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IV. Agricultures of Six Villages in Central Thailand and Central Java*

by

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1. Soil Conditions

This report aims at evaluating the environmental factors relevant to agriculture in each of the six villages studied in this survey. Emphasis is placed on soil factors which were not discussed in details in the two previous reports on the environmental conditions of these villages.

(i) Saraburi Village

The predominating soil is a low humic gley soil specified as *Hin Kong series*. This series is characterized by a dark grayish brown top soil and a light gray sandy subsoil, bearing Fe-Mn concretions throughout. Genetically, the soil appears to have been formed on the weathering product of terrace materials. In some places laterite is found very close to the ground surface as the final product of weathering.

Although the main portion of the village and its vicinity are covered by this poor soil, some places, particularly in the southern part, are covered by fresh washouts derived from nearby hills. These can be described as moderately fertile patches on this poor terrain. Reasonably good paddy lands are found on these patches.

(ii) Ayutthaya Village

The *Ratburi series* and the *Phimai series* are the dominant soil series comprising the backswamp portion of the area. These soils have a heavy clayey texture. On the other hand, the levee portion consists mainly of the *Sanphaya series* and the *Tha Muang series* which are generally loamy in texture. All these soils are alluvial soils of recent riverine sediment origin. Thus, they are young and hence hardly indicate any sign of weathering.

The distribution of the soils in this area is shown in Fig. 1.

(iii) Pathum Thani Village

The area is covered by either the *Bangkok series* or the *Bang Len series* which are quite

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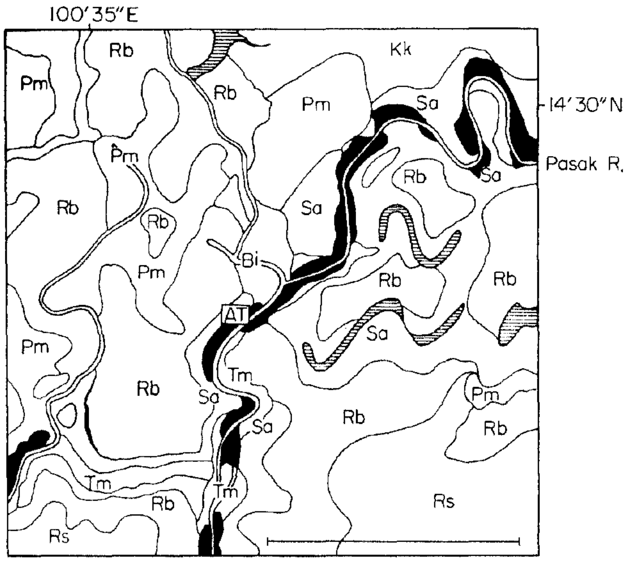
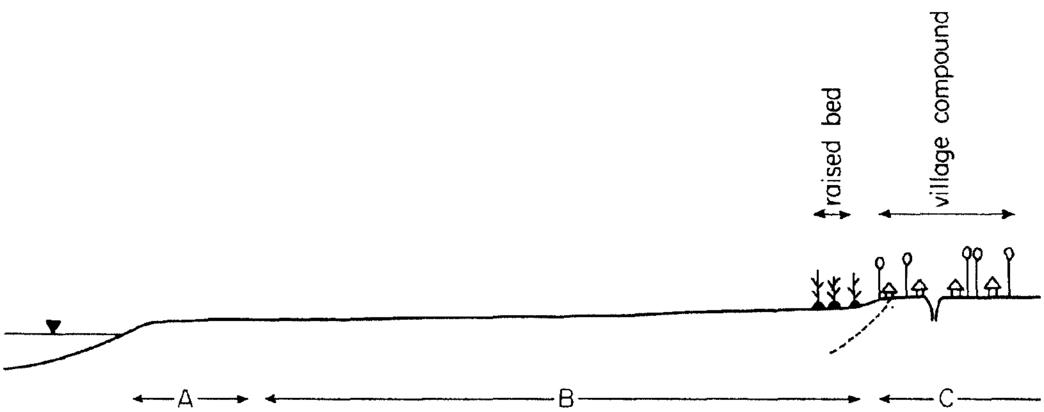


Fig. 1 Soil Map in the Vicinity of Ayutthaya (AT) Village (From F. J. Dent and Mana Cheuthongdee, 1966)

widely distributed in the Chao Phraya-Suphan inter-river area. The soils are of heavy clay texture and have gypsum crystals in their subsoils. They are hydromorphic alluvial soils developed on moderately acid marine alluvium.

(iv) Demak Village

The distribution of soils in and around the village is schematically illustrated by a profile (Fig. 2). Paddy fields, which are single cropped, are on a clayey hydromorphic alluvial soil developed from recent marine sediments. Because of their lowlying and near-sea position, the fields may suffer from floods in the rainy season and salt injury during the dry



	Land form	Soil	Land use
A	Recent alluvial plain	Clayey hydromorphic alluvial soil	Fish pond or salt evaporation field
B	do	do	Paddy field
C	Recent-subrecent alluvial plain	Grumusol	Village compound and paddy field

Fig. 2 A Schematic Profile through Demak (DM) Village and its Vicinity

season. Houses are located on slightly elevated places which coincide with the *Grumusol* zone of semirecent alluvium origin. The sea-facing strip, which is also lowlying and of recent marine alluvium origin, is utilized as sites of fish ponds in the wet season and salterns in the dry season.

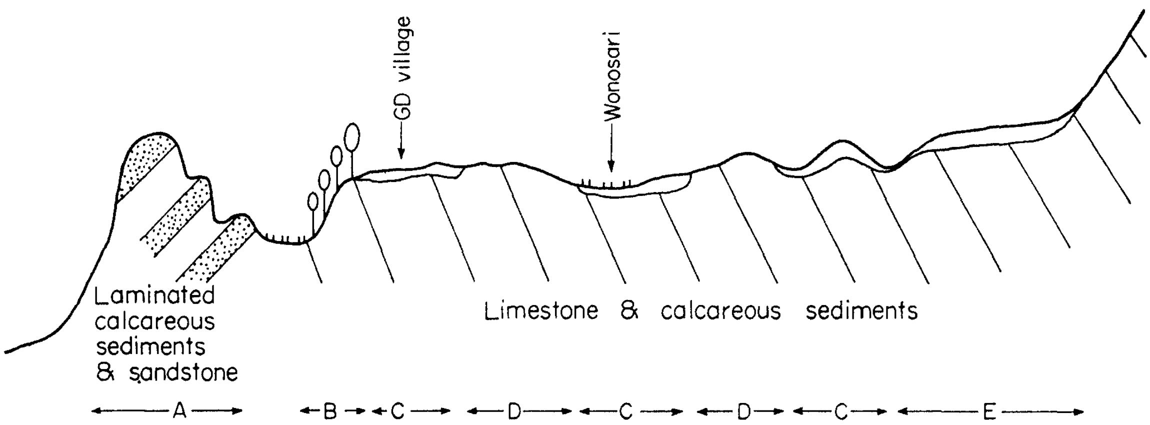
(v) Klaten Village

The foot-hill of the Mt. Merapi is extensively covered with fresh volcanic ejecta such as lava, ash and their fluvial deposits of varying grain size. Since the parent material varies so widely, the physical and chemical properties of the soils vary from place to place. At some localities, soil may be thick but at other places rock outcrops may be common. Some ejecta may be rich in chemical constituents that contribute to soil fertility, but some others such as fluvial deposits may be very poor in them. Pedologically this type of soil is classified into *Regosol,* but it is rather difficult to describe this soil in one word owing to the highly heterogeneous nature of the parent material.

According to T.W.G.Dames, the Merapi has errupted twice in the recorded history, one around 1000 A.D. and the other around 1900 A.D. The village seems to be located around the merging zone of the ejecta from the two eruptions.

(vi) Gading Village

The village is situated on a Tertiary limestone plateau on the southern coast. As illustrated in a cross-section (Fig. 3), the plateau is covered by either *Grumusol* (labelled



	Land form	Soil	Land use
A	Rolling	Mediterranean	Upland field (cassava, etc.)
B			Forest (teak, mahogany)
C	Undulating to rolling	Grumusol	Upland field (cassava & upland rice)
D		Mediterranean	
E	Gently sloping flat	Grumusol	Paddy field

Fig. 3 A Schematic Soil Profile through Gading (GD) Village

C) or Mediterranean soil (D). The former is a black colored heavy clay soil and occupies relative swales, while the latter is red in color and occurs on swells. In terms of fertility the former could be considered as slightly richer than the latter though the difference does not seem significant.

The housing plots of Gading is located on the *Grumusol* covered portion of the plateau, and most of the fields of the village, which are mainly utilized for cassava and upland rice rather than paddy, are also on this black colored soil, but some of the fields are located on Mediterranean soil.

(vii) Fertility Rating of Six Villages

According to Kawaguchi and Kyuma's method (Kyuma and Kawaguchi, 1972) the inherent potentiality index of fertility rating of the representative soils from the areas concerned are as follows.

Village	Soil	Index of inherent potentiality
Saraburi	Low humic gley soils	−1.00
Ayutthaya	Riverine alluvial soils	−0.41, −0.14, −0.11, −0.03
Pathum Thani	marine alluvial soils	0.75, 0.72, −0.01,
Demak	Alluvial soils	1.92, 0.59, 1.81, 2.69, 1.47, 1.20
Klaten	Regosol	−0.22, 0.35
Gading	Grumsol	2.29, 2.07, 2.57

The table clearly indicates that the villages rank in terms of potentiality of soil materials as Pathum Thani>Ayutthaya>Saraburi in Thailand and as Demak>Gading>Klaten in Java in descending order. However, nitrogen and phosphorus supplying power of *Grumusol* is usually lower than those of alluvial soils and *Regosol*, the overall soil fertility would be Demak>Klaten>Gading for the villages in Java.

2. Factors Determining Paddy Yield

The Social Science group made inquiries into various aspects of agriculture. This was done by interviewing the villagers. According to their report, the average yield in tonnes of unhusked paddy per hectare per crop in an ordinary year was as follows.

Pathum Thani	2.8	Klaten	5.5
Ayutthaya	2.0	Demak	1.0
Saraburi	1.5	Gading	0.8

The inherent potentiality of soil assessed by the Kyuma and Kawaguchi's method could explain the difference in paddy yield among the villages only to a limited extent. There are other factors affecting the paddy yield in the respective villages. They are discussed below.

(i) Water Condition and Broadcasting Method

Sometimes a certain water condition forces farmers to adopt a specific method of cultivation. The broadcasting method practiced in Ayutthaya is one such case. The water conditions under which no other system of planting except the broadcasting method is practicable are specified as; (a) a rapid rise of water level, which takes place some time in the mid-rainy season, and (b) water shortage in the early rainy season. Deep water depth and undrainability alone does not necessarily act as a deterrent to the practice of transplanting.

Paddy yield from broadcasting is not necessarily inferior to that from transplanting, at least at the present level of fertilizer application in Thailand. The average yield reported for the village of Ayutthaya 2.0 ton/ha, cannot be regarded as an indication of inferiority of the broadcasting method when the result of the soil potentiality rating is taken into consideration. Fertilizer application in the transplanted area is rapidly gaining popularity. This will improve the yield of the transplanted rice. When that happens, disadvantages of broadcasting will be more clearly evident, because the fertilizer applied to broadcast rice makes the competition of rice against weeds severer. Even without fertilizer application the competition is so severe that the crop often fails unless plowing and sowing are well timed in relation to the soil moisture regime.

The characteristics of rice varieties suited to the broadcasting method under such water conditions are (a) vigorous growth rate at the initial stage of growth in order to overcome weeds, and (b) great plant height by the internode elongation in order to withstand the rapid rise of water level. Both of these characteristics are not compatible with the varietal characteristics supposed to be ideal for high-yield capacity. Hence, the adoption of short and slow growing high-yielding varieties is unlikely.

Since the broadcasting method in Thailand is a natural consequence of the water condition, switching over to the transplanting method requires a drastic modification of the water conditions. Water shortage at the early rainy season could be improved by a canal system, but the rapid rise of water level is very difficult to remedy unless the total water balance of the whole central plain is altered.[1)]

(ii) Water Shortage and Paddy Yield

The paddy yield figures obtained in the interview is the average yield in an ordinary year. Therefore, the figures do not necessarily reflect the effect of direct damage by water stress or flood. Chronic water shortage will surely discourage risky investments such as fertilizer. Stable water supply at Pathum Thani and Klaten and chronic water shortage at Saraburi and Gading explain the use and non-use of fertilizer, respectively.

Water shortage in the latter villages is not due to inadequacy of the water distribution system but due to insufficient amount of water in the region as a whole. Therefore, the problem of water shortage will be difficult to solve. A carefully designed system of water tanks may relieve the shortage to some extent.

In the chronic water shortage area such as Saraburi and Gading, rice cultivation must

1) For the detailed discussion on the water condition and the broadcasting method, see Fukui, 1973 and Fukui, 1974.

depend on the local rainfall which is often very unpredictable both seasonally and geographically. Rice varieties adapted to this condition are characterized by sensitivity to photoperiod and medium to great plant height. The former assures the maturation of rice at the fixed date regardless of the time of planting which varies widely from year to year depending on the erratic rainfall during the early rainy season. The latter is needed to withstand the deep water in the paddy plots, each patch of which virtually serves as a storage tank. Thus, the dissemination of high yielding varieties is difficult unless the water conditions are improved.

Soils of the *water deficient foot-hills*[2] as represented by Saraburi in Thailand are very poor. A moderate amount of fertilizer application will give a significant increase in yield even if native varieties which are less responsive to fertilizer are used. Hence, the yield increase is possible at Saraburi in years of good rainfall.

(iii) Salt Water Intrusion and Paddy Yield

Damage by salt water at Demak makes it more risky to invest in production inputs just as drought does at Saraburi. Little use of fertilizer at Demak is partly attributed to this cause. However, the socio-economic factors such as poor transportation and communication facilities seem to be the real direct reason for the low level of investment in agricultural inputs. As an estuarine dam for preventing the intrusion of sea water is about to be completed, the damage by salt water injury will be relieved in the near future.

(iv) Damages by Rodents, Insects, and Diseases

Differences in the climatic conditions between central Thailand and Java can be demonstrated by the indexes of the Thornthwaite's climatic classification. Twenty-three and eleven observation stations located below 500 meter altitude in Java and in central Thailand, respectively, were classified according to the moisture index. (Table 1).

The aridity index for the humid climatic types (A, B, and C_2) further classifies 17 stations into "r" (little or no water deficiency throughout the year) and 4 into "s" (moderate summer water deficiency) out of 21 stations in Java. The humidity index for the arid climatic types (C_1, D, and E) classifies the 7 Thai stations into "d" (little or no water surplus) and 4 stations

Table 1 Thornthwaite's Moisture Index for the Central Thailand and Java

Climatic type according to the moisture index	A	B_4	B_3	B_2	B_1	C_2	C_1	D	E
	humid ←						→ arid		
Nos. of observation stations									
In Central Thailand	0	0	0	0	1	0	8	2	0
In Java	5	2	2	1	6	5	2	0	0

1) The stations below 500 meter altitude.
2) The indexes calculated by Kyuma (Kyuma, 1971).

2) One of the six rice cultural regions in the Chao Phraya River Basin. See Fukui, 1972.

into "w" (moderate summer water surplus) (Kyuma, 1971). Comparison of above data indicates longer-lasting drought and severer desiccation during the dry season in central Thailand than in the island of Java.

Generally speaking, damages to rice crop by various organisms occur more frequently in the insular part where the climatic condition is of the Javanese type than in the continental part of Southeast Asia where the dry season is distinct. At the Pathum Thani village in Thailand, the dry season cultivation of rice is common. Here, the soil moisture condition somewhat similar to that of the paddy fields in Javanese lowland is artificially created by irrigation during the dry season. And the crop tends more often to suffer from various biological damages in such areas than in the areas with only one cropping during the rainy season.

Although the knowledge on relationship between climate and biological damages is still very limited, it may be assumed that existence of the moist patches in the field throughout the dry season plays a significant role in causing various kinds of biological damages. The relatively low yields in the coastal plain of Java could partly be attributed to this type of damage. It might discourage the expansion of double cropping acreage in Thailand.

(v) Further Yield Increase in the Irrigated Villages

Water supply is stable in the villages of Pathum Thani and Klaten. The average yield reported for Klaten is already quite high. This can be attributed to the stable water supply, fertilizer use and adoption of high-yielding varieties of rice. Judging from the potential yield of high-yielding varieties of rice presently available, further yield increases of about 1 to 2 tons/ha seem possible in the case of the rainy season crop. But in the dry season yield of 8–9 tons/ha can be expected. For realization of such a high yield, precise timing of fertilizer application is indispensable. To do so, the patch-to-patch irrigation system presently common at Klaten must be improved to the ditch-to-patch system.

Though high-yielding varieties are also adopted at Pathum Thani, the average yield level reported is much lower than the potential yield of the varieties used. The distinct superiority in the yielding ability does not seem to have been realized at Pathum Thani. Yet farmers plant new varieties. The explanation of the reason given by farmers is that they adopted the new varieties not because of their high-yielding ability but because of their superiority as dry season varieties. Before the new varieties introduced to this village a few years ago, the varieties called "Luaung Tawn" and "Kao Sa-ad" were widely used. These varieties lack sensitivity to photo-period and hence can be planted during the dry season. But they have a defect, *i.e.* irregularity of the flowering time. RD variety, a new high-yielding variety developed in Thailand, was welcome by the farmers because of the simultaneous flowering. When the writers visited the village in the summer of 1973, some farmers were complaining of the deterioration of RDs; that is, irregular flowering after repeated cultivation of RDs. They were considering to switch back to the traditional varieties in the next season. Thus it seems that the farmers at Pathum Thani are not particularly eager to increase the yield of the dry season crop.

Apart from the problem of variety suitable for the dry season cultivation, the farmers' lack of keenness about the yield increase would be attributed to,

(a) the frequent damages by notorious rodents and other organisms as mentioned previously,
(b) that the farmers at Pathum Thani are not yet familiar with fertilizer application since it became popular only a few years ago, and
(c) that there is an alternative way to increase production, *i.e.* through the extension of the rainy season cultivation of rice.

The whole area of the low-lying part of the central plain is annually inundated. But the date at which inundation starts is quite uncertain owing to the year-to-year fluctuation of rainfall during the early rainy season. Early sowing, that is, in April or May, in the case of the broadcasting method is a measure to overcome the uncertain date of commencement of inundation. At Pathum Thani, however, the dry season cultivation of rice does not allow such an early sowing of the broadcast rice. That uncertainty must be overcome by the earliest possible harvest of the dry season crop followed immediately by transplanting of the rainy season rice. Therefore, double cropping of rice at Pathum Thani causes a labor peak in the months of May, June and July, and the labor shortage limits the expansion of double cropping.

The labor peak has been relieved to some extent by introducing RDs, which mature earlier than the traditional varieties. The village workshop is eager to mechanize post-harvest processing in order to save labor. Uncertainty of inundation may be lessened by further implementation of the Greater Chao Phraya Project. Steady increase of population will eventually supply more labor. It can be concluded that to the farmers at Pathum Thani, the quickest way for increasing production is to expand the acreage of double cropping rather than to increase the yield per acre in the dry season.

3. Factors Related to Crop Diversification

(i) Diversification in the Rainy Season

At the three villages of Ayutthaya, Pathum Thani and Demak, inundation of the whole region is unavoidable during the rainy season. Aside from the cultivation of lowland rice, the effective land use is limited to the growing of aquatic crops and fish culture. For growing upland crops one must construct a polder as seen at Pathum Thani or a raised bed as at Demak. At Pathum Thani, banks, 2–3 meter high, surround a small patch of land which seldom exceeds a few hectares. The poldered land is thus separated from the inundating water during the rainy season. As this type of polders are usually located along the trunk canals in the southern part of the central plain of Thailand, water can be pumped in during the dry season. Thus, vegetables and fruit trees are commercially grown throughout the year.

The height of the raised beds at Demak is about one meter above the ground level, which is enough to protect the plots from inundation. On the plots are planted trees for fire wood, various field crops and vegetables. Since they lack the irrigation facilities, the raised beds look like another version of back yard.

Vegetables and fruits growing on a small scale of poldered land around Bangkok have been monopolized by Chinese descendants till recent times. It is certain that the demand for products of poldered horticulture by Bangkokians is ever increasing, but it will take some time for the native Thai villagers at Pathum Thani to acquire the technical experience necessary for maximizing profit and to establish an efficient marketing route.

The raised beds for avoiding inundation are seen here and there in the coastal lowland of Java as well. As the coastal plain of Java is not so extensive as the deltaic plain of Thailand, more suitable places for growing upland crops during the rainy season are within a short distance from any consumer center. Therefore, the raised bed agriculture is and will basically be of a subsistence type.

In the other three villages inundation can be avoided. Though rice is yet the main crop at Klaten in the two seasons, various other upland crops like sugarcane and tobacco are grown successfully. That rice is yet the major crop is explained by the fact that rice is the staple diet of the people and that, compared to other crops, it can support the maximum population per unit land. At Gading, upland rice is the major crop in the rainy season. As stated before, the water supply is not sufficient to grow lowland rice in this village. The reason why upland rice is the most dominant among other grain crops is not found in the environmental condition.

At Saraburi and Gading, the rice cultivation depends mostly on local rainfall. Considering the rain-fed condition, Saraburi is definitely drier than Gading as indicated by the Thornthwaite's index; C_1A'd at Lop Buri (ca. 30 km north of Saraburi) and B_1A'r at Jokjakarta (ca. 20 km north of Gading). Yet the land is exclusively planted to lowland rice at Saraburi while upland rice is dominant at Gading. This could be explained by significant differences in the soil properties between the two villages.

Grumusol and *Mediterranean soil* at Gading are characterized by a heavy texture, a deep profile and well developed aggregates. When this kind of soils receives rainfall, it can absorb and maintain, on the one hand, a great amount of moisture for a long period, but, on the other hand, it needs an extremely heavy rainfall for the field to be submerged. Therefore, the soils at Gading are both resistant to drought and not subject to excessive moisture, and are suitable for upland crops. Acreage covered by the residual soils of this kind is not extensive in the tropical monsoon region. Their occurrence seems to be correlated with some particular parent materials, perhaps, basic to neutral materials.

The weathering product of more acidic rocks which are distributed far more widely easily erodes, often resulting in a coarse top soil. Where the coarse layer is deep, excessive permeability prohibits the cultivation of lowland rice. Highly drought-resistant crops like kenaf, cassava and kapok are grown on this kind of poor soils. Where the coarse textured layer is shallow and is underlain by an impermeable layer of unweathered material, cultivation of lowland rice may be possible. Its stability depends on balance between the permeability and the rainfall. Saraburi is an example where the balance barely permits rice cultivation. Low water-holding capacity of the shallow sandy top layer is prohibitive to annual field crops because they have a certain growth period during which water stress is very critical.[3)]

When Europeans did not come to Southeast Asia yet, and plantation agriculture was not in existence, the traditional society with mono-culture of rice found a relatively small acreage of soils suitable for upland annuals of no economic significance. However, ever increasing population pushed out the people from the rice growing area to the marginal area suited only for upland crops. Gading could be considered as an example of this. In Thailand where the population pressure is less than in Java, the area of *Grumusol* and similar kinds of soil went under the plow as the maize farmers migrated from various other parts of the kingdom since a decade ago. Opening of the area was motivated by the export demand for maize and supported by fast growing of a road system of transportation. Therefore, the farmers grow exclusively maize, while their main dish is still rice.

(ii) Diversification in the Dry Season

The dry season agriculture with irrigation is being practiced at two villages, Klaten and Pathum Thani. In these villages, the dry season rice is the main crop. Crop diversification at Klaten is possible for three reasons: (a) the area is equipped with not only irrigation but also drainage, (b) the physical properties of soils are suitable for tillage of various upland crops, and (c) the dense population will permit highly labor-intensive cultivation. On the whole, socio-economic conditions rather than the environmental ones seem to be the major determinants affecting the actual diversification.

At Pathum Thani, undrainability makes the moisture control of soil difficult. Heavy texture of soil may inhibit germination of some crops or at least necessitate intensive labor input for tillage. Apart from these unfavorable natural conditions, any farmer whose staple food is rice, but has no assured rainy season crops, cannot be expected to stop growing rice. Thus crop diversification at Pathum Thani is never an easy matter although water is available throughout the year.

The dry season agriculture without irrigation is extremely difficult in Thailand where the dry season is longer and severer than in Java. Crops resistant to drought and of short life span such as mung bean, may be able to be grown in the paddy field by utilizing the

3) Generally speaking, the cultivation of annuals seems impossible without irrigation under the tropical monsoonal climate. The reason for it is quick deterioration of soils through erosion and leaching. The exceptions are (a) the residual soils derived from the basic rocks such as *Grumusol,* (b) the soils on recently formed river levees and fans, and (c) the shifting cultivation on the mountain slope, which can be regarded as a kind of rotation with very long fallow. Thus, it is considered that the predominant form of agricultural land use in this part of the world, that is ,the lowland rice cultivation and the plantation agriculture of perrenials, is a natural consequence of the environmental conditions. Annual grain crops in the dry zone of Burma and on the tropical highlands can be explained as deviations from the tropical monsoonal climate toward the arid or temperate climates, respectively.

remaining moisture after harvest of the rainy season rice. But their economic importance is limited.

In Java, different types of the dry season agriculture are being practiced without irrigation. What type of dry season agriculture without irrigation is possible at a particular locality depends on the soil moisture regime, which is governed by not only the rainfall and evapo-transpiration but also the soil physical properties as discussed previously. In the "volcanic cone" region of high altitude where the moisture balance is favorable even during the summer, a variety of crops are successfully grown on almost any kind of soils. Here, very intensive land use by double or even triple cropping is observed. Coming down to the lower altitudes, the severer desiccation limits the kind of crops that can be grown and the kinds of soils on which they can grow.[4] In the case of Gading, it seems potentially possible to grow some crops in addition to cassava during the dry season, but this crop will continue to be the main crop so long as the subsistence agriculture prevails.

On the *Grumusol*-like soil around the village of Demak, it is seen that maize is grown as the second crop after rice during the dry season. Possible damage from drought in the middle of the dry season and/or from the excessive moisture in the early rainy season seems to restrict the expansion of this kind of dry season agriculture to the area of certain particular soils, having those specific characteristics as mentioned previously.

4. A Comparison of Thai, Javanese and Japanese Agriculture

As discussed in the foregoing sections, the agricultural outlook of the six villages differs substantially from each other. Broadly speaking, there is no doubt that the agriculture in the three villages in Java was much more intensive than in the Thai villages. Agriculture of Java & Madura is as intensive as that of Japan. Below is presented an examination of the statistical figures related to intensity and productivity of agriculture in Thailand, Java & Madura, and Japan.

As seen in Table 2, the pattern of land use is quite similar among three regions except for very high percentage of the arable land in Java & Madura (68.2%). As indicated by the percentage of food crop area as well as that of paddy area to total arable area, the high

4) For 9 observation stations above 590 meter altitude in Java, the moisture indexes by the Thornthwaite's method are either "A" (7 stations) or "B_4" (2 stations). The aridity indexes for those stations, i.e. "r", indicate little or no water deficiency throughout the year. The same can be said about 3 more stations located between 200 and 500 meter altitudes. The moisture indexes for the stations below 200 meter altitude are "B_3" or drier except for 4 stations. They are;

Nos.	Name of station	Altitude m	Climatic Type
79	Tjitajam	110	AA'r
233	Tjilatjap	6	AA'r
234	Subang	95	AA'r
242	Kadhipaten	45	B_4A'r

Table 2 Some Selected Statistical Data on the Agricultural Productivity in Thailand, Java & Madura and Japan[1)]

		Thailand (1965)	Java & Madura (1961)	Japan (1971)
[I] LAND USE				
1) Total land area	×1,000 ha	51,400	13,217	37,739
2) Total arable area	×1,000 ha	11,415[2)]	9,008[3)]	5,741
Percent to total land area	%	22.1	68.2	15.2
3) Area of food crops	×1,000 ha	10,166[4)]	7,937[5)]	5,328[6)]
Percent to total arable area	%	89.1	88.1	92.8
4) Percent of paddy area to total arable area	%	66.2	47.6	45.7
[II] POPULATION				
1) Total population	×1,000 persons	30,591	63,289	107,332
2) Population density				
to total land area	persons per sq-km	60	479	288
to total arable area	persons per ha	2.7	7.0	18.7
to the area of food crops	persons per ha	3.0	8.0	20.1
[III] AGRICULTURAL PRODCUTION				
1) Area of principal food crops	×1,000 ha	8,849[7)]	7,937[8)]	4,526[9)]
2) Per-ha-calories produced by the principal food crops[10)]	$\times 10^4$ cal./ha	338	463	1,339
[IV] INPUTS FOR PRODUCTION				
1) Farm labor[11)]	persons per ha	1.09	1.77	2.04
2) Consumption of N fertilizers[12)]	N kg per ha	1.57	4.82	157.99
3) Horse-power of tractors[13)]	Hp/ha	0.02	0.07	8.10

1) Main sources are "Sakumotsu Tohkei no. 14," "Agr. Stat. of Thailand 1965," and "Statistical Pocketbook of Indonesia 1962."
2) From "FAO Production Yearbook vol. 23 (1969)". Only "planted area" is found in the statistics of the Thai government.
3) Sum of "total area of arable land of farm agriculture" and "total area of estates".
4) The area planted to sugar cane, castor bean, fibre crops, and rubber was deducted from the total arable area.
5) Total area of estates, and that area of the farm agriculture which is planted to coffee, tea, kapok, areca, cloves, and sugar cane were deducted from the total arable area.
6) The area of the industrial crops such as mulberry, rape-seed, sugar cane, sugar beet was reduced from the total arable land. The area of fodder crops was included.
7) The sum of the following. Rice; total holdings minus one half of the area planted to suger cane. Mung bean; not counted. Cassava; total planted area. Oil seeds; one half of the planted area of sesame and soy bean, and the total planted area of ground nut and coconut. Vegetables; one halves of chili, shallot, onion, garilic, and the garden crops excluding root crops. Root crops except for cassava; one half of the planted area of various kind of potatoes and the total planted area of bananas. Fruits; the total planted area of pineapple. The area of water melon was not counted.
8) Same as the area of food crops.
9) The area of fodder crops was deducted from the area of food crops.
10) The food crops were grouped into five categories, and the average calories per 100 grams of each category were assumed as follows. 1) grain crops 352 2) root crops (including bananas) 88, 3) pulses (including coconut as copra) 386, 4) vegetables 29, and 5) fruits 51
11) "Economically active population in agriculture" as estimated for 1965 (From FAO Production Yearbook 1969)
12) From FAO Production Yearbook 1969
13) *ibid.* Assuming 60 Hp for large tractors and 15 Hp for garden tractors.

percentage of arable land in Java & Madura cannot be attributed to the plantation agriculture, which usually utilizes the land in the hilly or mountainous parts of the island. This percentage of Java & Madura is as high as that of arable land including pasture land in the European countries. The environmental setting of rice-producing countries in Asia is basically characterized by the topographic pattern of steep mountains and valleys, and the monsoon climate. Among Asian countries, no country has such a high percentage of arable land except for Java & Madura.

This high percentage itself does not seem to have influenced the development of specific agricultural practices. Such practices as the terraced paddy land and double or even triple cropping can be found in other countries.

In spite of the very high percentage of arable land in Java & Madura, the population density per hectare of arable land is 2.5 times greater in Java & Madura than in Thailand, but it is still much less compared to that of Japan. The same can be said as to the polulation density per acreage of food crops. Great population density of the rural area in Java & Madura is certainly impressive, but the density per arable acreage of the whole Java & Madura taking into account both rural and urban populations is less than one half of that in Japan. A comparison of the population density per arable land suggests a significant difference in the agricultural productivity of land among three regions. More direct comparison was made by calculating the calories of the edible part of principal foods crops per hectare of land. The land-productivity of Java & Madura thus calculated exceeds that of Thailand but yet it is only one third of that for Japan. The difference in land-productivity between Thailand and Java & Madura is greater when compared on the basis of population density per arable land than on the calories in edible parts per hectare basis.

High land-productivity of the Japanese agriculture can primarily be explained by the huge agricultural inputs as indicated, for example, by heavy application of nitrogenous fertilizers and the utilization of horse-power of tractors. However, the differences in labor input per unit of land among the regions are relatively small when compared to material inputs. The low level of labor input in Thailand rather than the high level in Japan is more noticeable. The difference in land-productivity between Java & Madura and Thailand can partly be attributed to the more favorable environmental conditions such as greater availability of water and the world-famous good fertility of soil in Java & Madura. However, a substantial part of the difference in land productivity could be explained by the difference in labor input.

The Japanese agriculture in 1879 lacked the chemical fertilizers and the modern farming machinery. The calories produced by the principal food crops in that year is calculated as 549×10^4 cal./ha,[5] which roughly coincides with the figure calculated above for Java &

5) The crops taken into account were rice, barley, wheat, oat, rye, potato, sweet potato, soybean, buckwheat, and 3 kinds of millet. Total acreage of $4{,}560 \times 1{,}000$ ha was planted to them and produced $2{,}514 \times 10^{10}$ calories.

Madura as of 1961. The population in Japan in 1879 was about one third of that at present and the change in the acreage of arable land since then has been only very slight. So that the population density per arable land in Japan about a hundred years ago has been at a similar level as that of Java & Madura in the recent years.

The discussions stated above leads to a hypothesis, that is, in the rice producing countries under the monsoon climate in Asia, the traditional technology of agriculture, which lacks modern inputs, may work in effecting the land-productivity to some extent with the greater input of human labor per unit land, but the productivity could not exceed a certain upper limit which roughly corresponds to

6–7 persons/ha in terms of population density per unit arable land,

ca. 2 persons/ha in terms of agricultural labor per unit arable land, and

ca. 500×10^4 calories/ha in terms of calories produced per unit land.

The land-productivity of the Japanese agriculture in the late 19th century and that of the Javanese one in the recent years are considered to be approaching to the maximum level under the traditional technology. In Thailand, aside from the potential for further extension of arable land, the land-productivity can further be raised even within the framework of the traditional technology. However, regardless of the present technological level, various modern inputs are being adopted and disseminated both in Thailand and Java & Madura. The difference in the level of labor input between Thailand and Java & Madura at such times as the modern inputs began to be adopted will affect the rate and pattern of the rearrangement of the whole technological framework of the traditional agriculture. How significant the difference would be to the future agricultural development of the regions is yet open to question.

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