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Intensifying Rice Production in the Lac Alaotra and Marovoay Regions of Madagascar:

Implications for Production, Employment, and Tanety/Tavy Land Use

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Preface

This study benefitted greatly from the assistance and suggestions of several institutions and individuals, including the staff of the United States Agency for International Development's Mission in Madagascar, Madagascar's Ministry of Agriculture, the International Rice Research Institute, and the Environmental and Natural Resources Policy and Training Project.

Executive Summary

In Madagascar, as with many other countries in Sub-Saharan Africa, rapid population growth contrasts with limited increases in agricultural productivity. This unfortunate situation encourages the conversion of fragile lands to agricultural production. Much of this conversion destroys tropical forests that contain unique plant and animal species or areas that serve valuable ecosystem functions. Herein lies an issue of concern to Madagascar--how can it increase agricultural yields, provide employment opportunities for a growing population and, simultaneously, reduce pressures on fragile ecosystems?

No study can provide a single answer to this question, but this study examines one important facet of the issue. Within Madagascar, can the intensification of rice production in two rice-producing zones, around Lac Alaotra and Morovoay, produce enough rice and employ enough labor between 1992 and 2007 to meet both the anticipated need for consumption and increased employment opportunities without the conversion of ecologically fragile lands to crop production? To address this question, five- and fifteen-year scenarios are developed for Morovaoy and Lac Alaotra, two areas that typically produce more rice than is consumed locally. Within these scenarios, the likely impacts of reasonable but optimistic technological changes on rice production and agricultural employment are examined.

The analysis suggests two key conclusions. First, modest but important increases in production could be expected from the increased application of existing and emerging technologies. Unfortunately, the application of these technologies will not provide enough rice to satisfy expected demand from domestic consumers. Second, the increases in employment associated with this increased rice production will likewise be modest, even when one considers multiplier effects. Indeed, the increased employment opportunities will not be sufficient to employ permanently the additional growth in the labor force that can be expected with current rates of population growth.

1. Introduction

Rice is a staple food in Madagascar and is grown on about 1.3 million hectares, or about 67 percent of the country's total cultivated land. Unfortunately, substantial population growth in the absence of consistent improvements in yield over the last thirty years have led to the expansion of agricultural cultivation onto economically and ecologically marginal lands. These lands include upland slopes (*tanety*) and areas associated with slash-and-burn agriculture (*tavy*).

Given the obvious disincentive to grow rice in such environmentally harmful locations, this study analyzes whether the intensification of rice production in two of Madagascar's surplus production zones, the area around Lac Alaotra and the Morovoay plains, can absorb enough labor and produce enough rice to slow the expansion of rice cultivation in *tavy* and *tanety* zones. The analysis presents five- and fifteen-year projections (from 1992 to 1997 and from 1992 to 2007) of the growth of Madagascar's agricultural labor force and then assesses the land requirements necessary for the absorption of this labor force. Such absorption is dependent not only on the availability of land, but also on changes in techniques and technologies. Consequently, several assumptions are made about the technological and sociocultural variables that might affect land use, migration, the absorption of labor, and productivity vis-à-vis anticipated demands for rice.

2. Population Growth and Future Rice Needs

Table 1 provides estimates of Madagascar's population, rice consumption, and production trends between 1985 and 2007. The population projections are based on a 1985 population estimate of 10.6 million provided in the agricultural census of 1984-1985. These projections assume an increase in Madagascar's population of 3.2 percent per year (Cleaver and Screiber 1992). Given this rate of growth, the estimated population is 13.2 million in 1992, and 21.2 million in 2007.[1]

Madagascar's Ministry of Agriculture places the average person's consumption at 130 kg of rice per year, so it is possible to estimate the anticipated need for rice. Based on this level of consumption, production equivalent is then projected. The translation to paddy equivalent (i.e., the amount of rice potentially available for human consumption) assumes a loss of slightly more than 38 percent due to processing and other uses.[2]

Extrapolating from paddy production between 1961 and 1989, a simple linear trend predicts an average increase in paddy production of slightly over 1 percent per year. Consequently, given historical production trends and the anticipated needs for rice, the difference between estimated production and estimated need is projected to grow to about 1.65 million metric tons by 2007. This amount is more than four times higher than the difference in 1992.

If current agricultural practices continue and rice production is to increase to eliminate the difference between production and need, then additional land will be required for cultivation. To accommodate this demand, the data in the last column of Table 1 suggest the need for 1.49 million hectares of additional paddy production. This is more than the amount of land already in rice production. Most important, without substantial investments in irrigation infrastructure, this increase could come from the expansion of *tavy* and *tanety* production. Not only is this land environmentally undesirable for rice production, but the estimated yield of such production is only 1.11 metric tons per hectare (MT/ha), which is far less than the yields elsewhere in Madagascar (Ministere de la Production Agricole et de la Reforme Agraire 1988f).

3. Technological Possibilities for Rice Production

Madagascar is not the only country experiencing a combination of high population growth, a relative lack of agricultural intensification and productivity improvements, an inability to employ productively a growing labor force, and resulting environmental concerns. In reference to the experience with the green revolution in Asia, for example, Barker et al. (1985) conclude that the increased employment associated with new rice technologies in most of Asia have not been able to offset the effects of population growth and the slow growth of the industrial sector. The point to be made is that a prosperous agricultural sector cannot employ most of the additional growth in labor force due to population growth and, through multiplier effects, generate sufficient additional employment outside of this sector.

By way of illustration, Figure 1 compares aggregate yield trends in Madagascar in relation to two major rice growing regions of the world, South and Southeast Asia. Average yields in Madagascar were above those in the two Asian regions in the early 1960s and remained comparable to yields in Southeast Asia until 1971-1972. Beginning around 1973, however, yields in Southeast Asia began a steady climb. Due to the combination of irrigation control and green-revolution technologies, yields reached about 3 MT/ha in 1989. Yields in South Asia grew more slowly through the 1970s than in Southeast Asia, and with considerably more variation, but then progressed steadily to about 2.6 MT/ha in 1989. In contrast, Madagascar's aggregate yields stagnated in the early 1970s, fell during the early 1980s, and then climbed slowly to about 2.1 MT/ha in 1989.

Given these yield histories, Figure 2 shows that the modest growth in aggregate production in Madagascar was due primarily to an expansion of cultivated area. As Figures 3 and 4 reveal, however, South and Southeast Asia have taken a different route to increased production; the land used for rice production in these areas has increased only marginally. Thus, given Madagascar's existing rate of population growth, aggregate rice yields would have to grow roughly at the same rate as those experienced in Southeast Asia, given the same level of rice imports, in order to keep pace with population growth over the next fifteen years. Alternatively,

either the amount of land devoted to rice production in Madagascar will have to expand or there will have to be substantial increases in imports, or both.

Increased domestic productivity is the preferred approach, and Barker et al. (1985) provide some important lessons that may be of relevance to Madagascar. Irrigation control and reasonably well-functioning irrigations systems provided key ingredients in increasing Asia's rice production. Barker and his colleagues also found that water control is associated with the best response of new seed varieties to fertilizers. In addition, water control makes it possible to grow more than one rice crop in the same season on the same field with the development of shorter-season varieties. As the data in Figure 5 reveal, aggregate fertilizer applications for all crops have grown steadily in South and Southeast Asia since the mid-1960s. In contrast, Madagascar's use of fertilizers has remained relatively unchanged since the late 1960s.

Barker also found that multiple seasons of rice are a main reason for increasing labor use per hectare whereas higher yields in a single season do not necessarily increase labor. In the single-season areas, mechanization (for land preparation, threshing, and milling) occurred and herbicides were substituted for labor in weeding. The availability and relative costs of labor to other inputs (e.g., chemicals and tillers) determined whether a labor-saving or labor-intensive path was followed.

4. Implications for Marovoay and Lac Alaotra

Asia's experience may have important implications for yield improvements and technological opportunities in rice production in the Marovoay and Lac Alaotra regions, which are found in the provinces of Mahajanga and Toamasina, respectively (see Figure 6). Marovoay is a relatively new rice production region that fits roughly into a "traditional wetland system" (Barker et al. 1985), where labor, water, and traditional seeds are the primary inputs. Animal inputs are becoming less important. A lack of year-round water control affects the two main rice seasons--a distinct dry season (*jeby*) from May to October and a wet season (*atriaty*) from November to April. Although temperatures are generally above 20 degrees centigrade, temperatures can fall to 10 degrees during the coldest months of June and July.[3] The typical wet season crop is grown on higher lands not flooded, while dry season crops are grown on the lowlands that are severely flooded during the wet season. Although there have been some attempts to develop shorter season varieties, two seasons of rice are not grown on the same field in the Marovoay region and should not be expected over substantial areas in the near future. Consequently, large increases in labor use per hectare through the spread of double seasons are not available for the foreseeable future absent a substantial change in the region's irrigation infrastructure.

The Lac Alaotra region has traditionally been a surplus production area and can be characterized as a "transitional wetland system." Some newer seed varieties are in use, and labor-saving inputs such as animals, herbicides, and machinery are more common than in

Marovoay (Richaud 1990). Unlike in Marovoay, however, rice is grown only during the distinct warm and wet season from about November to March but not during the dry and colder season from April to October. Accordingly, there is little opportunity for two seasons of rice in the Lac Alaotra area.

Based on the experience with technological changes in Asia and the cropping seasons in Marovoay and Lac Alaotra, it is probably unreasonable to expect that substantial increases in labor per unit of land would occur with yield improvements in the two regions. As a rough guide, the percentage increase in labor use per hectare associated with new technologies equals the percentage increase in yields (output/hectare) minus the percentage increase in labor productivity (output/labor). Since many technical changes can improve yields and improve labor productivity, the overall impacts on labor use per hectare can be small within a single season. This would be different, of course, if the changes allow for additional crop seasons.

5. Current Trends: Land Expansion Needed to Absorb Labor Force Growth With Existing Technology

Regional Agricultural Labor Force Projections

In order to assess whether increases in the production of rice are capable of absorbing labor that may be attracted to marginal lands (or environmentally harmful methods), it is first necessary to make some regionally based projections about the size of the labor force in coming years. In contrast to national growth rates, now estimated to be about 3.2 percent, regional growth varied considerably between 1975 and 1985. Specifically, the *Faritany* of Antananarivo grew at 2.9 percent per year, the *Faritany* of Fianarantsoa at 3.3 percent, the *Faritany* of Toamasina at 2.9 percent, the *Faritany* of Mahajanga at 3.2 percent, the *Fivondronana* of Marovoay at 5.4 percent, and the Lac Aloatra area at 4.5 percent per year. Unlike the national growth rates, the regional estimates include population changes due to internal migration.

Approximately 75 percent of Madagascar's population lives in rural areas (World Bank 1992). Of these residents, according to Madagascar's agricultural census of 1984-1985, approximately 60 percent are in the labor force (Ministere de la Production Agricole et de la Reforme Agraire, MPARA, 1988c). In rural areas, virtually all of those who are in the labor force are engaged in agriculture. In order to make assumptions about the size of labor force in the future, it is assumed that the agricultural population will grow at the same rate as the general rural population. Based on these assumptions, a projection for agricultural labor supply was computed for each of the six regions noted above. These estimates are based on recent historical growth (see Table 2). As an illustration, the projections imply that the labor force in the Lac Aloatra area will continue to increase at an annual rate of 4.5 percent, to about 605,000 in 2007.

Similarly, the projections indicate that the labor force in Marovoay will increase by 120 percent to over 125,000 in 2007 from only 57,000 in 1992.

Land Expansion Needed to Absorb Labor Force

Relying again on data from the agricultural census of 1984-1985, Table 3 reports the amount of cultivated land used to sustain existing agricultural populations in 1985 for the six regions as a whole and for each region individually.[4] Using the different regional growth rates (noted in Section 5.1), the table also indicates the amount of additional agricultural land that would be needed to absorb the agricultural labor force estimated in Table 2. Population densities in future years are assumed to resemble those that existed in 1985.

The data suggest the need for a dramatic increase in cultivated land of as much as 1.42 million hectares by 2007, compared to that in use in 1985. These figures assume maintenance of the current land-to-labor ratios to employ this labor force.[5] In the absence of significant increases in irrigation infrastructure, these numbers probably underestimate the land actually required. This obtains because the additional land would probably be acquired through reliance on the marginally productive *tavy* or *tanety* zones.

6. Potential Yield Improvements: Implications for Production, Employment, and *Tavy* and *Tanety* Rice Production

Given the preference to avoid increased reliance on *tavy* and *tanety* zones, what are the prospects that significant increases in production can be achieved, assuming both improvements in infrastructure and the adoption of new technologies? Two hypothetical scenarios for Lac Aloatra and Marovoay are used to address this question. A primary reason for the analysis is to consider the prospects of eliminating or reducing dependence on marginal *tavy* and *tanety* lands, so both scenarios assume that no additional land will be cultivated with rice beyond that in use in 1992.

The first scenario is based on best estimates of yield and changes in labor use associated with improvements in irrigation and the introduction of new seed varieties over a five-year period, from 1992 to 1997. This is a short-term scenario, and dependent on technology currently available. The scenario incorporates an important caveat that should be noted. Once the improvements are fully introduced in 1997, there will be no further increases in production due to the improvements after that year. Given past experience and the likelihood of continued successes in developing new seed varieties, this assumption may be unwarranted. A modest but more realistic increase in production of perhaps 1 percent per year beyond 1997 might be anticipated, but such an increase is not presently included in the analysis that follows.

The second scenario assumes a doubling of yields per hectare between 1992 and 2007, which is far more optimistic than the first scenario.[6] It will be difficult to achieve such gains, but the scenario is used to assess the possibility that Madagascar's rapidly growing agricultural labor force can be absorbed without reliance on additional land, especially in environmentally marginal areas. The two scenarios are not mutually exclusive, and the second can be viewed as a long-term complement to the first. In other words, the consequences of applying both scenarios will be a cumulative increase in production greater than that associated with with either scenario individually.

Prospects for Change: Lac Alaotra

Before assessing the consequences of the hypothetical scenarios, it is first necessary to examine current levels of production in each region. In the Lac Alaotra area, for example, the area used for the cultivation of rice increased to about 83,100 hectares in 1989 from 78,000 hectares four years earlier. Richaud (1990) estimates that about 35,000 of these are irrigated, of which 12,000 hectares are poorly irrigated and where transplanting is not used or late transplanting leads to yield losses. Of the remaining hectares devoted to rice (about 45,200 based on the 1985-89 average of 80,200 hectares), about 20,000 hectares are severly flooded during some portion of the year, and about 22,000 hectares are rainfed rice. In 1989, the area estimated to be in *tavy* or *tanety* production was approximately 3,700 hectares. This was well more than twice as much as had been in *tavy* or *tanety* production just four years earlier.

Considering all the land used to grow rice in the Lac Alaotra region, average yield per hectare was 2.37 MT between 1985 and 1989.[7] Over the same time period overall production averaged 190,692 MT per year. Of this amount, an estimated 70,000 MT of rice were marketed each year (Richaud 1990), and approximately 43,400 MT were suitable for human consumption. With annual average per capita consumption of rice at 130 kg, the annual consumable rice supply from the Lac Alaotra region is enough to feed approximately 334,000 people or about 2.5 percent of Madagascar's estimated population in 1992.

Can production be increased significantly and in such a manner as to have a measurable impact on employment? Assessment of the two hypothetical scenarios provides some answers.

Scenario 1: Reasonable Yield and Employment Changes in Lac Alaotra

The first scenario for Lac Alaotra is based on the assumption that improved irrigation control and new seed varieties, such as a change from MK34 to 2798, diffused over a five-year period, will reduce yield losses due to flooding, poor irrigation control, or late transplanting.

The outcomes anticipated with this scenario include an increase in total output of approximately 19,440 MT per year by 1997, based on increased yields of .5 MT per hectare on 38,880 hectares.[8] Similarly, such an increase in production would be associated with an increased demand for labor of 15.8 man-days per hectare per year from an average of 110.2 days

for nontransplanting methods to 126 days, which is the average for transplanting methods in Lac Alaotra estimated in the 1984-1985 agricultural census (see Table 4).[9] The total increase in direct annual labor is estimated to be 614,300 man-days (i.e., 37,880 hectares times 15.8 man-days per hectare). Direct labor includes activities associated with transplanting and production, transportation of rice to villages, threshing, and drying.

Women may account for as much as 50 percent of labor in rice production. According to the 1984-1985 agricultural census, women's labor is the equivalent of 0.5 man-days. Thus, new employment opportunities will increase by 921,450 days of labor (i.e., 614,300 man-days times 1.5). With full employment assumed to be 200 days per year, 921,450 days of additional labor produce direct annual employment for an additional 4,607 people (adult-male equivalent).

To assess potential increases in labor requirements indirectly associated with increases in production, following Dorosh et al. (1992), the multiplier for each additional day of direct employment in production is .91. Consequently, the total increase in direct employment of 4,607 presumably produces another 4,192 jobs indirectly for a total of just under 8,800 new jobs.

The data in Table 5 summarize these changes and illustrate that the anticipated increase in employment is equivalent to about 11.4 percent of the Lac Alaotra region's projected overall growth in its agricultural labor force between 1992 and 1997. There are no further gains in employment due to the improvements after 1997, so this employment increase is equivalent to only 3.0 percent of the expected growth in the region's labor force between 1992 and 2007. Given an annual average production of 190,692 MT, the projected increase due to the improvements (i.e., 19,440 MT by 1997) would increase average yields by 1997 by about 10 percent to 2.62 from 2.37 MT/Ha.[10]

In terms of the prospects for increased consumption, the anticipated increase from Scenario 1 would provide rice for about 92,500 people, or about 4 percent of the additional population growth between 1992 and 1997 (and about 1.2 percent of the additional population growth to the 2007).[11]

In sum, while the expected increase in production is reasonably important, the employment effects are relatively modest. This occurs because, while transplanting methods use more labor, transplanted production in Lac Alaotra is also associated with more animal use and other inputs, such as the herbicide 2,4-D, that substitute for labor.

Scenario 2: A Doubling of Yield

The second scenario for Lac Alaotra assumes that new technologies will become available that double average yields to 4.74 MT/ha from an average of 2.37 MT/ha on 80,200 hectares (i.e., the average area under rice cultivation between 1985 and 1989). Richaud (1990) reports that the application of 100 kg of urea can increase yields by .875 MT/ha. Similarly, the FAO Fertilizer Program reports that 104 kg of NPK can increase yields by .967 MT/ha.

The outcome anticipated with these changes includes a doubling of average annual yields to 381,384 MT from 190,692 MT by 2007. Little information is available on the changes in the demand for labor that would be required with such an increase. Nonetheless, data from the agricultural census of 1984-1985 suggest that doubling average yields in the Lac Alaotra region would increase labor use by 51.4 man days per hectare (to 159.7 man days from an average of 108.3 man days per hectare). Consequently, Scenario 2 is associated with an increase of 4,122,280 days of male-equivalent labor and 6,183,420 days of direct employment for males and females. At 200 days per year, the increase in labor is equivalent to annual direct employment for slightly more than 30,900 people and another 28,100 people through indirect employment, for a total of just over 59,000 jobs.[12] This change in employment is thus capable of absorbing slightly more than 20 percent of the increase anticipated in the agricultural labor force in Lac Alaotra between 1992 and 2007. The projected changes associated with Scenario 2 are summarized in Table 5.

Despite the increased demand for labor associated with a doubling of yields, it should be noted that such demand is likely to be seasonal. At certain times, such as during transplanting and harvesting, much of the additional demand will produce only short-term wage opportunities rather than permanent, sustained employment.

It is important to note as well that prices and the availability of credit and inputs will affect incentives to adopt alternative techniques and to intensify production. Moreover, returns to farmers in Lac Alaotra for each day of labor are higher for the transplanting methods than for the nontransplanting methods (as reported in the last column of Table 4). This finding suggests that farmers will be amenable to substituting techniques in favor of transplanted rice with high input technology.

Prospects for Change: Marovoay

The Marovoay plain has a surface area of 38,400 hectares potentially suitable for cultivation and 16,000 of these are irrigated. Of the 21,658 hectares cultivated in rice, about 40 percent is in the first season irrigated rice (*Jeby*), and most of the rest is in second season rice (*Atriaty*).[13] Unlike farmers in Lac Alaotra, those in Marovoay already rely substantially on transplanting methods for rice production. Moreover, farmers in Marovoay did not rely on *tavy* or *tanety* production, at least in the 1980s.

Scenario 1: Reasonable Yield and Employment Changes in Marovoay

The assumptions for the first scenario in Marovoay are the similar to those in Lac Alaotra, except that the analysis must account for two production seasons and a slightly higher anticipated increase in yield per hectare as a result of improving irrigation control and the introduction of new seed varieties. Table 6 displays the anticipated consequences of these changes in Marovoay.

For second-season rice production, improved irrigation should allow a change from nontransplanting to transplanting on 4,550 hectares for an increased yield of .6 MT/ha and an additional 2,730 MT of rice.[14] This increased yield is equal to 75 percent of the additional average yield associated with the change from nontransplanting to transplanting methods. For these 4,550 hectares, labor requirements are assumed to increase by 52 man-days per hectare, or about 75 percent of the difference in labor use between nontransplanted and transplanted rice methods, implying a total increase of about 236,600 man-days of labor.

The data in Table 6 also provide an indication of the other outcomes associated with the first scenario for Morovoay. Briefly, these data reveal an expected increase in production of 15,248 MT by 1997, and over 5,600 additional jobs per year. These are sizable increases, but the increased production will provide rice for slightly more than 3 percent of the additional population growth projected to occur between 1992 and 1997.

Scenario 2: A Doubling of Yield

Table 7 summarizes the anticipated effects of Scenario 2 in Marovoay, which assumes that the use of new technologies will double yields, to 5.6 from 2.8 MT/ha average yield in the first season on 8,446 hectares and to 3.4 from 1.7 MT/ha average yield in the second season on 13,212 hectares. The total effect of these yield changes would be to increase total production by just over 46,000 MT, thus producing almost 11,000 annual jobs and rice for another 220,000 people. Despite the magnitude of the increases, they are not sufficiently large to match the anticipated increases in the need for rice or the need for increased agricultural employment.

As discussed for Lac Alaotra, future economic conditions will actually determine the incentives to adopt new methods and to intensify production.[15] As an illustration, in Scenario 1 the main cash costs associated with increasing yields in Marovoay are related to new seed varieties, labor, and perhaps credit.[16] For Scenario 2, where average yields double, the additional costs to the farmer involve labor, fertilizers, seed varieties, pesticides, and improved irrigation.

7. Potential Impacts on Future *Tavy* and *Tanety* Land Use

The employment and output changes associated with the two scenarios can be related to pressures for the expansion of agriculture to more fragile and ecologically sensitive lands. Whether this labor would move into *tavy* and *tanety* rice production, to other crops, or to urban areas depends on the future economic environment.

For example, the total employment increase associated with the first scenario for Lac Alaotra and Marovoay exceeds 19,600. To the extent that *tavy* and *tanety* production is an (undesirable) alternative, about 19,000 hectares of land would have to be devoted to such production to create the same level of employment as is associated with the first scenario.[17] Similarly, the expected increase in employment for the two areas in the second scenario

approaches 80,000. If all the employment associated with this scenario was to be absorbed into *tavy* and *tanety* production, about 79,900 hectares of land would be needed to create the same level of employment. Given the low wages to labor and returns to farmers in *tavy* and *tanety* production, slowing the growth of such production may be possible through agricultural intensification.

In contrast, the total increase in rice production under Scenario 1 is nearly 34,700 MT. Given an average yield of roughly 1.11 MT/ha with *tavy* and *tanety* production, about 31,500 hectares of such production would be needed to provide an equivalent amount of rice. To match the increase in production associated with Scenario 2 (i.e., 236,801 MT), more than 213,300 hectares of *tavy* and *tanety* production would be needed. Most important, these data clearly indicate that while the production increases associated with either scenario cannot absorb the expected increases in the total labor force in the Lac Alaotra and Marovoay regions, the hypothesized increases in rice production can be expected to reduce some of the pressure for the expansion of rice production on *tavy* and *tanety* lands.

8. Conclusions

The study's main purpose has been to analyze the impacts of the intensification of rice production in Lac Alaotra and Marovoay on employment and aggregate rice production. Many sources were used to develop relevant scenarios for yield and labor requirements, including discussions with rice researchers, a survey of results of agricultural research programs, and detailed information from the 1984-1985 agricultural census. Potential yield changes associated with new technologies were readily available in summaries of research results, but the associated labor changes are not as accessible. Thus, specific labor requirements with technological changes had to be developed based on existing but scarce data.

There are two main conclusions of this analysis. First, reasonably important increases in rice production are possible from existing and newer technologies that are currently available. These technologies could probably become economically profitable to adopt. Second, the employment increases associated with these increases in production would be modest and not sufficient to employ a substantial portion of the additional labor force in the Lac Alaotra and Marovoay regions over the next fifteen years. These conclusions hold for both reasonable technological possibilities in the short term (Scenario 1) as well as optimistic yield and employment increases in the longer term (Scenario 2). An important limiting factor in the scenarios considered in this study is surface area. Given existing irrigated areas, Lac Alaotra and Marovoay cannot be expected to supply the country's rice and absorb rural labor force growth whatever the technology, at least according to the analyses presented in this study.

Endnotes

1. These estimates are higher than those used in other studies. For example, in *Bilan de la Recherche Rizicole* (Ministere de la Recherche Scientifique et Technologie pour le Developpement, 1992), the estimated population in 1992 is 12.1 million because a 2.8 percent growth rate is assumed. The 1985 population estimate was 10.0 million, which is lower than that estimated in the agricultural census of 1984-1985.

2. The Ministry of Agriculture assumes a 38 percent loss in the conversion from paddy production to rice consumption. Thirty-two percent of gross weight is lost in milling, transporting, and storage. Nine percent of the remaining amount is used for nonhuman consumption. Accordingly, for purposes of calculations, 61.88 percent of rice production is available for human consumption.

3. Temperatures below 20 degrees centigrade reduce yields of rice (Barker et al. 1985).

4. The regions comprise the *Faritany* of Antananarivo, the *Faritany* of Fianarantsoa, the *Faritany* of Toamasina except for the Lac Alaotra area, the *Faritany* of Mahajanga except for the *Fivondronana* of Marovoay, the *Fivondronana* of Marovoay, and the Lac Alaotra area, which comprises the *Fivondronana* of Amparafaravola, Ambatondrazaka, Andilamena, and Moramanga. The latter *Fivondronana* is included in the Lac Alaotra region because of its presence in the Lac Alaotra agroecologic zone in the agricultural census of 1984-1985. Moramanga's agricultural population in 1985 was estimated to be 124,500, or 32.5 percent of the total population for Lac Alaotra.

5. The regional agricultural-land to agricultural-labor ratios for 1985 were: 0.299 hectares per person of agricultural labor for Antananarivo; 0.286 for Fianarantsoa; 0.387 for Toamasina; 0.468 for Mahajanga; 0.594 for Lac Alaotra; and 0.815 for Marovoay. These data are from Ministere de la Production Agricoïe et de la Reforme Agraire (1988b).

6. A doubling of average yields in fifteen years is equivalent to an increase in yields of slightly over 4.7 percent per year, which would require considerable increases in productivity.

7. A weighted-average yield based on land area is slightly lower at 2.31 MT/ha.

8. This amount is equivalent to 90 percent of the amount of land in the region where seed variety 2798 was not already in use in 1989, minus the 23,000 hectares of land that is well irrigated and where late transplanting is not a problem. For reference, 38,880 equals 80,200 (average land in rice production between 1985 and 1989), minus 14,000 (area already using variety 2798), minus 23,000 (already well irrigated), times .90.

9. Specifically, 126 man-days per hectare per year represents the average of: a) the man-days of labor associated with transplanted, second-season rice grown with modern implements but no chemicals in Lac Alaotra (i.e., method "rta2s" in Table 4, which involves 143.72 man-days

per hectare per year); plus, b) the labor associated with transplanted, second-season rice grown with modern implements and chemicals (i.e., method "raa2s" in Table 4, which involves 108.29 man-days per hectare per year). Thus, 143.72 + 108.29 = 252.01/2 = 126.

10. This yield change is equivalent to a 2.5% annual growth in average yields.

11. See Section 2 for a discussion of the assumptions underlying per capita rice consumption and the relation between paddy production and quantities of rice available for human consumption.

12. The calculation of indirect employment uses a multiplier of .91, as explained above.

13. The estimate of 40 percent in first season rice (i.e., 8446 hectares) is from Ministere de la Recherche Scientifique (1992). A small portion is in the intermediate season crop (*asara*).

14. Rice was grown on approximately 4,550 hectares using nontransplanting methods in Marovoay in the late 1980s.

15. For example, wage labor used in second season transplanting techniques in Marovaoy is paid more per day than in nontransplanting methods, although returns to farmer labor per day are smaller (20.82 kg per day for nontransplanting techniques versus 12.25 kg per day for transplanting techniques). These techniques correspond to methods "nra2s" and "rta2s" for Marovoay in Table 4.

16. Of course, higher levels of nutrients in the soil would probably be needed to sustain these production increases over time.

17. As the data in Table 4 reveal, about 127-130 man days of labor per hectare are used in *tavy* and tanety production in Lac Alaotra. This is equivalent to about 190-195 days of employment when increased to incorporate women's labor.

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Tables and Figures

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Table 1

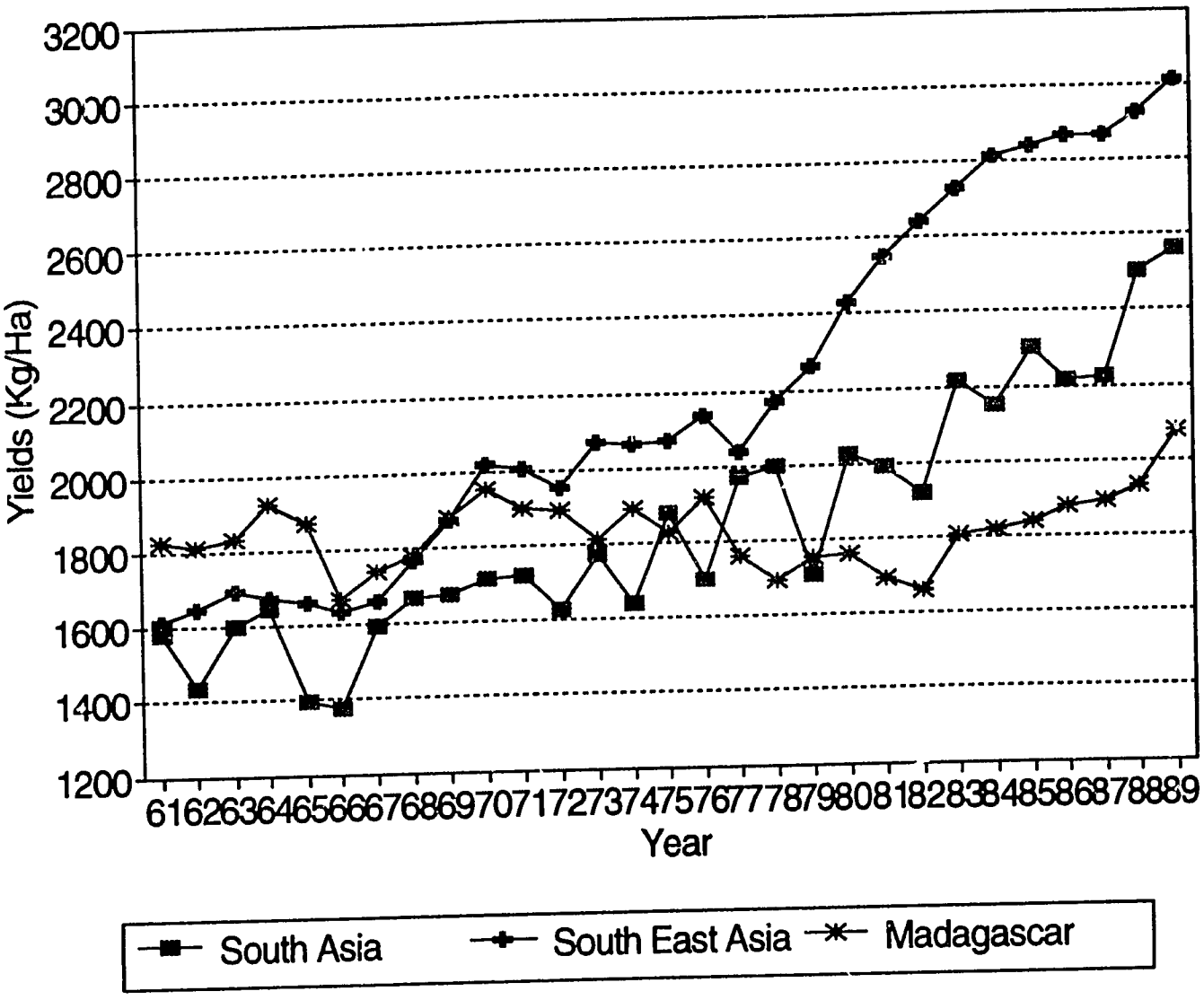
Trends in Madagascar's Population, Rice Production, and Consumption, 1985-2007

Year	Population (1000)	Consumption (1000mt)	Need (1000mt)	Production Trend (1000mt)	Gap (1000mt)	New Land (1000Ha)
1985	10600.000	1378.000	2222.714	2200.405	22.3	20.1
1986	10939.200	1422.096	2293.841	2226.986	66.9	60.2
1987	11289.254	1467.603	2367.244	2253.568	113.7	102.4
1988	11650.511	1514.566	2442.996	2280.150	162.8	146.7
1989	12023.327	1563.032	2521.171	2306.732	214.4	193.2
1990	12408.073	1613.050	2601.849	2333.314	268.5	241.9
1991	12805.1[illegible]	1664.667	2685.108	2359.895	325.2	293.0
1992	132[illegible]	1717.936	2771.032	2386.477	384.6	346.4
1993	1363[illegible]	1772.910	2859.705	2413.059	446.6	402.4
1994	14074.181	1829.644	2951.215	2439.641	511.6	460.9
1995	14524.555	1888.192	3045.654	2466.223	579.4	522.0
1996	14989.341	1948.614	3143.115	2492.804	650.3	585.9
1997	15469.000	2010.970	3243.695	2519.386	724.3	652.5
1998	15964.008	2075.321	3347.493	2545.968	801.5	722.1
1999	16474.856	2141.731	3454.613	2572.550	882.1	794.7
2000	17002.051	2210.267	3565.160	2599.132	966.0	870.3
2001	17546.117	2280.995	3679.245	2625.713	1053.5	949.1
2002	18107.593	2353.987	3796.981	2652.295	1144.7	1031.2
2003	18687.036	2429.315	3918.485	2678.877	1239.6	1116.8
2004	19285.021	2507.053	4043.876	2705.459	1338.4	1205.8
2005	19902.142	2587.278	4173.280	2732.041	1441.2	1298.4
2006	20539.010	2670.071	4306.825	2758.622	1548.2	1394.8
2007	21196.258	2755.514	4444.643	2785.204	1659.4	1495.0

Note: The arithmetic increases assume: a) a growth in population of 3.2 percent per year; b) average annual per capita consumption of 130 kg of rice; c) a 38-percent reduction from production to quantities available for human consumption; and , d) average production of 1.11 MT/ha on tavy and tanety land.

Figure 1

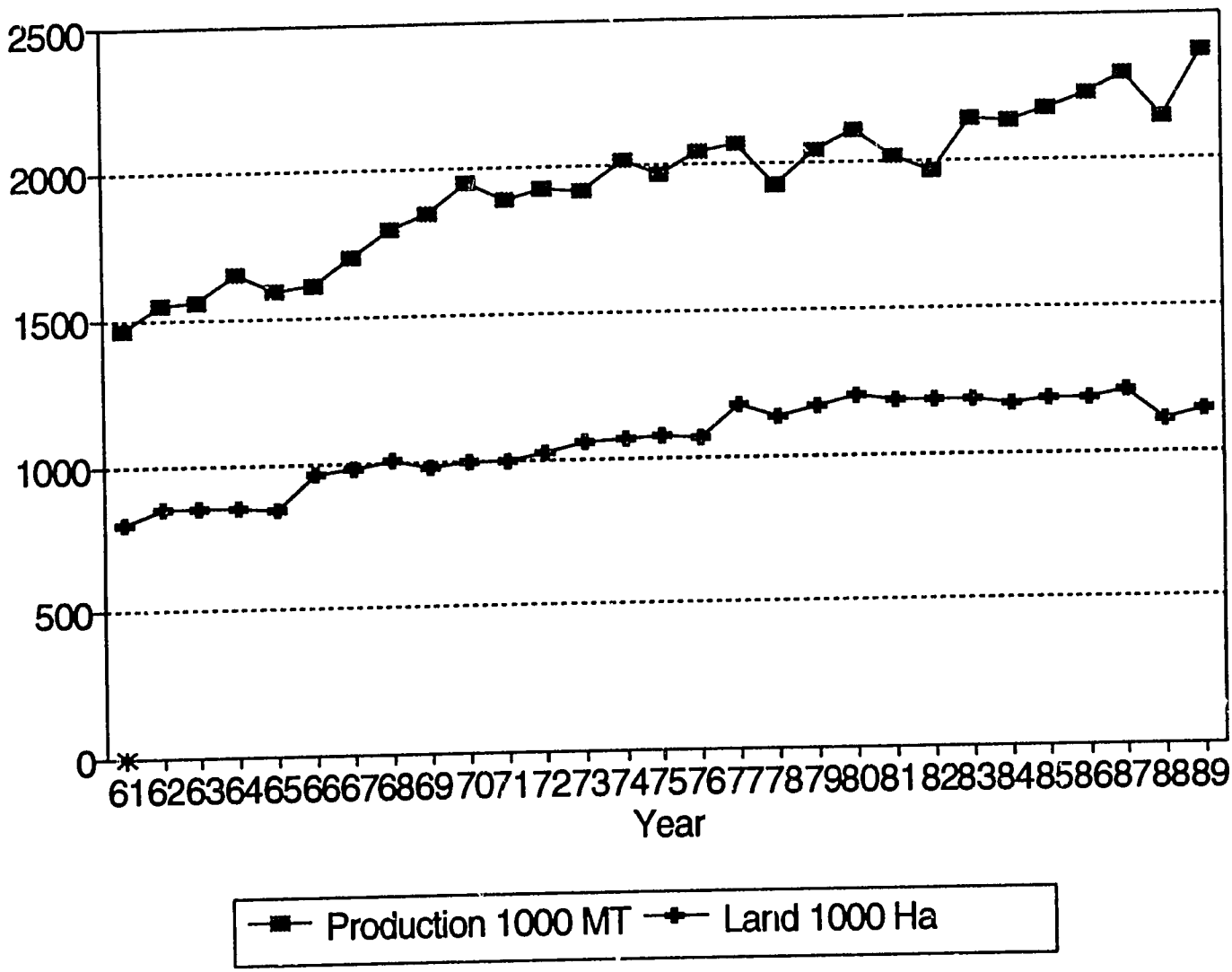
Trends in Rice Yields:
South Asia, Southeast Asia, and Madagascar, 1961-1989



Source: U.S. Department of Agriculture 1992.

Figure 2

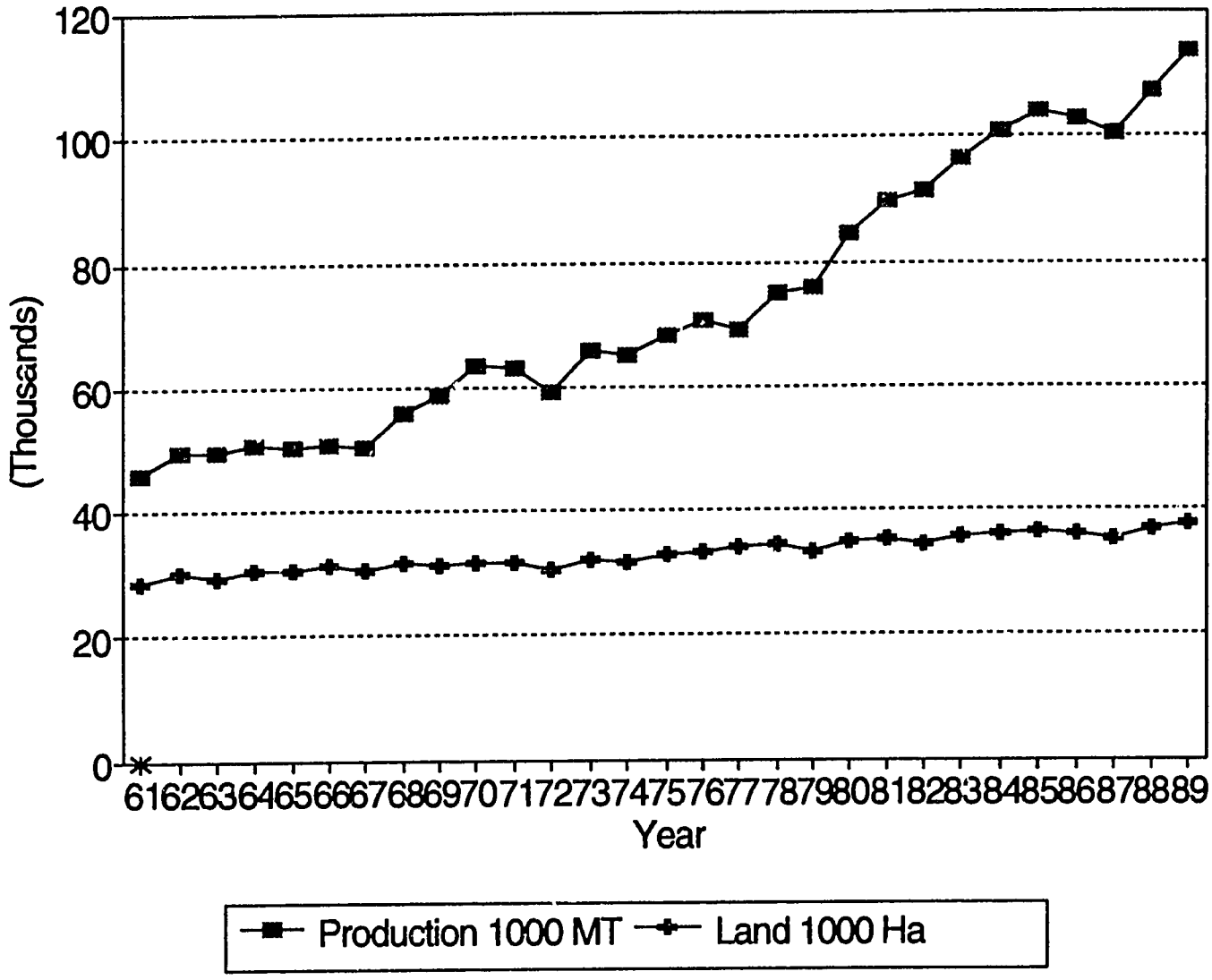
Madagascar's Rice Production and Land Devoted to Rice Production, 1961-1989



Source: U.S. Department of Agriculture 1992.

Figure 3

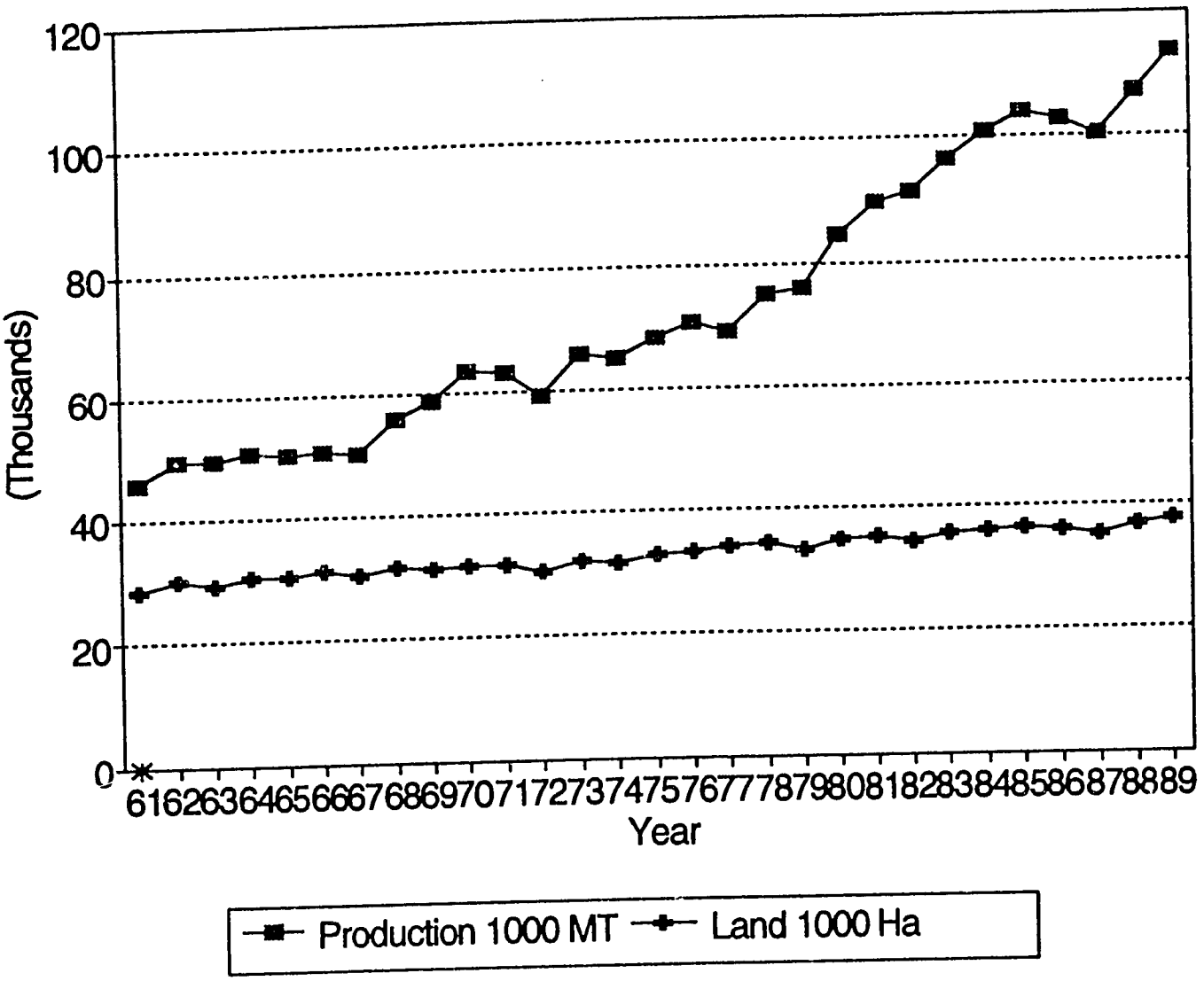
South Asia's Rice Production and Land Devoted to Rice Production, 1961-1989



Source: U.S. Department of Agriculture 1992.

Figure 4

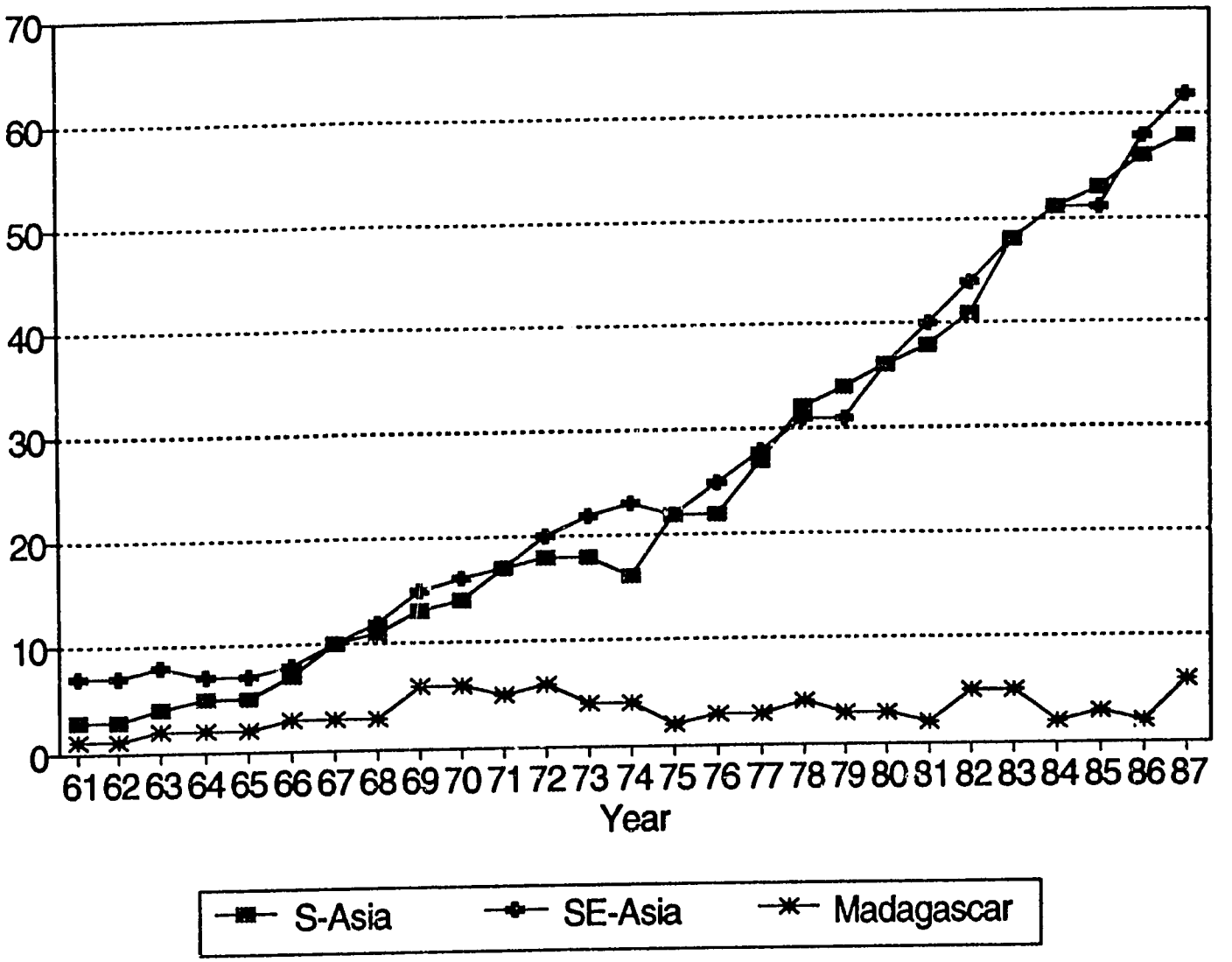
Southeast Asia's Production and Land Devoted to Rice Production, 1961-1989



Source: U.S. Department of Agriculture 1992.

Figure 5

Trends in the Use of Fertilizer (kg/ha)
in South Asia, Southeast Asia, and Madagascar, 1961-1989



Source: U.S. Department of Agriculture 1992.

Figure 6

Madagascar's Provinces (or *Faritany*)

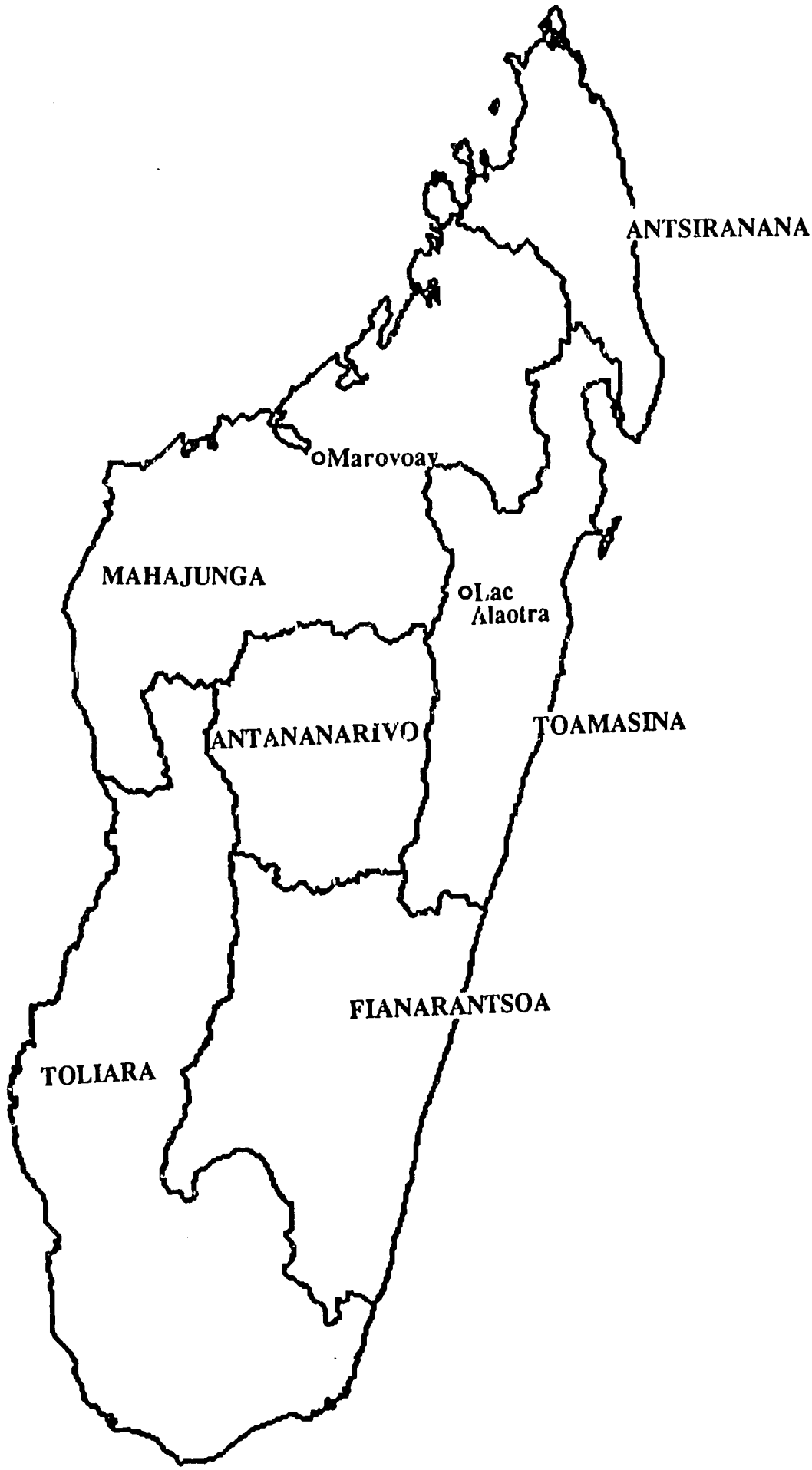


Table 2

Projected Agricultural Labor Force, 1985-2007

Growth Rate (%)	Antana 2.9	Fiana 3.3	Toama 2.9	Mahaj 3.2	Lac Ala 4.5	Marov 5.4	Total
1985	1166.340	1312.080	569.100	510.480	229.680	39.480	3827.160
1986	1200.164	1355.379	585.604	526.815	240.016	41.612	3949.589
1987	1234.969	1400.106	602.586	543.673	250.816	43.859	4076.010
1988	1270.783	1446.310	620.061	561.071	262.103	46.227	4206.555
1989	1307.635	1494.038	638.043	579.025	273.898	48.724	4341.363
1990	1345.557	1543.341	656.546	597.554	286.223	51.355	4480.576
1991	1384.578	1594.271	675.586	616.676	299.103	54.128	4624.342
1992	1424.731	1646.882	695.178	636.409	312.563	57.051	4772.814
1993	1466.048	1701.229	715.338	656.775	326.628	60.121	4926.150
1994	1508.563	1757.370	736.083	677.791	341.326	63.379	5084.513
1995	1552.312	1815.363	757.430	699.481	356.686	66.801	5248.072
1996	1597.329	1875.270	779.395	721.864	372.737	70.408	5417.003
1997	1643.651	1937.154	801.998	744.964	389.510	74.210	5591.487
1998	1691.317	2001.080	825.256	768.803	407.038	78.218	5771.711
1999	1740.365	2067.116	849.188	793.404	425.355	82.441	5957.869
2000	1790.836	2135.331	873.814	818.793	444.496	86.893	6150.163
2001	1842.770	2205.797	899.155	844.995	464.490	91.586	6348.800
2002	1896.210	2278.588	925.231	872.034	485.400	96.531	6553.995
2003	1951.201	2353.781	952.062	899.939	507.243	101.744	6765.971
2004	2007.785	2431.456	979.672	928.737	530.069	107.238	6984.958
2005	2066.011	2511.694	1008.083	958.457	553.922	113.029	7211.196
2006	2125.925	2594.580	1037.317	989.128	578.849	119.132	7444.932
2007	2187.577	2680.201	1067.399	1020.780	604.897	125.566	7686.420

Table 3

Land Needed to Employ Estimated Labor Force,
1985-2007 (in 1000ha)

Year	Antana 0.299	Fiana 0.286	Toama 0.387	Mahaj 0.468	Lac Ala 0.594	Marov 0.815	Total
1985	348.736	375.255	220.242	238.905	136.430	32.176	1351.743
1986	358.849	387.638	226.629	246.550	142.569	33.914	1396.149
1987	369.256	400.430	233.201	254.439	148.985	35.745	1442.056
1988	379.964	413.645	239.964	262.581	155.689	37.675	1489.518
1989	390.983	427.295	246.923	270.984	162.695	39.710	1538.589
1990	402.321	441.396	254.083	279.655	170.017	41.854	1589.326
1991	413.989	455.962	261.452	288.604	177.667	44.114	1641.788
1992	425.994	471.008	269.034	297.840	185.662	46.496	1696.035
1993	438.348	486.552	276.836	307.370	194.017	49.007	1752.131
1994	451.060	502.608	284.864	317.206	202.748	51.654	1810.140
1995	464.141	519.194	293.125	327.357	211.871	54.443	1870.132
1996	477.601	536.327	301.626	337.832	221.406	57.383	1932.175
1997	491.452	554.026	310.373	348.643	231.369	60.481	1996.344
1998	505.704	572.309	319.374	359.800	241.781	63.747	2062.714
1999	520.369	591.195	328.636	371.313	252.661	67.190	2131.364
2000	535.460	610.705	338.166	383.195	264.030	70.818	2202.374
2001	550.988	630.858	347.973	395.457	275.912	74.642	2275.831
2002	566.967	651.676	358.064	408.112	288.328	78.673	2351.820
2003	583.409	673.181	368.448	421.172	301.303	82.921	2430.434
2004	600.328	695.396	379.133	434.649	314.861	87.399	2511.767
2005	617.737	718.345	390.128	448.558	329.030	92.119	2595.916
2006	635.652	742.050	401.442	462.912	343.836	97.093	2682.984
2007	654.086	766.538	413.083	477.725	359.309	102.336	2773.076

Note: The land-to-labor ratios for 1985 are used. The applicable ratios (Ministere de la Production Agricole et de la Reforme Agraire 1988b) are noted below each region.

Table 4

Labor Requirements and Returns per Hectare
by Technology (Method) and Region

Region Method	% Total Area	Labor (M/D)	Meals (kg-M/D)	Tot-Wage (kg-M/D)	Tot-Labor (M/D)	Yield (kg)	Net Returns to Farmer (kg-M/D)
Lac-Alaotra							
rta2s	0.17	88.62	4.62	8.33	143.72	1911	19.08
raa2s	0.14	54.26	9.7	18.24	108.29	2330	26
nr	0.67	51.86	6.3	14.56	110.21	1445	19
average	0.98	57.41	6.36	13.72	113.43	1619	19.61
tavy	0.015	33.91	4.1	8.22	130.79	1081	6.82
tanety	0.005	36.25	4.68	9 02	127.42	1203	7.92
Marovoay							
rta1s	0.2	22.88	6.98	15.68	123	2342	2.91
rta2s	0.27	28.81	8.61	18.86	105.89	1693	12.25
ra2s	0.07	32.28	8.77	18.2	116.49	1711	11.1
rteb1s	0.19	27.09	8.16	16.36	108.62	1834	16.6
rteb2s	0.06	35.73	9.03	16.55	111.27	1720	12.51
nra2s	0.21	13.36	5.06	9.98	37.25	897	20.82
average	1	24.71	7.49	15.70	96.48	1875	12.94

Source: Ministere de la Production Agricole et de la Reforme Agraire 1987a, 1988d, 1988f.

Definition:

M/D is man-day equivalents.
Labor refers to workers employed for a salary.
Tot-wage includes the salary and meals, per worker, in kg of rice equivalent.
Tot-Labor includes the workers employed for a salary, family labor, and help among farmers.
Net Returns to Farmer include nonlabor costs and refer to net returns in rice equivalent per day of work of his own and his family's labor.

Methods:

rta2s. Repiquée, traditionelle, attelée, 2ème saison. (Transplanted, traditional, modern implements, 2nd season).
raa2s. Repiquée, ameliorée, attelée, 2ème saison. (Transplanted, chemicals, modern implements, 2nd season).
rta1s. Repiquée, traditionelle, attelée, 1ere saison. (Transplanted, traditional, modern implements, 2nd season).
ra2s. Repiquée, attelée, 2ème saison (rta 86%, raa 14%). (Transplanted, modern implements, 2nd season).
rteb1s. Repiquée, traditionelle, émottage boeuf, 1ere saison. (Transplanted, traditional, animal traction, 1st season).
rteb2s. Repiquée, traditionelle, émottage boeuf, 2ème saison. (Transplanted, traditional, animal traction, 2nd season).
nra2s. Nonrepiquée, attelée, 2ème saison. (Non-transplanted, modern implements, chemicals, 2nd season).

For additional explanation on the meaning of certain terms and aggregation procedures see next page.

The coefficients in Table 4 are derived from the 1984-1985 Census of Agriculture and reflect data for the relevant *Faritany*. In contrast, the costs of production and budgets for each rice technology are available only for agroclimatic region (MPARA 1987a). The correspondence between these regions and the *Faritany* is as follows:

1. Lac Alaotra.

The *Faritany de Toamasina* (*Découpage en Circonscriptions de Vulgarisation Agricole)* includes regional agricultural subdivisions 312 (Amparafaravola), 313 (Ambatondrazaka), 314 (Moramanga), and 316 (Andilamena). These subdivisions correspond roughly to *Sous-Region* 52: Lac Alaotra of the *Agroclimatique Grande Region 5: Les Hauts Plateaux.*

2. Marovoay.

The *Faritany de Mahajanga* (*Découpage en Circonscriptions de Vulgarisation Agricole)* includes regional agricultural subdivision 406 (Marovoay). This subdivision corresponds to *Sous-Region* 43: *Nord-Oeust* of the *Agroclimatique Grande Region 4: Le Littoral Ouest.*

The production techniques discussed in Table 4 include:

1. traditional with traditional techniques in nursery transplanting and cultivation;
2. manual with only manual labor with traditional tools, such as the *angady*;
3. modern implements, in which such implements as ploughs are used;
4. *tavy* cultivation on steep slopes of forested areas with tillage and broadcasted seed; and,
5. *tanety* cultivation on the high plateau, with little or no tillage and broadcasted seed.

The coefficients in the table correspond to aggregates of techniques used in transplanted versus (nontransplanted) broadcasted irrigated and nonirrigated rice production. Total labor requirements (in man days) per hectare or metric ton of paddy include hired workers, family labor, and help among farmers (*entr' aide*).

Table 5

Summary of Scenario 1 and 2 for Lac Alaotra Region

Variable	Unit	Scenario 1 (by 1997)	Scenario 2 (by 2007)
Change in Yield	MT/ha	0.5	2.4
Area	Ha	38,880.0	80,200.0
Production Increase	MT	19,440.0	190,692.0
Direct Employment			
	Days (Male Units per ha)	15.8	51.4
	Days (Male Units per ha)	614,300.0	4,122,280.0
	Days (+50% for Women's Labor	921,450.0	6,183,420.0
	Jobs (200 days/year)	4,607.0	30,917.0
Indirect Employment	Jobs	4,192.0	28,135.0
Total Employment	Jobs	8,799.0	59,052.0
Labor Growth to 1997	percent	11.4	*
Labor Growth to 2007	percent	*	20.2
Rice Equivalent (for Consumption)	MT	12,029.0	118,000.0
People Rice Goal	People	92,531.0	907,694.0
Population Growth to 199	Percent	4.0	*
Population Growth to 200	Percent	*	11.4

Table 6

Summary of Scenario 1 for Marovoay

Variable	Unit	Season 2	Season 2	Season 1	Total
Yield Change	MT/ha	0.6	0.5	0.7	*
Area	Ha	4,550.0	13,212.0	8,446.0	*
Production Increase	MT	2,730.0	6,606.0	5,912.0	15,248.0
Direct Employment					
	Days (Male Units per ha)	52.0	26.5	20.0	*
	Days (Male Units)	23,660.0	350,118.0	168,920.0	*********
	Days (+50% for Women's labor)				*********
	Jobs (200 days/year)				5,667.0
Indirect Employment	Jobs				5,167.0
Total Employment	Jobs				10,824.0
Labor Growth 1997	Percent				63.0
Labor Growth 2007	Percent				15.7
Rice Equivalent (for Consumption)	MT				9,453.0
People Rice Goal	People				72,721.0
Population Growth to 1997	Percent				3.2
Population Growth to 2007	Percent				*

Note: The changes are assumed to occur over a five-year period, 1992-1997

Table 7

Summary of Scenario 2 for Marovoay

Variable	Unit	Season 2	Season 1	Total
Yield Change	MT/ha	1.7	2.8	*
Area	Ha	13,212.0	8,446.0	*
Production Increase	MT	22,460.4	23,648.8	46,109.2
Direct Employment				
	Days (Male Units per ha)	72.0	60.0	*
	Days (Male Units)	951,264.0	506,760.0	1,458,024.0
	Days (+50% for Women's labor)			2,187,036.0
	Jobs (200 days/year)			10,935.0
Indirect Employment	Jobs			9,951.0
Total Employment	Jobs			20,886.0
Labor Growth to 1997	Percent			*
Labor Growth to 2007	Percent			30.0
Rice Equivalent (for Consumption)	MT			28,587.0
People Rice Goal	People			219,904.0
Population Growth to 1997	Percent			*
Population Growth to 2007	Percent			2.6

Note: The changes are assumed to occur over a fifteen-year period, 1992-2007.

Appendix A

Scope of Work

ARTICLE I - TITLE

Madagascar Rice Study, Program Development and Support (698-0510)

ARTICLE II - OBJECTIVE(S)

The objective is to provide USAID/Madagascar with order of magnitude estimates of the economic and environmental impacts of a scenario for improving the productivity and efficiency of Madagascar's rice subsector.

ARTICLE III - STATEMENT OF WORK

The contractors will assemble desegregated population and labor force data from Government of Madagascar sources for the two surplus rice producing areas--Lac Alaotra and Marovoay--and for the potential labor supplying areas. Labor force growth will be estimated for fifteen-year horizon. The land requirements necessary for the rural portion of the labor force growth to be absorbed in agriculture will be estimated.

Potential rice yield increases based on new techniques/technologies will be determined by interviewing rice researchers working in Madagascar. Estimates of the labor requirements per unit of land of the new technologies will be coupled with possible assumptions of farmer-adoption rates to derive labor demand over a fifteen-year horizon. A simple wage differential model will be developed to provide labor supply estimates.

Using the derived labor supply estimates, the consultants will calculate the difference in land use under tanety/tavy production (i.e., with and without new rice technology). The potential additional demand for rice for domestic consumption during the planning horizon will be estimated. If quantity supplied exceeds quantity demanded during the fifteen-year horizon, the consultants will estimate the additional amount of land that could be taken out of tanety/tavy production.

Contractor shall prepare a draft final report which shall provide the various order of magnitude estimates described above. In this report the contractor shall document all economic and social assumptions used in the course of developing the estimates.