Environmental Change Affecting the Rice Production in Thailand and in Monsoon Asia

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Abstract: Environmental change, particularly climatic change during the recent years, and its impact on rice production in Thailand and in Monsoon Asia were dealt with. First, it was pointed out that Thailand is situated roughly on the northeastern border of the area dominated by the SW monsoon in South Asia in the northern summer. On the other hand, it is located on the southwestern border of the prevailing NE monsoon in Southeast Asia in the northern winter. So Thailand is located in the most sensitive region for year-to-year change of the monsoons. Secondly, differences of precipitation and rice production between the El Niño years and the La Niña years in South Asia and Southeast Asia, including Thailand were dealt with. It is shown that a decrease in the El Niño years and, in contrast, an increase in the La Niña years is obvious. This is clearer in South Asia than in Southeast Asia, where there are some exceptional cases. Thirdly, examples in Northeast Thailand were presented. It is interesting to note that the differences of precipitation between 1992 (dry year) and 1994 (wet year) were negative, but the rice yield in the dry season was positive. This was considered to be a result of rapid technological development in the provinces of Northeast Thailand in the early 1990s, excepting the provinces of the surrounding mountainous or border region. Lastly, the concluding remarks took into consideration environmental problems on the global and Monsoon Asian scale as well as those in Thailand on a regional scale.

Key words: El Niño, environmental change, Monsoon Asia, rice production, Thailand

Introduction

It has been said that rice production has been sustaining the high population density of the countries in Southeast Asia. This was particularly true of the deltas of these regions, as has been studied by European and American researchers mainly in the first half of the 20th century (Yoshino 1998). Studies in regional geography examined this situation up to 30-40 years ago (Cressey 1963; Dobby 1970; Fryer 1970; Pendleton 1963; Robinson 1966). On the other hand, the pace of global and regional environmental change has been increasing over the last 15-20 years. From the standpoint of agroclimatology, research has been carried out taking into consideration food security problems in Monsoon Asia (Yoshino 1998, 1999). In the present paper, rice production in association with climatic variation is dealt with in Monsoon Asia, focusing on Thailand.

Climate Change in Thailand

During the recent decades

According to a recent report by IPCC (Intergovernmental Panel for Climate Change) (McLean et al. 1998, 1999), annual rainfall in Thailand has increased in the last decade and may continue increasing in the future, especially in the areas situated on the windward side of the monsoon season (Rungdilokraja and Nimma 1990). As discussed later, increasing precipitation in the dry season has become clear in Northeast Thailand during the last two decades, but decreasing tendency or no clear change is observed in the rainy season.

A thorough work on El Niño and La Niña has been published recently (Allan et al. 1996). According to their maps showing the distributions of temperature and precipitation anomalies, the impacts are estimated as given in Table 1. It is very clear that air temperature is higher (about
+0.7°C) and precipitation is lower (about −12%) in the El Niño years. In contrast, the air temperature is lower (about −0.7°C) and precipitation is higher (about +14%) in the La Niña years.

Differences between El Niño and La Niña years on a global scale

Sea surface temperature and monsoon conditions over Southeast Asia in El Niño years are somewhat different from those in the western Equatorial Pacific and Indian Oceans respectively. It has been made clear that the SW monsoon in northern summer is weaker in South and Southeast Asia and, in contrast, sea surface temperature (SST) is higher after the La Niña years, or before the El Niño years.

As has been well understood, in the El Niño years, SST is higher and the easterly trade wind is weaker in the eastern Equatorial Pacific region. In contrast, in the La Niña years, SST is lower and the easterly trade wind is stronger in the eastern Equatorial Pacific region. In the western Equatorial Pacific region, SST is lower after the period of El Niño years, and SST is higher after the La Niña years (Schopf and Suarez 1988). This situation results in the difference that the SW monsoon is weaker in the El Niño years and stronger in the La Niña years. This can be concluded from an examination of the results shown in Table 1.

Rainy season and dry season

Rainy season in Thailand has been generally recognized as from May to September and the dry season from November to March. Of course, it slightly fluctuates year-to-year and region to region. The earlier study on the period from 1906 to 1925 shows that the mean onset date of the rainy season was 25 April and the termination date was 12 December. The longest rainy season was 236 days in 1925 and the shortest, 174 days (Blöndli 1930). According to a recent study on the ten-day period, the rainy season starts in the first ten-day of May and ends in the third ten-day period of October in Bangkok (Matsumoto 1988, 1992).

The lengths of rainy and dry seasons, dates of onset and ending, and amounts of rainfall (grade of flooding and drought) which fluctuate widely, are of importance in particular for agriculture (Brookfield and Byron 1993). Japanese

| Table 1. Impacts of El Niño and La Niña on temperature and precipitation anomalies in Thailand and its surrounding regions during 1877–1982 |
|---------------------------------------------------------------|
| **Number of cases during the statistical period** | El Niño years | La Niña years |
|---------------------------------------------------------------|
| **Temperature** |
| Negative anomaly cases | 1 | 14 |
| Estimated mean values | − | −0.7°C |
| (with range) | — | (0~−1.1°C) |
| Positive anomaly cases | 9 | 0 |
| Estimated mean values | +0.7°C | — |
| (with range) | (+0.5°C~+1.0°C) | — |
| No data or unknown cases | 6 | 4 |
| **Precipitation** |
| Negative anomaly cases | 12 | 0 |
| Estimated mean values | −12% | 0 |
| (with range) | (0~−30%) | — |
| Positive anomaly cases | 0 | 11 |
| Estimated mean values | — | +14% |
| (with range) | — | (0~+24%) |
| No data or unknown cases | 4 | 7 |
researchers also have dealt with the impact of such conditions in regional geography in the period before World War II (Noh 1941) and in a recent detailed field study (Fukui 1993, 1996; Takaya 1985; Konchan and Kono 1996). Kono (1997) researched unstable rice production based on anomalous drought and its influence on human societies.

**Relation to monsoon**

In the northern summer, the SW monsoon, causing the rainy season, prevails over South Asia including Southeast Asia. On the other hand, in the northern winter, the NE monsoon which causes the dry season predominates over South Asia including some parts of Southeast Asia (Bländli 1930). Of course, the SW monsoon reaches East Asia including South China and Southwest Japan on the extreme boundaries. Similarly, the NE monsoon reaches South Asia including Sri Lanka and the surrounding tropical seas on the extreme boundary (Schopf and Suarez 1988; Webster et al. 1998).

In order to clarify such boundaries, two maps are introduced from the work by Kawamura (2000) and Kawamura et al. (2000). Distributions of sensible heat flux deviation with an interval of 10 W/m² and wind stress vector (shown by the arrows) is given for March and May. In Figure 1, the distribution of difference of these values between strong monsoon cases minus weak monsoon cases are shown. As has been mentioned, March is the month within the dry season. On the other hand, May is the month of the rainy season, so it can be understood that they are the conditions in the cases of the winter monsoon (dry season) and the summer monsoon (rainy season), respectively.

From Figure 1, it is noteworthy that Thailand is located on the most southwestern boundary of the strong NE monsoon and, in contrast, at the most northeastern boundary of the strong SW monsoon. It is quite important that Thailand is located in the region where the year-to-year fluctuation of monsoons is the most sensitive among Southeast Asian countries. According to a figure showing monsoon circulations (Meehl 1994), Thailand is situated just on the boundary between warm/cold SST region over the Indian Ocean and cold/warmer SST region over tropical Southeast Asia, data which reinforces the meaning explained above.

**Precipitation Distribution On Regional Scale**

Taking examples of the dry season and the wet season of typical El Niño and La Niña years, differences between the precipitation distributions are studied in this part of the present study. Details of the periods of dry and rainy seasons are given in Table 2.

**Rainy season**

In Figure 2, distribution of precipitation in the wet season of El Niño year is shown. Regions with the most scarce precipitation, less than 500 mm, appear in the central part and on the coast of the Gulf of Thailand. The northwestern basin is also relatively drier, but less than 600 mm. Isohyet line of 750 mm surrounds these scarce precipitation regions. The mountain region of the peninsula receives more than 4,000 mm. The sharp decrease of precipitation from the mountain region to the coast is drastic.

The relatively drier parts on the lee of the mountain range to the SW monsoon have been pointed out in general terms in every type of monsoon circulation (Yoshino and Aihara 1971; Yoshino 1973), but the details were first made clear in Figure 2.

Figure 3 shows the precipitation distribution in the wet season of the La Niña year. The relatively drier parts are less than 750 mm in the central plain, the northwestern basin and the innermost part of the Gulf of Thailand. The general tendency for precipitation in the El Niño years to be more than in the La Niña years, as shown in Table 1, coincides with the facts given in Figures 2 and 3. It is quite interesting to note that the relatively drier region of less than 750 mm in the northwestern basin shifts slightly eastward. The reason can be attributed to the fact that the SW monsoon, causing the foehn effect, is stronger in the La Niña year than in the El Niño year.

Differences between the El Niño and La Niña years in the rainy season are given in Figure 4. Broadly speaking, precipitation in the main
Figure 1. Composite deviation distribution simulated by atmosphere-ocean interaction for wind stress vector (length of arrow is shown at the lower part of maps) and sensible heat flux deviation (10 W/m²). Adopted from Kawamura, 2000.

Table 2. Examples of dry season and wet season of typical El Niño and La Niña year

|            | El Niño year                  | La Niña year                 |
|------------|-------------------------------|------------------------------|
| Dry season | Nov. 1996–March 1997          | Nov. 1995–March 1996         |
| Wet season | May–September 1997            | May–September 1996           |

part of Thailand is less in the El Niño years than the La Niña years. Exceptions are found in the northern mountain areas and southern peninsula areas. The exception in the north can
be related to the stronger convective activity in the mountain regions in the El Niño years. The exception in the south may be due to the positional shift or activity change of ITCZ (Yoshino 1971). In other words, the regional scale tendency is quite different from the macro (global)-scale tendency given in Table 1. Future studies are needed to clarify this situation. Because of space, short time precipitation has not been discussed, but the pattern given in Figure 4 resembles the pattern of the observed 24-hour maximum rainfall given by Yoshino (1976). Soil erosion and other hazards are related to short period rainfall intensity caused by strong convection. However, further detailed analysis is needed.

**Dry season**

As shown in Figure 5, isohyets in the dry season of El Niño year run zonally except for the western mountain areas, where it shows less than 50–100 mm. In the central part, these areas also have less than 100 mm. In the peninsula area, precipitation is as great as 500 mm or more, with extremes of more than 1,500 mm. This is related to the activity of ITCZ or NE monsoon in the El Niño years. A similar pattern was observed on the distribution map of precipitation days (Yoshino 1980).

Comparing Figure 5 with Figure 6, which show the precipitation distribution in the dry season of La Niña year, we can see a similar zonal tendency of isohyet directions in the central part and the peninsula part. But the absolute values are much smaller: for example, a zonal area less than 50 mm appears in the middle of Thailand. That means precipitation is about one third in the La Niña year compared with the El Niño year. As has been made clear in Table 1, precipitation in the La Niña years is more than in the El Niño years on the broad-scale. However, this is not the case for most
areas of Thailand.

In Figure 7, the difference between the El Niño and La Niña year is given. It is worth noting that the negative value of $-100$ mm appears in the northeastern part and the central part of Thailand, which should be taken into consideration in rice cultivation.

**Rice Production in Relation to Climate**

**Problems in Monsoon Asia**

In this section of the study, cultivation, production and the yield of rice in Monsoon Asia are dealt with. First, we should note the area of Monsoon Asia, where physical conditions (vegetation, soil and climate) and human societies, based on rice production, are similar. In particular, homogeneities with historical, anthropological, and cultural backgrounds are taken into consideration. According to researchers, the boundaries are slightly different as shown in Figure 8, in which Yoshino (1999) proposed the boundaries shown by the thick line.

The important points in Monsoon Asia should be as follows: 1) The recent trends in consumption, self-sufficiency, and demand for rice; 2) rice production in relation to El Niño and La Niña; 3) the rice cropping calendar in relation to environmental change; and 4) the historical development of paddy cultivation. The following three topics are the most urgent subjects of study: 1) urbanization/industrialization and rice-producing societies in Monsoon Asia; 2) the assessment of the impact of climatic fluctuations/changes on paddy production potential; and 3) the influence of arid or humid climate tendencies on regional/cultural development (Yoshino 1998, 1999).
An example is discussed by showing the differences of rice production between the El Niño and La Niña years in Southeast Asia and South Asia. The El Niño years taken are 1965, 1972, 1976, 1982, and 1987 and the La Niña years are 1968, 1971, 1975, 1985, and 1989 considering the available data. Southeast Asia includes Thailand, Malaysia and Indonesia, and South Asia includes India, Sri Lanka, Bangladesh, and Myanmar. The results are given in Table 3. Although the cultivation area, rice yield and rice production in South Asia are negative without exception in the El Niño years, there are one or two exceptional cases in Southeast Asia. The impacts of anomalous SW monsoons should result in the same tendencies in South Asia, as has been well discussed by Gadgil (1995) for the Indian case, but there is an exceptional case which impacts on rice cultivation in Southeast Asia.

In the La Niña years, deviations are positive, except for one case among the five. The reason why such exceptions occurred in different years according to the cultivation area, yield or production, may be: the data used is (i) an annual total, including cases with various impacts in the rainy season and dry season, (ii) cultivation types and agricultural structure vary according to countries or regions calculated as South Asia or Southeast Asia in total, and (iii) El Niño/La Niña start and end in any month of the year, so that the impacts are different among cases.

It can be concluded, however, that (i) agricultural activities are negative in the El Niño years and, in contrast, positive in the La Niña years, and (ii) Southeast Asia has more exceptional cases than South Asia.
Figure 8. The boundary of Monsoon Asia.

Table 3. Differences of rice production between the El Niño and La Niña years in Southeast Asia and South Asia

|       | SE Asia |                   |                   | S Asia |                   |                   |
|-------|---------|-------------------|-------------------|-------|-------------------|-------------------|
|       | Cultivation area (×1,000 ha) | Yield (t/ha) | Production (×1,000 t) | Cultivation area (×1,000 ha) | Yield (t/ha) | Production (×1,000 t) |
| Year  |         |                   |                   |       |                   |                   |
| El Niño year |         |                   |                   |       |                   |                   |
| 1965  | -107    | +0.00             | -31               | -932  | -0.16             | -8,953            |
| 1972  | -1,314  | -0.03             | -3,515            | -924  | -0.06             | -4,113            |
| 1976  | +358    | +0.05             | +1,961            | -1,316| -0.12             | -7,787            |
| 1982  | -840    | +0.08             | +1,511            | -2,419| -0.05             | -6,019            |
| 1987  | -763    | +0.03             | -96               | -2,458| -0.01             | -4,079            |
| Mean  | -533    | +0.03             | -34               | -1,610| -0.08             | -6,190            |
| La Niña years |         |                   |                   |       |                   |                   |
| 1968  | +1,290  | +0.02             | +2,193            | +552  | +0.05             | +3,037            |
| 1971  | +191    | +0.00             | +74               | -544  | +0.01             | -253              |
| 1975  | +1,298  | +0.01             | +2,022            | +2,213| +0.16             | +10,760           |
| 1985  | +1,114  | -0.01             | +1,899            | -98   | +0.11             | +5,744            |
| 1989  | +1,013  | +0.02             | +2,707            | +607  | +0.08             | +5,178            |
| Mean  | +981    | +0.01             | +1,779            | +585  | +0.08             | +4,893            |
Table 4. Arable land area, cereal and rice production and rice yield in selected countries in Monsoon Asia

| Arable land | Production | Rice       |
|-------------|------------|------------|
|             | Total area* | Ratio (%)  | Cereal/head** | Rice*** | Yield**** |
| Thailand    | 20,800     | 40.5       | 427           | 21,130  | 2,385     |
| China       | 95,782     | 10.0       | 341           | 187,192 | 4,665     |
| Indonesia   | 30,171     | 15.8       | 300           | 49,860  | 3,840     |
| Japan       | 4,422      | 11.7       | 107           | 12,625  | 5,737     |
| Myanmar     | 10,076     | 14.9       | 459           | 20,109  | 2,962     |

* In 1994. Unit is × 1,000 ha
** In 1995. Unit is kg.
*** In 1995. Grain. Unit is × 1,000 t
**** In 1995. Unit is kg/ha

Table 5. Difference of rice yield between the El Niño and the La Niña years (negative means rice yield is less in the El Niño years than in La Niña years)

| Name of provinces or met. station | Rainy season* | Dry season** |
|----------------------------------|---------------|-------------|
|                                 | -10 kg/rai    | +20 kg/rai  |
| Nakhon Phanom                    | -14           | -70         |
| Sakon Nakhon                     | -8            | -14         |
| Nong Khai                        | -38           | -40         |
| Udon Thani                       | -28           | +29         |
| Loei                             | -33           | +62         |
| Mukdahan                         | +17           | +22         |
| Ubon Ratchathani                 | -25           | -28         |
| Knok Kaen                        | -50           | -72         |
| Roi Et                           | +29           | -10         |

* Rainy season in the El Niño years: 1982, 83, 87, 91, and 93, and in the La Niña years: 1984, 85, 89, 90, and 94
** Dry season in the El Niño years: 1983, 87, 88, and 92, and in the La Niña years: 1985, 86, 90, 93, and 94.

Problems in Thailand

Thailand is geographically located at the center of Monsoon Asia, as shown in Figure 8. This means, as already discussed in Figure 1, that Thailand is climatologically sensitive because of the SW boundary of the strong NE monsoon in the dry season. On the other hand, it is sensitive, because it is just on the NE boundary of the strong SW monsoon in the rainy season.

Rice production in relation to water resources, climatic anomaly or climate change has been studied for many years. Maruyama (1978) analyzed rice production in Thailand mainly in consideration of water balance components. Rasmidatta (1978) studied corn production in Thailand from the standpoint of agricultural meteorology, while Tsuji (1978) reported the results of economic studies on the effect of climatic fluctuation on rice production in Thailand. Macro-economic research has been developing during the recent years. In particular, there are several intensive studies by economic models. The various studies on agricultural statistics show the outstanding characteristics of Thailand to be a high ratio of arable land area and cereal production per head as shown in Table 4. This means that the effects of climatic anomalies caused by global warming will be the most serious among the countries in Monsoon Asia.

An example in Northeast Thailand

Rice production in the northeastern region occupies about 56% (5.12 million ha) of the total rice area of Thailand. However, the irrigated area is only 17% (0.79 million ha) throughout Thailand (Jongkaewwattana 1998). The year-to-year variations of rice yields and zero harvest areas show different trends from other major regions. The rice cultivation in Northeast Thailand has been a subject of study for many years (Fukui et al. 2000), and the changes in accordance with the improvement of irrigation techniques has been made clear. In this section, rice production in the rainy season and the dry season in Northeast Thailand is analyzed for the El Niño years and La Niña years. The El Niño and La Niña years selected are given in the lower part of Table 5. The results show that in the rainy season eight provinces among ten are negative, which means
that rice yields are less in the El Niño years than the La Niña years. On the other hand, six La Niña cases among ten were negative in the dry season. These differences of exception cases among all cases between the rainy and dry seasons can be attributable to the facts that rice cultivation in the dry season weakly depends on precipitation amount; in other
words, precipitation is more localized and irrigation plays more role in the dry season than the rainy season.

In Figure 9 (a) and (b), the secular variation in the dry season at Udon Thani and Khon Kaen are given. The increasing tendency is clear during the last two decades. In Figure 10, relationships between the precipitation differences (1992–1994) at the provincial level are shown. Actual precipitation values in 1992 and 1994 can be understood in Figure 9. As has been made clear by Konchan and Kono (1996), the accelerated economic growth attracted Northeastern Thai farmers to Bangkok and its suburbs, and this resulted in the introduction of labor-saving techniques, for example, direct seeding, during the early 1990s.

It is intriguing to note in Figure 10 that the differences of precipitation (1992–1994) were negative, because 1992 has the El Niño and 1994 has the La Niña tendency in the dry season, but the differences of rice yield (1992–1994) were positive, which means rice yield has not been dependent on precipitation in the central part of Northeast Thailand during this decade. Exceptions were found in the provinces which are located in the surrounding mountain region, like Nakhon Phanom, Loei and Sakon Nakon. Therefore, it is a good example to show the impact of precipitation anomalies on the rice yield in a period of rapid technological change. In the rice producing societies in shifting cultivation in Southeast Asia, changing tendencies to upland rice cultivation were pronounced during the historical period (Sasaki 1989). Such tendencies should be studied further in the mountain regions of Northeast Thailand, particularly considering recent technological development.

Concluding Remarks

Early studies concluded that the high density of population in Monsoon Asia could be supported only by agricultural societies based on rice production. This conclusion has been generally accepted and still appears in textbooks today. Is this conclusion applicable for the 21st century? More work is required to answer this question from the standpoint of each country in Monsoon Asia.

Food security has been considered on a national basis. On the other hand, world food security is discussed as a global scale problem from a long-term viewpoint. In the future, however, food security should be considered in a relatively broader region, which can be considered by geographical unit, such as Monsoon Asia, which is composed of the countries connected by similar physical and human characteristics. Thailand is located in the center of Monsoon Asia not only geographically, but also in terms of agricultural production problems.

Adaptations of agricultural societies to the environmental change due to the global warming are also important, as (1) change of sensitivity/deviation/range of anomaly, according to period (e.g. type of agriculture, life style, stage of infrastructure); (2) change of relationship between yield and climatic elements; (3) change of human impact, according to development stages of societies; and (4) changes of correlated regions or changes of parallel and opposite trends between individual regions. These are closely related to Monsoon circulations. These points should be emphasized in the 21st century in the studies relating to this field.
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