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IN SEARCH OF UPLAND RICE FOR THE THAILAND OPIUM ZONE: A CLIMATE-BASED APPROACH

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Introduction

The mountains of northern Thailand are a *cul-de-sac* for hill tribes migrating from China, Laos, and Myanmar, because bordering lowlands to the south and east are already inhabited by Thai people. The hill tribes practice swidden agriculture and rely on illicit cultivation of the opium poppy (*Papaver somniferum*) for their only important source of cash income. They grow opium to purchase rice and other basic subsistence items, but land shortages are forcing them to seek replacement crops and to consider permanent settlement. Moreover, recent international pressures on the Thai government to eradicate opium production are acting to destroy their marginally productive economic system (Crooker, 1988).

The identification and extension of alternative cash crops for the hill tribes is fundamental to the amelioration of current and future economic hardships in the region. There are several factors associated with successful agricultural inno-

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vations in developing countries: tradition, information dissemination, government policies, international development agencies, and environmental and ecological considerations. In a previous publication I summarized how these factors are related to the opium economy and crop substitution efforts in Thailand (Crooker, 1988). This study concerns a corollary of the crop substitution problem: the development of more dependable upland rice yields in order to lessen the need for growing and selling opium to replace shortfalls in this principal food crop. If rice yields can be improved, there should be an attendant reduction in the economic risk of switching from opium to other cash crops.

My research focuses on atmospheric temperature, which is the most important climatic constraint to the production of upland rice in northern Thailand (Somrith and Promman, 1986). Precipitation is also important, but it is less limiting than temperature because monsoon rains in the areas of opium production are adequate and fairly dependable. Conditions for growing upland rice are considered marginal between 1000 and 1300 mm and at 1600 mm the amount of rainfall ceases to be a constraint. The opium zone receives 1200 to 2200 mm, so only a small portion of its area receives marginal levels (Moorman and van Breemen, 1978). There are several research projects concerned with crossing indigenous and imported cold-tolerant upland rice strains, but none has been successful. In addition, Thai and United Nations agricultural experts have had no success in locating adaptable rice cultivars or experimental germplasm during brief expeditions to Brazil, Nepal, India, New Guinea and Hong Kong (Mann, 1986). These efforts were hampered because investigators did not have a method of adequately examining the adaptation of upland rice varieties to their indigenous climates.

This study uses a general climate model to derive a set of sites with similar temperature regimes around the world.

This cluster of places could be targeted for visits by agronomists to see if better-yielding strains of highly adapted rice could then be found for eventual use in northern Thailand. The methodology used to identify this cluster of places relies on monthly averages of climatic data. A more complex interregional comparative model is not possible because other kinds of climatic data are not typically available for Thailand's opium-producing areas or for most other areas where upland rice is produced. The results are tentative, but part of this paper's rationale is to demonstrate the need for greater interchange of information between geographers and plant scientists so that research on narcotic crop replacement problems can be more effective.

This article makes a contribution to the specialized field of applied geography in two ways. Firstly, it makes regional climatic comparisons with the goal of changing an area's agricultural production. Secondly, it substantiates the need for more effective crop replacement research through the integration of institutional components in the international scientific and academic community.

Upland Rice and the Constraint of Temperature

Opium-producing villages in northern Thailand are located in an elevational zone between 700 and 1500 meters, which will be referred to hereafter as the opium zone. This zone accounts for nearly all of the mountainous area above 700 meters, since few elevations exceed 1500 meters. As a result of its mountainous topography, the opium zone is fragmented into isolated areas located on mountainsides or straddling ridge crests. Due to the effect of elevation on temperature, the opium poppy flourishes best above 1000 meters within this zone; whereas, upland rice performs better at lower elevations. Consequently, the vast majority of poppy growing villages are located within the optimum elevational range of 900 to 1100 meters so that both crops can be produced as efficiently as possible (Office of Narcotics Control Board, 1981).

Rice (*Oryza sativa*) is cultivated using dryland techniques, which means the fields are not bunded, are prepared and seeded under dry conditions, and depend on rainfall for moisture. When rice is grown in this manner, it is termed upland rice to distinguish it from rainfed wetland and irrigated wetland rice, which involve cultivation in fields with standing water. Population pressure in the opium zone has resulted in overcrowding, a shortening of fallow periods, and a thirty percent decline in yields per acre of this upland rice in the last twenty years. Current upland rice yields of the opium zone are among the lowest in the world, averaging less than 1000 kg per hectare (Crooker, 1988).

Rice is planted in May and June at the onset of the summer monsoon rains, but the growing season extends into the cool, dry monsoon period. The lower temperatures of the opium zone's mountain elevations combine with the cooling effects of Asia's winter continental air mass to limit rice yields significantly by lengthening the vegetative period (DeDatta and Vergara, 1975; International Rice Research Institute, 1979; Vergara and Chang, 1976; Yoshida, 1981). Flowering does not occur until September, and heading and ripening proceed through October and early November, when daily mean temperatures drop below 20° C (68° F). For native varieties the length of the growing season is between 120 and 160 days (Tiyawallee, 1983). The phenological effects of the cool season temperatures are a reduced yield capacity through retardation of flowering, self-pollination, and the flow of carbohydrates from culms and leaf sheaths to spikelets (Yoshida, 1981). By harvest time plants have large numbers of seedsthat are sterile (up to eighty percent for imported varieties at 1400 meters), and they have low numbers of filled seeds per panicle and low seed weight (Thai-Australian Highland Agricultural Project, 1981; Tiyawallee, 1983; Tiyawallee, 1986).

Data Base and Methodology

The climatic data base for this study includes monthly, seasonal and annual temperature and precipitation averages. It is assumed that the data sources contain reliable statistics, since the use of recording equipment and calculation of temperature and precipitation averages require minimum training. There are about two dozen weather stations operating within the opium zone, but only those stations with data for five years or more are used in the analysis. The data were compiled from various sources by the author during field work in 1981-1989. The longest period of data among the stations is fifteen years, the average is nine years.

The opium zone stations were compared with stations located worldwide that have data for a minimum of ten years. Information about the latter stations was drawn from *World Climate Data* (Wernstedt, 1981), *The World Weather Records* (U.S. Department of Commerce, 1965-68), *World Survey of Climatology* (Landsberg, 1969), and *Tables of Temperature, Relative Humidity and Precipitation for the World* (Great Britain Meteorological Office, 1958).

The specification of locations with thermal properties similar to those of Thailand's opium zone involves three operations. First, the Köppen climate classification (Trewartha, 1954) is used as the standard for selecting general areas with similar climates where experimental rice varieties may be located. Next, the opium zone's highest and lowest average annual precipitation recordings are used as parameters to sort out stations that are either too dry or too moist. Then, since crop yields in the opium zone are keyed to cool season temperatures, H.P. Bailey's warmth index (Bailey, 1960) is used to identify specific locations which have thermal characteristics that are similar to the Thailand opium zone.

Due to its specificity, the Bailey warmth index is used to characterize the geographic limits of upland rice strains that would be adaptable to the temperature regime of the opium zone. Bailey assumed that the earth's annual march of temperature can be approximated as a sine curve and that plant life responds predictably to correspondent changes in the amplitude of temperature. Thus, Bailey derived a planetary scale of temperatures (warmth indexes) representing temperatures at the beginning and end of the thermal summer period in which plants prosper. He also calculated the number of days that temperatures exceed each warmth index.

Bailey used a nomogram and trigonometry to model this global range of warmth indexes and their durations. A simple nomogram plot of a weather station's average annual temperature and average annual range in temperature provides an index and its duration for any given location (Figure 1)(Bailey, n.d.). The nomogram consists of two sets of coordinates; the first is the average annual temperature and the average annual range of temperature and the second, superimposed at a 45° angle, is the index limits for summer warmth. The latter set of coordinates is an index of 64.4° F (18° C), which is the lowest index expressing a 365-day summer, and 50° F (10° C), which represents the highest index with zero days of summer warmth. The warmth indexes are displayed as radii diverging from the left margin of the graph. The angles formed between an index's radius and the limits of summer warmth is a function of the poleward advance and retreat of the vertical sun.

The warmth index has distinct advantages for this study compared to temperature summations, which are commonly used by plant ecologists to relate temperature and crop productivity (Mather, 1974; Yoshida, 1981). Temperature sum-

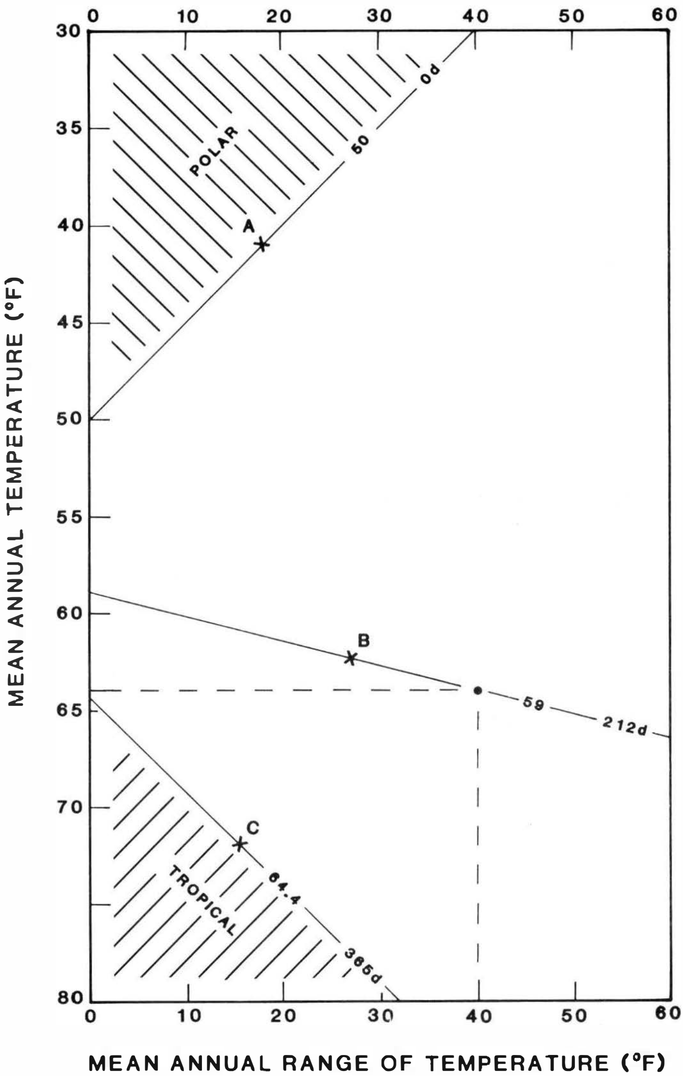

Figure 1. Bailey nomogram with warmth index limits of the thermal summer (letters A and C) and a warmth index radius (B). A determination of a warmth index and the duration of the thermal summer requires a plot of a location's temperature data. In this example, a location with an average annual temperature range of 40° F (4.4° C) and average annual temperature of 64° F (17.8° C) has a 59° F (15° C) warmth index and 212 days with mean temperatures above the index.

mation is a summation of daily mean temperatures over a certain period of growth and development. However, daily temperatures are not easily obtainable for locations worldwide. In addition, the nonlinear relationship between temperature and growth duration of the rice plant limits use of the summation term (Yoshida, 1981). Thus, the Bailey warmth index, which is based on mean monthly temperatures and nonlinear trigonometric functions, is a practical and perhaps a more accurate alternative for the study of rice and temperature relationships.

Analysis

According to the Köppen climate classification *Cwa* and *Cwb* climates are found in northern Thailand's opium zone. Data from more than 3300 weather stations located worldwide were analyzed using the Köppen classification and 184 of these were identified as having either Cwa or Cwb climates. In order to select those stations in the Cw climate group which are more climatically similar to the opium zone, only stations with comparable rainfall levels (1200 to 2200 mm) were chosen for plotting on the Bailey nomogram. As a result, seventy qualifying stations are plotted and analyzed (Figure 2).

The opium zone's nomogram plot consists of twelve weather stations (Figure 3). The stations are ranked according to elevation with the lowest number representing the station with the highest elevation. Warmth indexes for the zone range from 59.9° F (15.5° C) to 64.7° F (18.2° C), and thermal summer durations are from 226 to 365 days. There is a negligible overestimate of thermal summers for most of the stations in the opium zone. This discrepancy can be discerned on the nomogram by observing the plots of lowest elevation stations (numbers eleven and twelve). According

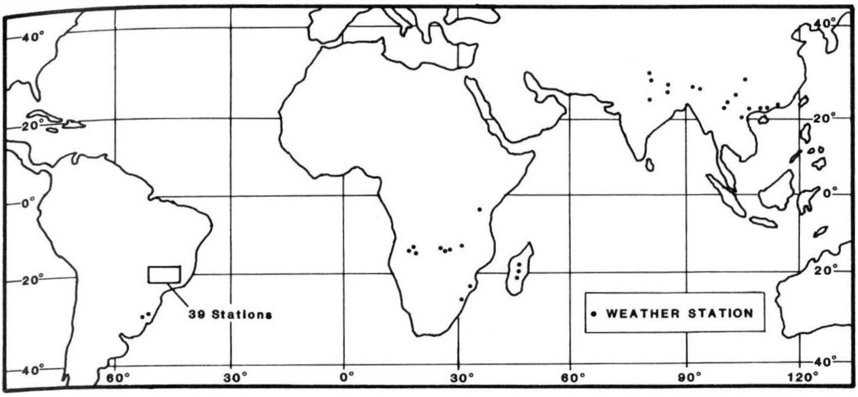

Figure 2. Location of selected Cw weather stations

to the nomogram, these stations should have 365 days with only occasional cool spells restricting plant growth, but each station has a January mean temperature slightly less than the prescribed limit of 64.4° F (18° C); 63.3° F (17.4° C) and 63.5° F (17.5° C), respectively. Such a difference is the result of minor deviations from the planetary norm and is associated with the opium zone's high elevations and the inflow of winter monsoon air.

The warmth index plots in Figure 4 are grouped to show qualifying weather stations for five broad geographic regions, each region is designated by a first-order letter. Subregions are indicated by second-order numbers. The area of index plots for Thailand's opium zone is designated by the letter A and shaded for reference. Other Cw climate areas and their first-order letter designations include: highland Brazil, B; southern Africa and Madagascar, C; South Asia, D; and northeastern Myanmar and Far East, E.

The nomogram reveals strong thermal congruence between the opium zone and many of the station locations in highland Brazil (B) and interior southern Africa (C1). Most weather stations of the other areas fall within the opium

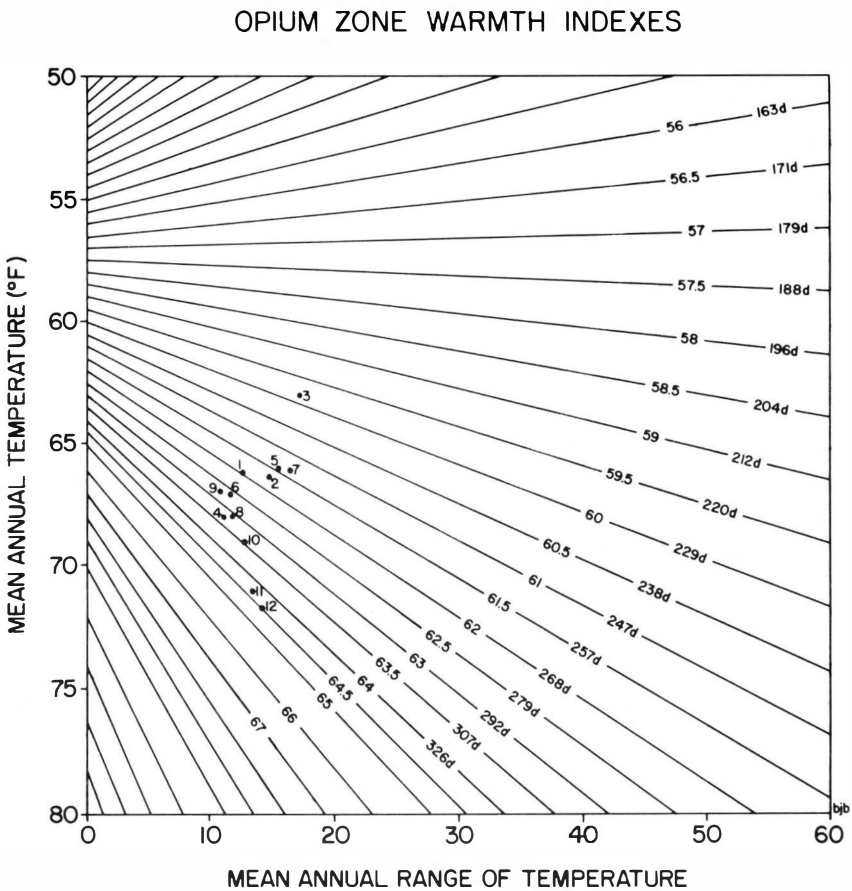

Figure 3. Warmth index plots of twelve weather stations in the Thailand opium zone

zone's index range, but outside of the zone's nomogram plot. In many cases winter temperatures account for these thermal departures (Figure 5). Such stations should be considered as secondary prospects for cold-tolerant rice cultivars and experimental genetic material. The temperature characteristic and rice production of the analog regions identified on the nomogram are discussed below.

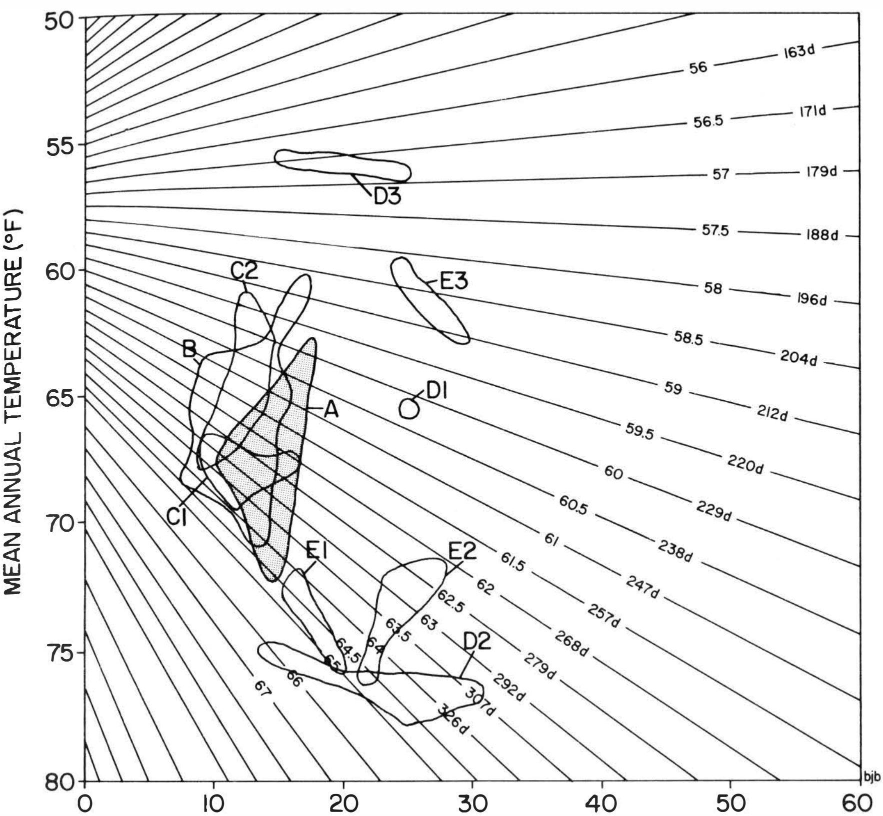

Figure 4. The nomogram plots of the Thailand opium zone (shaded plot) and comparable Cw regions. The letter designations are explained in the text.

Discussion

1. Brazil (B) — The temperatures of highland Brazil (B) have the greatest degree of similarity with Thailand's opium zone, as indicated by the overlap of the two areas' index plots (Figure 4). The wide range in elevations and comparable temperature ranges of both regions account for much of this thermal congruence. More temperature data are avail-

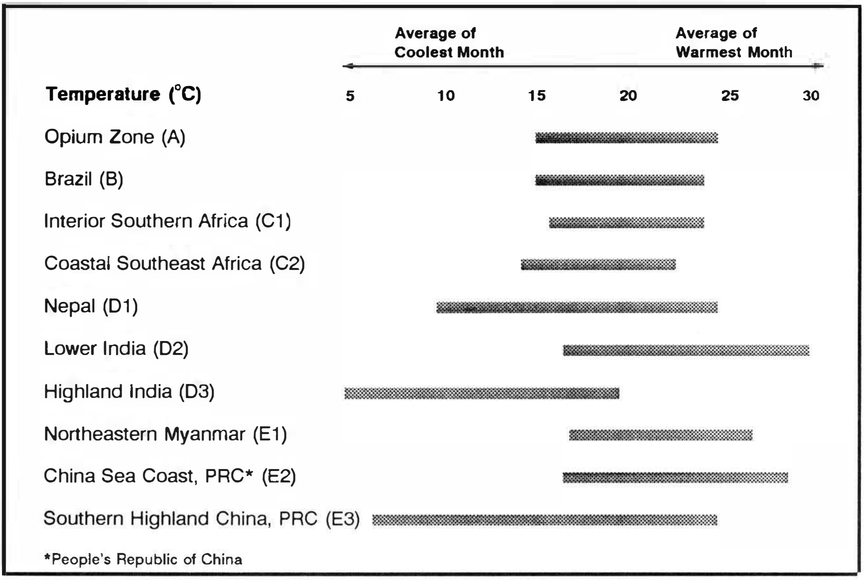

Figure 5. Winter versus summer thermal departures from the opium zone

able for this region than the combined total of all other regions (Wernstedt, 1981). The Brazilian stations are concentrated in the state of Minas Gerais (Table 1), which included 371,386 hectares of upland rice in 1979 (Sant'Ana, 1984; Gupta and O'Toole, 1986). Only two stations are located outside of Minas Gerais, in the state of Rio Grande do Sul, but they are in areas of wetland rice cultivation.

The Minas Gerais station data typify the *cerrado savanna* region of the Brazilian highlands which also includes portions of Goiás, São Paulo, Maranhão and Mato Grosso states. This region is the only significant Cw upland rice area in Latin America and the world's largest continuous upland rice-growing area. It accounts for about three-fourths of Brazil's rice production with approximately 4.0 million hectares planted annually. Rice culture is semi-mechanized and is often the first crop on newly cleared savanna lands.

Table 1. Brazil: Selected *Cw* Weather Stations

Station	Lat. (S)	Long. (W)	Figure 4 Area Plot
1. Alegrete	29.46	55.47	B
2. Barbacena	21.15	43.47	B
3. Barreiro do Araxa	19.32	47.00	B
4. Bonsucesso	21.02	44.46	B
5. Cachoeiera do Itapemerim	20.51	43.30	B
6. Cambuquira*	21.51	45.18	B
7. Caxambu	21.59	44.57	B
8. Caxias	29.10	51.12	B
9. Conceicao do Serro*	19.02	43.00	B
10. Diamantina	18.14	43.34	B
11. Franca	20.32	47.25	B
12. Gameleira*	19.56	43.56	B
13. Guaratinga*	18.36	46.38	B
14. Itabira do Mato Dentro*	19.37	43.13	B
15. Itajuba	22.25	43.27	B
16. Juiz de Fora*	21.46	43.20	B
17. Lavras*	21.14	45.00	B
18. Mar de Hespanha*	21.52	43.01	B
19. Mendes*	22.32	43.43	B
20. Monte Alegre*	18.52	48.51	B
21. Monte Serrat	22.27	44.37	B
22. Muzambinho	21.22	46.31	B
23. Nova Friburgo	22.17	42.32	B
24. Oliveira	20.42	44.50	B
25. Ouro Fino	22.16	46.22	B
26. Ouro Preto	20.23	43.29	B
27. Passoquatro	22.23	44.58	B
28. Pinheiros*	22.31	44.00	B
29. Piracicaba*	22.43	47.38	B
30. Pitangui*	19.40	44.53	B
31. Pocos de Caldas	21.47	46.33	B
32. Rezende*	22.29	44.28	B
33. Santos Dumont	21.28	43.33	B
34. Sao Joao Del Rei*	21.08	44.16	B
35. Sao Joao Evangelista*	18.25	42.47	B
36. Sao Lourenco*	22.06	45.01	B
37. Tres Coracoes	21.02	45.16	B
38. Uba*	21.07	42.57	B
39. Valenca*	22.13	43.44	B
40. Vargem Alegre*	22.29	43.54	B
41. Vicosa*	20.46	42.54	B

*Stations with a warmth index that overlaps into the opium zone's area of index plots.

Regional yields average between 1.2 to 1.5 tons per hectare (DeDatta, 1975).

Brazilian upland rice research has increased substantially since the early 1970s, but virtually no published work could be found on the development of cold-tolerant varieties (EMBRAPA, 1984; CIAT, 1984; Dall'Acqua, 1986; Steinmetz, 1986). It is unlikely that Brazilian varieties are uniquely adapted to low temperatures, but there are two plausible explanations for this surprising lack of research. Firstly, interest in moisture supply has superseded concern for temperature, because the region receives marginal levels of rainfall (1200 mm) and is subject to frequent prolonged droughts (International Rice Research Institute, 1979; Martinez, 1984; Dall'Acqua, 1986; Steinmetz, 1986). Secondly, low temperature has little impact on overall rice production because most cultivations are at lower elevations. Notwithstanding the lack of interest in temperature constraints, Brazil's highland genetic pool has considerable research potential because many primitive varieties (landraces) are used by subsistence farmers in less favorable elevations (Laing, et al., 1984).

2. Southern Africa and Madagascar (C) — There are two Cw climate subregions in southern Africa that are comparable to the Cw climates of the opium zone (Figure 4). The first location stretches across southern Africa's interior (C1), beginning in central Angola and ending in northeastern Tanzania. The eight qualifying Cw weather stations have warmth indexes that correspond with indexes of the lower opium zone. The second area is the southeast subregion (C2), represented by five highland stations scattered in Swaziland, Mozambique and Madagascar. The stations at Espungabera, Mozambique and Fianarantsoa, Madagascar (Table 2) account for some overlap on the nomogram with the opium zone. The predominately offset position of these stations on the nomogram relative to the opium zone reflects

Table 2. Southern Africa and Madagascar: Selected *Cw* Weather Stations

Station	Lat. (S)	Long. (E)	Figure 4 Area Plot
1. Ceilunga, Angola	12.22	16.54	C1
2. Coemba, Angola*	12.06	17.42	C1
3. Kasama, Zambia*	10.12	31.11	C1
4. Mwinilunga, Zambia*	11.45	24.26	C1
5. Ndola, Zambia*	12.59	28.37	C1
6. Nova Lisboa, Angola	12.48	15.45	C1
7. Solwezi, Zambia*	12.11	26.41	C1
8. Lyamunga, Tanzania	3.14	37.15	C1
9. Mbabane, Swaziland	26.19	31.08	C2
10. Espungabera, Mozambique	28.28	32.46	C2
11. Antsirabe, Madagascar	19.52	47.00	C2
12. Fianarantsoa, Madagascar	21.27	47.05	C2
13. Tananarive, Madagascar	18.55	47.33	C2

*Stations with a warmth index that overlaps into the opium zone's area of index plots.

milder temperatures of a maritime location, but the stations' high elevations account for winter temperatures that are slightly cooler than the opium zone (Figure 5). Therefore, despite the southeast subregion's general thermal departure, some cultivars grown here might be adaptive to the winter continental influence experienced in northern Thailand.

An endemic African species, *Oryza glaberrima,* is still grown as a food staple in a few areas of southern Africa, but higher-yielding cultivars of introduced Asian *O. sativa* are more common in the region today (DeDatta, 1975). A diversity in natural habitats and a long history of selection pressures have led to considerable variety of Asian rice (Alluri, 1985; Zafera Antoine, 1985). The average yield is about 1.0 tons per hectare. The southern interior area produces just over 200 tons of dryland rice and the southeast area produces 2,206 tons. Nearly all of the latter tonnage comes from farms in Madagascar (2,000 tons), the only country in the southern Africa and Madagascar region that depends on rice as a dominant food staple (Garrity, 1985).

Most of the upland rice research in the southern Africa and Madagascar region is limited to varietal screening with little or no emphasis on cold-tolerance; probably because upland rice is generally cultivated at elevations lower than 1,000 meters. However, the problem of cold-induced yield reduction is beginning to attract attention as a result of regional population growth and an increase in demand for rice in Africa's urban areas. Such factors are making rice production more practical economically in areas above this elevation (Ching'ang'a, 1985; IITA, 1984; Shahi, 1985).

3. South Asia (D) — The only Cw station in Nepal (D1) is at Kathmandu (Table 3). This location's warmth index is representative of the higher elevations in the opium zone, and winter temperatures account for much of this location's thermal departure from the opium zone (Figure 5). Therefore, as in southern Africa and Madagascar, a case can

Table 3. South Asia: Selected *Cw* Weather Stations

Station	Lat. (S)	Long. (E)	Figure 4 Area Plot
1. Kathmandu, Nepal	27.42	85.12	D1
2. Jabalpur, India	23.10	79.59	D2
3. Tezpur, India	26.37	92.47	D2
4. Darbhanga, India	26.10	85.54	D2
5. Guvahati, India	26.11	91.45	D2
6. Mukteswar, India	29.28	79.39	D3
7. Simla, India	31.06	77.10	D3

No station has a warmth index that overlaps into the opium zone's area of index plots.

be made for investigating the possible transfer of cold-tolerant rice cultivars. Despite a more extreme temperature range caused by cold winters, rice yields fare better than those in the opium zone (Huke, 1982). In the Kathmandu Valley (600 to 2,000 m) they average 2.6 tons per hectare. However, this high average is primarily the result of the intense use of labor and cultivation on rainfed terraces (Mallick, 1982).

Rice screened in Nepal for cold-tolerance trials have concerned only varieties grown on wetland terraces (Shahi and Hue, 1979). Nonetheless, eastern Nepal, where Kathmandu is located, possesses a rich spectrum in varietal diversity among upland varieties that can tolerate cool night temperatures. Over much of the region settlements are scattered in small isolated valleys, where wetland rice is grown in the valley bottoms and nonirrigated rice is grown on terraces in rotation with other crops (Uhlig, 1978).

In Lower India (D2), which encompasses the Brahmaputra lowland and an area south of the Ganges River, only Jabalpur has a warmth index that falls within the opium zone range, but very little rice is produced here (Huke, 1982). In addition, its winter temperatures are extremely mild compared to the opium zone (December averages 16.4° C). Thus, it would be unlikely to find cultivars with cool season adaptations. The remaining stations in Lower India fall outside of the zone's index range due to their warmer summer temperatures (Figure 5).

Highland India (D3) stations, located west of Nepal in the higher portions of the Himalayan foothills, are totally outside of the range of opium zone warmth indexes. Injury due to low temperature is a major constraint to rice production. Short growing seasons require seedling bed transplantation and almost all cultivation is on wetland terraces (Hamdani, 1979; Huke, 1982). Because of extreme thermal departure from Thailand's opium zone, this region probably does not have transferable rice cultivars.

4. Northeastern Myanmar and Far East (E) — There are two stations in northeastern Myanmar: Bhamo and Lashio (Table 4). Bhamo, which is located in the Irrawaddi River Valley, has much higher summer temperatures than the opium zone (Figure 5). This location accounts for the offset position of the region's plot on the nomogram (Figure 4). It is a center of irrigated rice production and little or no upland rice is cultivated here (Hamdani, 1979; Huke, 1982). On the other hand, Lashio's nomogram plot is nearer the opium zone due to its relatively cooler summer temperatures. About one-third of the rice produced in hills surrounding Lashio is cultivated using dryland methods (Hamdani, 1979; Huke, 1982). The total area is not extensive (12,000 hectares) because production is by means of shifting cultivation. Yields average between 0.75 and 1.1 tons per hectare (DeDatta, 1975).

Table 4. Northeast Myanmar and Far East: Selected *Cw* Weather Stations

Station	Lat. (S)	Long. (E)	Figure 4 Area Plot
1. Lashio, Myanmar	22.58	97.51	E1
2. Bhamo, Myanmar	24.16	97.17	E1
3. Hanoi, Vietnam	21.02	105.52	E2
4. Hong Kong	22.18	114.10	E2
5. Hsi-Ying, PRC	21.03	110.28	E2
6. Lungchow, PRC	22.22	106.45	E2
7. Pakhoi, PRC	21.28	109.05	E2
8. Tengchong, PRC	25.00	98.40	E3
9. Ya-an, PRC	30.00	103.03	E3

No station has a warmth index that overlaps into the opium zone's area of index plots.

There are perhaps hundreds of landraces and wild relatives of cultivated plants still to be collected in the hills of northern Myanmar and adjoining areas in Laos; yet, there is no evidence in the literature of upland rice research by Burmese agronomists (Plucknett, et al., 1982; Arraudeau and Harahap, 1986). Notwithstanding this deficiency, at least one variety from Myanmar has been tested in the opium zone, and it has yielded better than other imported cultivars (Thai-Australia Highland Agriculture Project, 1981).

The China Sea coast area (E2) includes weather stations in Hanoi, Hong Kong and the southern coast of the People's Republic of China (Table 4). Prospects for finding suitable rice varieties are doubtful, because the subregion's thermal departure is due primarily to high summer temperatures (Figure 5). Moreover, only irrigated rice is grown at the locations of the weather stations (Huke, 1982).

Ya-an and Tengchong are southern highland stations in the People's Republic of China (E3, Table 4). They are located in the interior southwest of the country. Useful rice varieties are unlikely to be found here as a consequence of low warmth indexes compared to the opium zone. Continental winters account for the thermal departure (Figure 5). Prospects are reduced further because little or no rice is produced in the vicinity of Ya-an and only small amounts of upland rice (3000 hectares) are cultivated near Tengchong (Huke, 1982).

Conclusions

This article demonstrates that in certain instances successful drug crop replacement studies require detailed information about several geographic regions. In considering upland rice as an opium replacement crop in Thailand, it is apparent that the Cw region in highland Brazil and the two

Cw subregions of southern Africa have considerable potential for locating useful rice varieties. There also seems to be sufficient similarity of temperatures to warrant further investigations at specific locations in Nepal and northeastern Myanmar. More information is needed about rice strains in each of these areas, particularly information regarding cold-tolerance. Moreover, the suitability of local wetland cultivars should also be investigated, since continuation of population pressures in the opium zone can be expected to force expansion of field terraces and cultivation using gravity irrigation technology.

These are not conclusive findings because only a few years of temperature data are available for many of the weather stations. The range of warmth indexes for the opium zone might be different if thirty or forty years of data were available. Similarly, if data for more weather stations were available for the other Cw climate regions, their index plots might overlap more with the opium zone. Despite these shortcomings, this climate-based approach is of practical value because it provides a beginning point for more in-depth location-specific analyses.

The regional rice yields that are discussed are useful as general references, but more information is needed to sort out how each region's physical, economic, and cultural environment effects yields. Information about factors of production is particularly important, since new rice varieties will be grown by subsistence farmers to increase their food supplies. Therefore, more data are needed about other climatic elements, about soil characteristics, varietal yields, taste and nutrition, plant physiognomy and phenology, and biological stresses. Additionally, to help maximize yields, agricultural extension workers will need more information about cultivation and management practices in the analog regions. All of these factors are overlapping concerns of plant scientists and geographers, and any further research at the many locations identified in this study would benefit from a liaison between these groups.

Fragments of a possible liaison already exist. The United Nations Fund for Drug Abuse Control operates small crop replacement programs in Thailand, Myanmar, Laos, Colombia, Bolivia, Peru, Mexico, Brazil and Pakistan. Moreover, it has field advisors working on various other projects in nearly every country of Latin America, Asia, Africa and the Middle East. Other possible links in the network are international nurseries. By working in cooperation with academic plant scientists, these nurseries have helped launch the development of hundreds of successful crops in various countries (Plucknett, et al. 1982; Smith, 1987), but only occasional collaboration has taken place with the various narcotic crop replacement programs. Geographers could also serve as links in a liaison against illicit drug production. Indeed, their role in this network has tremendous potential through the auspices of specialty groups of professional geography organizations, which could bring together geographers and non-academic scientists who are interested in combating illicit drug production.

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