2.31	-	-	-

[a]Rubber is included in the Damrongsak 1950-1976 series. For the earlier period, estimates in Table A2 include rubber and were used in computing the average annual rate of change for 1913-1975.

Source: See Tables A1, A2 and 2 and Damrongsak (1978, pp. 34,113,128, and 146).

Table 4: Various Estimates of the Area under Forests and Rates of Change in the Area under Forests, 1913-1980

Year	Percent of Total Area in Forest	Area in Forest in 000 ha	Source and Comments
1913	75	38,514	Graham (1913, p. 347); includes forests, marsh, and jungle.
1930	70	35,946.4	Ministry of Commerce (1930, p. 35).
1947	63		Tsujii (1979, p. 29); taken from Ministry of Agriculture data.
1949	69	32,600	Donner (1978, p. 71); area in forests and pasture.
1955	63	32,129	Sukhum (1955, p. 8).
1956	58	30,288.3	Pendleton (1962, p. 134); area in forests and pasture.
1959	58	30,010	Charlermrath (1972, p. 20); official estimate.
1961	56	29,000	Donner (1978, p. 133); estimate from aerial photography survey.
1961	52		Charlermrath (1972, p. 24); guesstimate of forestry official.
1963	53	27,100	ADB (1969, p. 475); estimate based on FAO world forest inventory.
1965	53	27,300	Donner (1978, p. 22); author indicates that this estimate which is based on a land-use survey is probably an over-estimate.
1965	< 40		Charlermrath (1972, p. 24); guesstimate of forestry official.
1966	51	26,500	Krit (1966, p. 5).
1969/70	52	26,900	Land Development Department estimates based on aerial photography.

Table 4: Continued

Year	Percent of Total Area in Forest	Area in Forest in 000 ha	Source and Comments
1970	39-49	20,000-25,000	Donner (1978, p. 134); author's guesstimate.
1970	30		Tsujii (1979, p. 29); guesstimate of forestry expert.
1974	37	19,040	NESDB (1977, p. 149); estimate based on satellite imagery.
1975	41	21,068	World Bank estimate based on satellite imagery.
1978	25	13,018	Wilson (1983, p. 133); estimate based on satellite imagery.
1980	< 30		NESDB (1981, p. 7).

Period	Average Annual Rate of Change in Forest Area in percent per year
1930-1974	-1.43
1930-1975	-1.18

Note: The total area in Thailand is 51,352,000 ha; see Donner (1978, 907).

Table 5: Comparison of Changes in the Area under Forests and Changes in the Cropped Area, 1913-1975

Year	(1) Area under Forests in 000 ha[a]	(2) Change in Area under Forests in 000 ha	(3) Cropped Area in 000 ha: From Table A1	(4) From Table 2	(5) Change in Cropped Area in 000 ha	(6) = (5)/ in percen
1913	38514	-	2195.70	-	-	-
		2567.6		-	1053.64	41
1930	35946.4		3249.34	-	-	-
		3817.4			2939.6	77
1955	32129	-	6188.94	8657.92	-	-
		3129			1267.2	41
1961	29000	-	-	9925.12	-	-
		7932	-		7035.04	89
1975	21068	-	-	16960.16	-	-
1913-1955		6385			3993.24	63
1913-1975		17446			14764.46	85

[a]Sources are given in Table 4.

Table 6: Average Annual Production of Teak, Other Timber, Total Timber Firewood, and Charcoal in cubic meters, 1890-1978

Period	Teak	Other Timber	Total Timber	Firewood	Charcoal
Up to 1890[a]	62,500 to 69,500	-	-	-	-
1890s[a]	83,400 to 97,300	-	-	-	-
1898-1907[b]	130,268	-	-	-	-
1900-1930[c]	222,907	-	-	-	-
1932-1936[d]	195,171	377,327	572,498	788,017	220,357
1937-1941	141,019	485,432	626,451	861,934	337,587
1942-1946	60,993	460,488	521,481	1,297,987	544,499
1947-1951	209,380	929,434	1,138,814	1,557,705	629,030
1952-1956	294,462	1,270,841	1,565,303	1,137,015	669,639
1957-1961	158,362	1,248,812	1,407,174	1,196,795	598,890
1962-1966	153,662	1,646,091	1,799,753	1,392,811	632,777
1967-1971	261,013	1,984,995	2,246,008	1,395,455	495,143
1972-1973	183,188	1,989,661	2,172,848	1,261,607	417,345
1974-1978[e]	196,800	2,806,000	3,002,800	993,800	279,400

[a]Data are taken from Smyth (1898, Vol. 1, p. 71).

[b]Data are for teak floated via the Chao Phya valley only, as recorded at the main duty station at Paknampoh and therefore omit shipments via the Salween and Mekong as well as teak used in northern Thailand.
Data are taken from Dickson (1908, p. 172).

[c]Data are taken from Ministry of Commerce (1930, p. 130).

[d]Data are taken from Sukhum (1955, pp. 61-62).

[e]Data are taken from Wilson (1983, p. 138).

Source: Unless otherwise noted data are taken from Statistical Yearbook Thailand Nos. 20-22, 24, 29-31.

Table A1: Whole Kingdom Paddy Area, Paddy Output, Paddy Yield, and Major Crop Area, 1905/06-1955

Year	Paddy Area Planted in 000 ha	Paddy Output in metric tons	Paddy Yield in kg/ha	Major Crop Area in 000 ha
1905/06	1281.23	n.a.	n.a.	n.a.
1906/07	1388.42	2,614,472	1883	n.a.
1907/08	1385.23	2,616,637	1889	n.a.
1908/09	1253.15	2,387,267	1905	n.a.
1909/10	1752.86	3,068,314	1750	n.a.
1910/11	1454.75	2,976,743	2046	n.a.
1911/12	1571.69	2,903,648	1847	1606.96
1912/13	1974.73	3,698,885	1873	2007.61
1913/14	2162.32	2,876,064	1330	2195.70
1914/15	2038.30	3,126,732	1534	2066.70
1915/16	2072.24	3,046,692	1470	2104.48
1916/17	2169.44	3,816,160	1759	2198.14
1917/18	2222.50	3,013,143	1356	2247.41
1918/19	2158.57	3,411,275	1580	2184.43
1919/20	2478.80	2,288,574	922	2504.31
1920/21	2446.90	4,311,735	1761	2475.01
1921/22	2595.87	4,266,166	1644	2621.68
1922/23	2527.26	4,375,187	1731	2558.76
1923/24	2686.60	4,434,923	1652	2710.34
1924/25	2776.98	4,941,573	1779	2807.77
1925/26	2736.54	4,193,102	1532	2766.33
1926/27	2894.68	5,226,037	1804	2923.02
1927/28	2927.75	4,564,096	1560	3008.04
1928/29	2849.68	3,882,165	1361	2931.87
1929/30	3035.86	3,874,834	1275	3114.56
1930/31	3180.08	4,826,301	1515	3249.34
1931/32	3090.79	4,068,530	1316	3167.14
1932/33	3213.79	5,116,405	1590	3291.45
1933/34	3245.30	5,007,734	1541	3329.43
1934/35	3336.69	4,597,786	1376	3425.83
1935/36	3377.70	4,726,983	1399	3458.96
1936/37	3258.18	3,379,856	1039	3337.86
1937/38	3369.98	4,555,706	1350	3461.54
1938/39	3507.02	4,523,663	1290	3595.86
1939/40	3463.88	4,560,463	1316	3552.46
1940	3806.98	4,923,350	1294	3892.20
1941	3969.25	5,120,097	1290	4077.25
1942	4398.63	3,868,806	880	4528.41
1943	4314.72	5,702,005	1322	4474.39
1944	4240.04	5,107,635	1205	4392.21
1945	3942.39	3,699,322	938	4066.61

Table A1 (cont'd)

1946	3981.99	4,442,271	1116	4099.91
1947	4825.00	5,453,110	1130	4979.66
1948	5211.75	6,768,852	1299	5371.03
1949	5268.22	6,618,908	1256	5557.77
1950	5539.98	6,715,813	1212	5872.26
1951	5959.26	7,254,318	1217	6323.01
1952	5368.12	6,538,029	1218	5736.87
1953	6171.93	8,159,456	1322	6556.26
1954	5557.16	5,653,604	1017	5967.03
1955	5769.57	7,262,453	1259	6188.94

Source: All data were originally taken from official Thai government sources. The data for 1905/06 through 1941 are from Feeny (1982, pp. 138 and 140). Data for 1942 through 1955 are from Statistical Year Book of Thailand No. 21 (1939-40 to 1944) and No. 22 (1945 to 1955).

Table A2: Area Planted in Rubber Trees and Total Area Under Major Crops, 1913-1955

Year	Rubber Area in 000 ha	Total Area in Major Crops including rubber in 000 ha
1913	1.60	2197.30
1914	1.60	2968.30
1915	1.92	2106.40
1916	5.44	2203.58
1917	10.72	2258.13
1918	10.72	2195.15
1919	14.72	2519.03
1920	16.48	2491.49
1921	16.48	2638.16
1922	16.48	2575.24
1923	16.48	2726.82
1924	16.48	2824.25
1925	16.48	2782.81
1926	22.40	2945.92
1928	107.36	3039.23
1928	107.36	3039.23
1929	107.36	3221.92
1930	107.36	3356.70
1932	140.48	3431.93
1932	140.48	3431.93
1933	140.48	3469.91
1934	140.48	3566.31
1935	140.48	3599.44
1936	140.48	3478.34
1937	140.48	3602.02
1938	184.64	3780.50
1939	228.80	3781.26
1940	272.96	4165.16
1941	290.56	4367.81
1942	n.a.	n.a.
1943	n.a.	n.a.
1944	n.a.	n.a.
1945	n.a.	n.a.
1946	n.a.	n.a.

Table A2 (cont'd)

1947	n.a.	n.a.
1948	290.56	5661.59
1949	346.56	5904.32
1950	361.44	6233.70
1951	383.84	6706.85
1952	393.44	6130.31
1953	441.92	6998.18
1954	526.24	6493.27
1955	530.88	6719.82

Source: Data on the area planted in rubber are taken from Stifel (1973, p. 130). His estimates are based on export and domestic usage estimates, taking into account the short-run price elasticity of supply and the effect of the age composition of the trees on average yields. The sources for the major crop area (without rubber) are given in Table A1.

Table A3: Various Estimates of the Thai Population, 1906-1956, in thousands

Year	Estimate from Skinner	Estimate from Bourgeois-Pichat	Estimate from Sternstein	Census Estimate
1906	7896	8364	6200	n.a.
1911	8432	8947	7204	8266
1919	9608	9966	9158	9207
1929	12059	12433	11606	11506
1937	14721	14549	14218	14464
1947	17643	17647	18117	17443
1956	20865[a]	20776	23286	20095[b]

[a]The 1956 Skinner estimate was interpolated from the 1955 estimate by adding 1.8813 percent.

[b]The 1956 census estimate is based on a survey rather than a census.

Source: The Skinner series is taken from Skinner (1957, pp. 79 and 183). Bourgeois-Pichat is taken from Bourgeois-Pichat (1959). The data for the 1906-1919 period were interpolated from Bourgeois-Pichat's 1919 estimate assuming that the Thai population grew at 1.36 percent per year over that period, the rate of growth given by the census estimates for the 1911-1919 period. The Sternstein estimates are from Sternstein (1965) and Cochrane (1979, p. 6). The figure for 1906 is interpolated from the graph presented in Sternstein. Census data are gaken from Feeny (1982, p. 147). Annual data were interpolated between these benchmarks for all three series for use in constructing the rice balance sheet estimates.

Table A4: Average Annual Rates of Growth of Population in percent per year, 1906-1955.

Period	Using Population Estimates from:			
	Skinner	Bourgeois-Pichat	Sternstein	Census
1906-1911	1.32	-	-	-
1911-1919	1.65	-	3.05	1.36
1919-1929	2.30	2.24	2.40	2.25
1929-1937	2.52	1.98	2.57	2.90
1937-1947	1.83	1.95	2.45	1.89
1947-1956	1.88	1.82	2.83	1.59
1906-1955	1.96	1.84	2.67	-

Source: See Table A3.

Table A5: Comparison of Rice Balance Sheet Estimates to Official Paddy Production Figures, 1906-1955

Period	Per Capita Rice Consumption in kg	Seed Rate kg/ha	Population Series	Mean of Ratio of Rice Balance Sheet to Official Estimate	Variance of Ratio	Range of Ratio
1906-1940	170	125	Skinner	1.45	0.036	1.11-1.93
	170	125	B-P	1.48	0.034	1.15-1.92
	170	125	Sternstein	1.39	0.035	1.07-1.89
	144	125	Skinner	1.33	0.030	0.99-1.74
	144	125	B-P	1.35	0.028	1.02-1.73
	144	125	Sternstein	1.28	0.029	0.95-1.70
	144	100	Skinner	1.31	0.029	0.97-1.72
	144	100	B-P	1.33	0.028	1.00-1.71
	144	100	Sternstein	1.26	0.028	0.94-1.68
	170	100	Skinner	1.44	0.035	1.10-1.91
	170	100	B-P	1.47	0.033	1.13-1.90
	170	100	Sternstein	1.38	0.034	1.05-1.86
1906-1955	170	125	Skinner	1.41	0.042	1.01-1.93
	170	125	B-P	1.42	0.043	1.01-1.92
	170	125	Sternstein	1.37	0.037	1.04-1.89
1930-1941	170	125	Skinner	1.55	0.039	1.25-1.93
	170	125	B-P	1.55	0.038	1.25-1.92
	170	125	Sternstein	1.52	0.036	1.25-1.89
1906-1929 and 1942-1955	170	125	Skinner	1.36	0.035	1.01-1.76
	170	125	B-P	1.38	0.038	1.01-1.82
	170	125	Sternstein	1.33	0.028	1.04-1.71

Note: B-P means Bourgeois-Pichat.

Table A6: Regressions of the Ratio of the Rice Balance Sheet Estimates to the Official Production Figures on Time, 1906-1955

Period	Per Capita Rice Consumption in kg	Seed Rate in kg/ha	Population Series	Regression Coefficient on: Intercept	Time	$\bar{R}^2$
1906-1940	170	125	Skinner	- 7.25(1.21)	0.005(1.46)*	0.03
	170	125	B-P	- 3.38(0.57)	0.003(0.82)	0.00
	170	125	Sternstein	-15.06(2.82)***	0.009(3.08***	0.20
	144	125	Skinner	- 6.60(1.21)	0.004(1.45)*	0.03
	144	125	B-P	- 3.32(0.61)	0.002(0.86)	0.00
	144	125	Sternstein	-13.22(2.68)***	0.008(2.94)***	0.18
	144	100	Skinner	- 6.30(1.16)	0.004(1.45)*	0.03
	144	100	B-P	- 3.01(0.56)	0.002(0.81)	0.00
	144	100	Sternstein	-12.91(2.64)***	0.007(2.90)***	0.18
	170	100	Skinner	- 6.94(1.17)	0.004(1.41)*	0.03
	170	100	B-P	- 3.07(0.52)	0.002(0.77)	0.00
	170	100	Sternstein	-14.76(2.79)***	0.008(3.05)***	0.20
1906-1955	170	125	Skinner	6.70(1.75)**	-0.003(1.38)*	0.02
	170	125	B-P	9.45(2.50)***	-0.004(2.13)**	0.07
	170	125	Sternstein	- 0.87(0.24)	0.001(0.62)	0.00
1930-1941	170	125	Skinner	4,76(0.14)	-0.002(0.10)	0.00
	170	125	B-P	8.97(0.27)	-0.004(0.23)	0.00
	170	125	Sternstein	- 0.06(0.00	0.008(0.05)	0.00
1906-1929 and 1942-1955	170	125	Skinner	9.15(2.68)***	-0.004(2.28)**	0.10
	170	125	B-P	11.69(3.38)***	-0.005(2.98)***	0.18
	170	125	Sternstein	1.30(0.39)	0.000(0.01)	0.00

F-Tests of Structural Stability 1906-1955 versus 1906-1929/1942-1955 and 1930-1941

Case	Calculated F	Critical F(2,46) at the 1% level
Skinner (170/125)	6.29	5.10
Bourgeois-Pichat (170/125)	5.34	5.10

*Significant at the 10% level, one-tailed test.
**Significant at the 5% level, one-tailed test.
***Significant at the 1% level, one-tailed test.
Note: t-statistics are given in parentheses.
B-P means Bourgeois-Pichat.