2. TWO TYPES OF ECOSYSTEMS

Inner vs. Outer Indonesia

A handful of mere statistics of the most routine, humdrum sort can sketch a picture of the basic characteristics of the Indonesian archipelago as a human habitat with more immediacy than pages of vivid prose about steaming volcanoes, serpentine river basins, and still, dark jungles. The land area of the country amounts to about one and one-half million square kilometers, or about that of Alaska. Of this only about one hundred and thirty-two thousand square kilometers are in Java, the rest making up what are usually called "the Outer Islands"—Sumatra, Borneo (Kalimantan), Celebes (Sulawesi), the Moluccas, and the Lesser Sundas (Nusa Tenggara). But the country's total population (1961) is around ninety-seven million, while Java's population alone is about sixty-three million. That is to say, about 9 percent of the land area supports nearly two-thirds of the population; or, reciprocally, more than 90 percent of the land area supports approximately one-third of the population. Put in density terms, Indonesia as a whole has about 60 persons per square kilometer; Java has 480, and the more crowded areas of the central and east-central parts of the island more than a thousand. On the

other hand, the whole of Indonesia minus Java (i.e., the Outer Islands) has a density of around twenty-four per square kilometer. To summarize: all over, 60; the Outer Islands, 24; Java, 480: if ever there was a tail which wagged a dog, Java is the tail, Indonesia the dog.[1]

The same plenum and vacuum pattern of contrast between Java and the Outer Islands appears in land utilization. Almost 70 percent of Java is cultivated yearly—one of the highest proportions of cropland to total area of any extensive region in the world—but only about 4 percent of the Outer Islands. Estate agriculture aside, of the minute part of the Outer Islands which is cultivated, about 90 percent is farmed by what is variously known as swidden agriculture, shifting cultivation, or slash-and-burn farming, in which fields are cleared, farmed for one or more years, and then allowed to return to bush for fallowing, usually eventually to be recultivated. On Java, where nearly half the smallholder's crop area is under irrigation, virtually no swidden agriculture remains. In the irrigated regions, field land is in wet-rice terraces, about half of them double-cropped, either with more wet rice or with one or several secondary dry crops. In the unirrigated regions, these dry crops (maize, cassava, sweet potatoes, peanuts, dry rice, vegetables, and others) are grown in a crop-and-fallow regime. Production statistics present, of course, the same picture: in 1956 approximately 63 percent of Indonesia's rice, 74 percent of her maize, 70 percent of her cassava, 60 percent of her sweet potatoes, 86 percent of her peanuts, and 90 percent of her soya beans were produced in Java.[2]

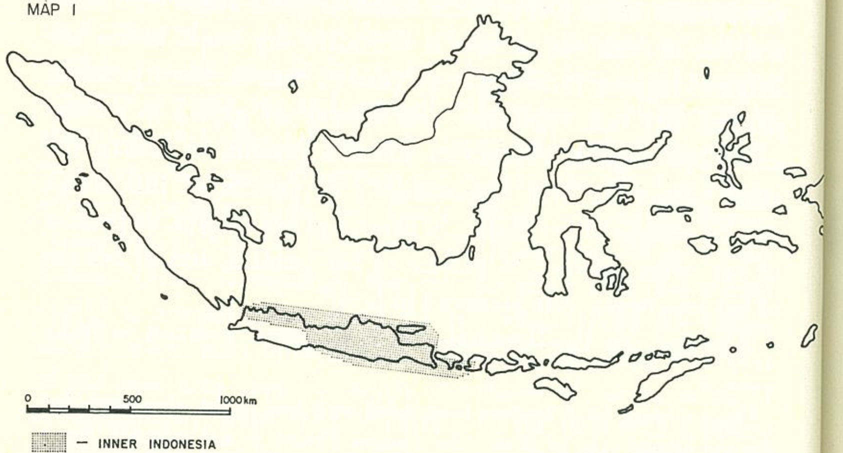
Actually, this fundamental axis of ecological contrast in Indo-

[1] Sumaniwata, 1962. Madura is included with Java in the calculations but the transitional area of West New Guinea (Irian) is not included. For a useful general summary of Indonesian demographic realities, see The Population of Indonesia, 1956.

[2] Metcalf, 1952. Statistical Pocketbook of Indonesia, 1957, p. 51. Commercial crop cultivation shows, however, a sharply contrasting pattern.

nesia is not altogether accurately demarcated when one phrases it, following the received practice of the census takers, simply in terms of Java (and Madura) versus the Outer Islands, because in fact the "Javanese" pattern is found in southern Bali and western Lombok as well, and is but weakly represented in the southwestern corner of Java (South Bantam and South Priangan) where a pattern more like that of the Outer Islands, including a certain amount of swidden, is found. Thus, we might better refer to the contrast as one between "Inner Indonesia"—northwest, central, and east Java, south Bali, and west Lombok; and "Outer Indonesia"—the rest of the Outer Islands plus southwest Java, which do in fact form more or less of an arc pivoted on central Java. (See Map 1.) Such a division is, in any case, a gross one which needs modification in detail: patches of relatively intensive irrigation agriculture are found at either tip,

MAP I



INNER vs OUTER INDONESIA

around Lake Toba, and in the western highlands in Sumatra as well as in the southwest arm of the Celebes, for example, and eastern Madura deviates somewhat from the Javanese norm.[3] But it does lead, in a broad and general way, to a fruitful discrimination of two different sorts of ecosystems with two different sorts of dynamics—one centering on swidden agriculture, one on wet-rice agriculture—in terms of which the striking differences in population density, modes of land use, and agricultural productivity can be understood.

Swidden

As Conklin has pointed out, much of the inadequate treatment swidden agriculture has received in the literature is a result of the fact that characterizations of it have tended to be negatively phrased.[4] Thus, Gourou outlines as its four most distinctive features: (1) it is practiced on very poor tropical soils; (2) it represents an elementary agricultural technique which utilizes no tool except the axe; (3) it is marked by a low density of population; and (4) it involves a low level of consumption.[5] Similarly, Pelzer says that it is marked by a lack of tillage, less labor input than other methods of cultivation, the nonutilization of draft animals and manuring, and the absence of a concept of private landownership.[6] For Dobby, it represents "a special stage in the evolution from hunting and food gathering to sedentary farming," this specialness evidently consisting of such null traits as nonrelation to pastoral pursuits and the production of very little which is of trading or commercial significance.[7] And for many, by far its most outstanding feature is that singled out by Spate—namely, that its practice is "attended by serious defores-

---

[3] Terra, 1958.
[4] Conklin, 1957, p. 149.
[5] Gourou, 1956.
[6] Pelzer, 1945, pp. 16 ff.
[7] Dobby, 1954, pp. 347–349.

tation and soil erosion." [8] Aside from the fact that most of these depreciatory statements are dubious as unqualified generalizations (and a few are simply incorrect), they are not of much help in understanding how swidden farming systems work.

In ecological terms, the most distinctive positive characteristic of swidden agriculture (and the characteristic most in contrast to wet-rice agriculture) is that it is integrated into and, when genuinely adaptive, maintains the general structure of the pre-existing natural ecosystem into which it is projected, rather than creating and sustaining one organized along novel lines and displaying novel dynamics. In the tropics, to which, for reasons we may postpone considering, this form of cultivation is today largely confined, the systemic congruity between the biotic community man artificially establishes on his swidden plot and that which exists there in stable climax independent of his interference (in the main, some variety of tropical forest) is striking. Any form of agriculture represents an effort to alter a given ecosystem in such a way as to increase the flow of energy to man: but a wet-rice terrace accomplishes this through a bold reworking of the natural landscape; a swidden through a canny imitation of it.

The first systemic characteristic in which a swidden plot simulates a tropical forest is in degree of generalization. By a generalized ecosystem is meant one in which a great variety of species exists, so that the energy produced by the system is distributed among a relatively large number of different species, each of which is represented by a relatively small number of individuals. If, on the contrary, the system is one with a relatively small number of species, each of which is represented by a relatively large number of individuals, it is said to be specialized. Put somewhat more technically, if the ratio between number of species and number of organisms in a biotic community is called its *diversity index,* then a generalized ecosystem is one characterized by a

[8] Spate, 1945, p. 527, quoted in Leach, 1954, p. 22.

community with a high diversity index, a specialized one by a community with a low diversity index. Natural communities tend to vary widely in their degree of generalization, or the size of their diversity index: a tropical forest, and in particular a rain forest, is a very generalized, very diverse community, with an enormous variety of plant and animal species sporadically represented; a tundra is characterized by a very specialized, uniform community, with relatively few species but, at least in the subarctic, a large number of clustered individuals.[9]

Much of the most effective human utilization of the natural habitat consists of changing generalized communities into more specialized ones, as when natural ponds containing a wide variety of green plants, aquatic animals, and fishes are transformed into managed ones in which the number of types of primary plant producers is sharply reduced to those which will support a few select types of fish edible by man. The rice terrace, which can, in these terms, be viewed as a sort of slowly drained, managed pond focused on an edible plant, is an outstanding example of artificially created specialization. The reverse process, increased generalization, also occurs, of course, as when man introduces into a temperate grassland area (for example, the American prairie) a wide variety of interrelated domestic plants and animals, which, though they constitute a much more diverse community than that indigenous to the area, nonetheless prove to be viable within it.

Still other human adaptations, however, attempt to utilize the habitat not through altering its diversity index, but through more or less maintaining its over-all pattern of composition while changing selected items of its content; that is, by substituting certain humanly preferred species for others in functional roles ("niches") within the pre-existing biotic community. This is not to say that such adaptations do not seriously alter the indigenous ecosystem (as, in a gross sense, most hunting and gathering adaptations do not), or that their general effect on the balance of

[9] These concepts are taken from Odum, 1959, pp. ii, 50–51, 77, 281–283, 316, and 435–437.

nature may not sometimes be a radical one; but merely that they alter the indigenous ecosystem by seeking to replace it with a system which, although some of its concrete elements are different, is similar to it in form, rather than by a system significantly more specialized or more generalized. Large-scale cattle herding during the nineteenth century on the previously buffalo-dominated southern and western plains is an example of this type of adaptation within a specialized system. Swidden agriculture is certainly an example of it within a generalized one.

The extraordinarily high diversity index of the tropical forest, the kind of natural climax community which still characterizes the bulk of Outer Indonesia, has already been mentioned. Though there are probably more floral species in this region than any other of comparable size in the world (van Steenis has estimated that between twenty and thirty thousand species of flowering plants, belonging to about 2,500 families, can be found in the archipelago), continuous stands of trees or other plants are rare, and the occurrence of as many as thirty different species of trees within a hundred square yards is not at all uncommon.[10] Similarly, on about a three-acre swidden plot in the Philippines (detailed field studies are lacking for Indonesia as such) Conklin has seen as many as forty different sorts of crops growing simultaneously, and one informant drew an ideal plot containing at one time forty-eight basic kinds of plants. The people of the area, the Hanunóo of Mindoro, distinguish more than sixteen hundred different plant types (which is a finer classification than that employed by systematic botanists), including the astounding number

[10] van Steenis, 1935; and Dobby, 1954, p. 61. This floral diversity is paralleled by an equally great wealth of fauna: the industrious as well as famous naturalist A. R. Wallace found 200 species of beetles in a square mile of Singapore forest and brought back a total of more than 125,000 animal specimens from the general Malaysian region. Robequain, 1954, pp. 38–59. For a general ecological analysis of tropical forest plant diversity, see Richards, 1952, pp. 231–268. More popular accounts, but which include some discussion of fauna as well, are Bates, 1952, pp. 175–211; and Collins, 1959.

of four hundred thirty cultivates.[11] Conklin's vivid description of what a Hanunóo swidden in full swing looks like gives an excellent picture of the degree to which this agriculture apes the generalized diversity of the jungle which it temporarily replaces:

> Hanunóo agriculture emphasizes the intercropping of many types of domesticated plants. During the late rice-growing seasons, a cross section view of a new [plot] illustrates the complexity of this type of swidden cropping (which contrasts remarkably with the type of field cropping more familiar to temperate zone farmers). At the sides and against the swidden fences there is found an association dominated by low, climbing or sprawling legumes (asparagus beans, sieva beans, hyacinth beans, string beans, and cowpeas). As one goes out into the center of the swidden, one passes through an association dominated by ripening grain crops but also including numerous maturing root crops, shrub legumes and tree crops. Pole-climbing yam vines, heart-shaped taro leaves, ground-hugging sweet potato vines, and shrublike manioc stems are the only visible signs of the large store of starch staples which is building up underground, while the grain crops fruit a meter or so above the swidden floor before giving way to the more widely spaced and less rapidly-maturing tree crops. Over the first two years a new swidden produces a steady stream of harvestable food in the form of seed grains, pulses, sturdy tubers, and underground stems, and bananas, from a meter below to more than 2 meters above the ground level. And many other vegetable, spice and nonfood crops are grown simultaneously.[12]

The second formal characteristic common to the tropical-forest and swidden-agriculture ecosystems is the ratio of the quantity

[11] Conklin, 1954. Other valuable field studies of swidden in Malaysia include, Freeman, 1955 (on diversity, pp. 51–54); and Geddes, 1954 (on diversity, pp. 64–65). A brief description of swidden-making in East Indonesia can be found in Goethals, 1961, pp. 25–29.

[12] Conklin, 1957, p. 147. Conklin estimates that in the first and most active year of the swidden cycle up to 150 specific crop types may be planted at one time or another.

of nutrients locked up in living forms (that is, the biotic community) to that stored in the soil (that is, the physical substratum): in both it is extremely high. Though, as with the tropical forest itself, much variation is found, tropical soils are in general extensively laterized. As precipitation in most of the humid, rain-heavy tropics greatly exceeds evaporation, there is a significant downward percolation through the soil of relatively pure, lukewarm water, a type of leaching process whose main effect is to carry away the more highly soluble silicates and bases, while leaving behind a dreary mixture of iron oxides and stable clays. Carried to an extreme, this produces ferralite, a porous, crumbly, bright-red, acidic soil which, however excellent the Indonesians find it for making bricks without straw, is of much less value from the point of view of the support of plant life. Protected to a certain extent by the shielding effects of the thick vegetation cover, most tropical soils have not developed such a serious case of what Gourou has called pedological leprosy.[13] But the great majority of them, having been exposed to these ultrastable climatic conditions over very long periods of time, are markedly leached, and thus seriously impoverished in minerals requisite to the sustenance of life.[14]

This apparent and oft-remarked paradox of a rich plant and animal life supported on a thin soil is resolved by the fact that the cycling of material and energy among the various components of a tropical forest is both so rapid and so nearly closed that only the uppermost layers of the soil are directly and significantly involved in it, and they but momentarily. The intense humidity and more or less even distribution of rainfall, the equable, moderately elevated temperatures, the small month-to-month variations in day length and amount of sunlight—all the monotonous con-

[13] Gourou, 1953b, p. 21.

[14] This paragraph and those immediately following are based mainly on Richards, 1952, pp. 203–26; Dobby, 1954, pp. 74–84; and Gourou, 1953b, pp. 13–24. However, much remains to be learned about soil factors in the tropics.

stancies of the tropics—are conducive to a high rate of both decomposition and regeneration of animal and vegetable material. Speedy decomposition is insured by the multiplication of bacteria, fungi and other decomposers and transformers which the humid conditions favor, as well as by the multitude of herbiverous animals and insects who are so ravenous that, as Bates remarks, virtually "every fruit and every leaf [in the tropical forest] has been eaten by something." [15] An enormous amount of dead matter is thus always accumulating on the forest floor—leaves, branches, vines, whole plants, faunal remains and wastes; but their rapid decay and the high absorptive capacity of the luxuriant vegetation means that the nutrients in this dead organic matter are reutilized almost immediately, rather than remaining stored to any great extent or for any great length of time in the soil where they are prey to the leaching process.

The role of humus in creating a topsoil storehouse of nutrient materials in colloidal form to be drawn upon gradually as needed, which looms so prominently in ecosystems at higher latitudes, is here minimized; organic materials rarely extend in significant quantity more than a few inches beneath the forest floor, because the nutrients set free by the rapid decay of dead matter are quickly taken up again by the shallow, splayed root systems of the intensely competitive plants. Thus, despite the heavy rains, loss of nutrients due to runoff in this process of transfer is very slight, so that quite marginal additions of energy from outside the system through nitrogen fixing in leguminous trees and adsorption of minerals released by rock decomposition are themselves enough to compensate for it. The climax community, once established, through still imperfectly understood processes of ecological succession, is thus virtually self-perpetuating. By maintaining most of its energy in the form of living things most of the time, the tropical-forest ecosystem is able to prevent any significant escape of energy across its boundaries and to circumvent

[15] Bates, 1952, p. 209.

the problem of impoverished soil conditions by feeding largely upon itself.

Swidden agriculture operates in essentially this same supernatant, plant-to-plant, direct cycling manner. The burning of the slashed plot is at base a means both of accelerating the process of decay and of directing that process in such a fashion that the nutrients it releases are channeled as fully as possible into certain selected food-producing plants. A significant proportion of the mineral energy upon which swidden cultivates, and especially the grains, draw for their growth comes from the ash remains of the fired forest, rather than from the soil as such, so that the completeness with which a plot is burnt is a crucial factor in determining its yield, a fact of which probably all swidden cultivators are aware.[16] A good burn, in turn, is dependent on the one hand upon the care and thoroughness with which the vegetation has been cut, and on the other upon the dryness of the weather during the cutting-planting period. Over the thoroughness of the cutting the cultivators have a high degree of control and, though different groups of swidden agriculturalists, as any other type of farmers, vary widely in their skills, yet their felling, slashing, trimming techniques, as well as their actual firing methods, are commonly well developed. Over the weather they have, of course, no control (though they are usually adept at estimating it), and intense ritual activity is commonly directed toward preventing rain, or at least maintaining confidence, during the anxious, all-important few weeks between cutting and sowing. At any rate, the primary function of "slash and burn" activities is not mere clearing of the land (the use of the term "clearing," with respect

[16] For example, among the Mandaya of eastern Mindanao, those cultivating over 1,700 feet where burning is impossible because of the absence of a dry period harvest about 10 to 15 cavans of rice per hectare, while those cultivating in lower areas where burning is possible average 30–35; Aram A. Yengoyan, personal communication. In general, however, the precise effect of firing as a fertilizing mechanism remains to be investigated experimentally, like so much else about swidden.

to swiddens is actually somewhat misleading) but rather the transfer of the rich store of nutrients locked up in the prolific vegetation of the tropical forest to a botanical complex whose general ecological productivity, in the sense of the total energy flow in the system, may be substantially smaller but whose yield to man is a great deal larger.[17]

General ecological productivity is lower because this transfer is less efficient than that which takes place under natural conditions of decay and regeneration. Here, a large amount of energy does escape across the boundaries of the system. Gourou estimates that between six and nine hundred pounds of nitrogen alone go up in smoke in the burning of a single acre of forest; and, despite the utmost shrewdness in judging the weather and the greatest speed in firing and planting, much ash is inevitably washed away by the rains before it can be utilized by the cultivates, fast growing as they tend to be.[18] Further, as the cultivates are less woody in substance than those indigenous to the forest, they do not form a very appropriate material for the technique of accelerating and channeling nutrient transfer through the deliberate production of ash, and so the firing process is not continuously repeatable. The result is, of course, the well-known drop in fertility on swidden plots (rice output of south Sumatran plots is known to drop as much as 80 percent between a first and second cropping), and the surrender of the plot to natural regeneration.[19]

But, despite the fact that secondary forest growth is, at least in the earlier phases of regeneration, notably less luxuriant than primary, if the period of cultivation is not too long and the period of fallow long enough, an equilibrated, nondeteriorating and reasonably productive farming regime (productive in the sense of

[17] This analysis is based on the descriptions of swidden techniques given in Conklin, 1957, pp. 49–72; Freeman, 1955, pp. 40–48; and Hose and MacDougal, 1912. For the distinction between ecological productivity and yield to man, see Clarke, 1954, pp. 482–500.

[18] Gourou, 1953b, p. 26.

[19] Pelzer, 1945, p. 16.

yield to man) can be sustained, again to a significant degree irrespective of the rather impoverished soil base on which it rests.[20] The burned forest provides most of the resources for the cultivates; the decaying cultivates (nothing but the edible portions of plants is removed from the plot) and the natural processes of secondary succession, including invasions from the surrounding forest within which plots are usually broadly dispersed rather than tightly clustered, provide most of the resources for the rapidly recuperating forest. As in the undisturbed forest, "what happens" in an adapted swidden ecosystem happens predominantly in the biotic community rather than in the physical substratum.

Finally, a third systemic property in which the tropical forest and the swidden plot tend to converge is general architecture: both are "closed-cover" structures. The tropical forest has often been compared to a parasol, because of the effectiveness with which the tall, closely packed, large-crowned, evergreen trees both deflect the rain and shut out the sun so as to protect the soil against the worst effects of the leaching process, against baking, and against erosion. Photosynthesis takes place almost entirely at the very top of the forest, from a hundred to a hundred and fifty feet up, and so most of the growing things (as well as much of the faunal life) reach desperately toward this upper canopy seeking their small place in the sun, either by climbing, as the thousands of woody lianas and other vines, by finding an epiphytic perch, as the orchids and ferns, or by mere giantism, as the dominant trees and the bamboos, leaving the darkened floor relatively free of living plants.[21] In a swidden, this canopy is, of course, radically lowered, but much of its umbrella-like continuity is maintained, in part by planting cultigens not in an open field, crop-row manner, but helter-skelter in a tightly woven, dense botanical fabric, in part by planting shrub and tree crops of vari-

[20] Conklin, 1957, p. 152; Leach, 1954, p. 24; and Geddes, 1954, pp. 65–68.
[21] Bates, 1952, pp. 200–203.

ous sorts (coconuts, areca, jakfruit, banana, papaya, and today in more commercial areas rubber, pepper, abaca, and coffee), and in part by leaving some trees standing. In such a way, excessive exposure of the soil to rain and sun is minimized and weeding, exhausting task in any case, is brought within reasonable proportions because light penetration to the floor is kept down to a much lower level than in an open-field system.[22]

In sum, a description of swidden farming as a system in which "a natural forest is transformed into a harvestable forest" seems a rather apt one.[23] With respect to degree of generalization (diversity), to proportion of total system resources stored in living forms, and to closed-cover protection of an already weakened soil against the direct impact of rain and sun, the swidden plot is not a "field" at all in the proper sense, but a miniaturized tropical forest, composed mainly of food-producing and other useful cultivates. Yet, as is well known, though less well understood, the equilibrium of this domesticated form of forest system is a great deal more delicate than that of the natural form. Given less than ideal conditions, it is highly susceptible to breakdown into an irreversible process of ecological deterioration; that is, a pattern of change leading not to repeated forest recuperation but to a replacement of tree cover altogether by the notorious *imperata* savannah grass which has turned so much of Southeast Asia into a green desert.[24]

[22] For an excellent description of the concurrent employment by recent immigrant Javanese farmers of an open-field system and by indigenous farmers of a closed-field one in the Lampong area of south Sumatra, and of the essential defeat of the former by the weeding problem, see, Kampto Utomo, 1957, pp. 127–132. Some forms of partial swidden-farming—i.e., where swidden is auxiliary to other forms of cultivation—are, however, open-field systems; while integral systems—i.e., where swidden is the sole form of cultivation—commonly are not. I owe this point to Harold Conklin.
[23] Kampto Utomo, 1957, p. 129.
[24] Gourou, 1953a, p. 288, estimates that about 40 percent of the Philippines and 30 percent of Indonesia are covered with *imperata,* presumably

Swidden cultivation may turn thus maladaptive in at least three ways: by an increase in population which causes old plots to be recultivated too soon; by prodigal or inept agricultural practices which sacrifice future prospects to present convenience; and by an extension into an insufficiently humid environment in which the more deciduous forests have a much slower recovery rate and in which clearing fires are likely to burn off accidentally great stands of timber.[25] The population problem has been much discussed, though exact figures are difficult to obtain. Van Beukering has put the population ceiling for swidden in Indonesia over-all at about 50 per square kilometer, Conklin estimates that the Hanunóo area can carry 48 per square kilometer without deterioration, and Freeman calculates 20–25 as the maximum in his central Sarawak region; but it is not known to what degree the various local population densities in Outer Indonesia now exceed critical limits and are producing grassland climaxes as a result of the need for more rapid recultivation.[26] With the population of the region now increasing at 2 percent or more annually, however, the problem seems likely to become overtly pressing in the not too distant future; glib references to Outer Indonesia as "grossly underpopulated" constitute a simplistically quantitative and ecologically naive view of demography.

The fact that wasteful or inept methods may be destructive to the long-run equilibrium of swidden agriculture not only underscores the wide variation in proficiency with which different groups of shifting cultivators operate, but, even more important,

nearly all of it caused by man. These figures may be somewhat high, however: Pelzer, 1945, p. 19, estimates the Philippine grassland percentage at 18.

[25] A full consideration of the factors relating to the breakdown of the swidden cycle into a deflected grassland succession would need, of course, to consider topographical and edaphic variables, the role of animal husbandry, associated hunting practices, and so on. For such a micro-analysis, see Conklin, 1959.

[26] Van Beukering, 1947. Conklin, 1957, pp. 146–147. Freeman, 1955, pp. 134–135. These various figures are all somewhat differently calculated.

demonstrates that cultural, social, and psychological variables are at least as crucial as environmental ones in determining the stability of human modes of adaptation. An example of such a thriftless use of resources by swidden farmers is provided by Freeman who says that the Iban have been less shifting cultivators than *mangeurs de bois*.[27] Located in a primary forest area into which they have fairly recently expanded at the expense of indigenous tribes, the Iban are well below maximum population densities. But they nevertheless seriously overcultivate, often using a single plot three years in succession or returning to a fallowed one within five years, and thereby causing widespread deforestation. The reasons for this overcultivation are various, including an historically rooted conviction that there are always other forests to conquer, a warrior's view of natural resources as plunder to be exploited, a large village settlement pattern which makes shifting between plots a more than usually onerous task, and, perhaps, a superior indifference toward agricultural proficiency. But, again, to what degree such prodigality exists among the swidden agriculturalists of Outer Indonesia is virtually unknown.

As for the climatic factor, the most highly generalized, evergreen, closed-cover tropical forest, commonly specified as "rain forest" is chiefly characteristic of equatorial lowland areas where a marked dry season is absent; as one moves toward higher-latitude areas with a marked dry season, it shades off, more or less gradually, into a shorter, more open, less diverse, and at least partly deciduous variety of tropical forest, usually called "monsoon forest."[28] The delicacy of swidden equilibrium increases at equal pace with this transition toward a more subtropical environment because of the steadily diminishing power of the natural community rapidly to reconstitute itself after human interference. The greater ease, and uncontrollability, with which such drier wood-

[27] Freeman, 1955, pp. 135–141.

[28] Dobby, 1954, pp. 62, 65–70. Variation in tropical forest composition is also affected by altitude, soil, and local land mass configurations. For a full discussion, see Richards, 1952, pp. 315–374.

lands burn, fanned often by stronger winds than are common in the rain forest areas, only increases the danger of deterioration to grassland or scrub savannah and, in time, by erosion to an almost desert-like state. The southeast portion of the Indonesian archipelago, the Lesser Sundas, where the parching Australian monsoon blows for several months a year, has been particularly exposed to this general process of ecological decline, and in some places devastation is widespread.[29] All in all, the critical limits within which swidden cultivation is an adaptive agricultural regime in Outer Indonesia are fairly narrow.

Sawah

The micro-ecology of the flooded paddy field has yet to be written. Though extensive and detailed researches into the botanical characteristics of wet rice, its natural requirements, the techniques of its cultivation, the methods by means of which it is processed into food, and its nutritional value have been made, the fundamental dynamics of the individual terrace as an integrated ecosystem remain unclear.[30] The contrast between such a terrace—an artificial, maximally specialized, continuous-cultivation, open-field structure to a swidden plot could hardly be more extreme; yet how it operates as an organized unit is far from being understood. Knowledge remains on the one hand specialized and technical, with developed, even experimental, analyses of breeding and selection, water supply and control, manuring and weeding, and so on, and, on the other, commonsensical, resting on a vast, unexamined accumulation of proverbial, rice-roots wisdom concerning similar matters. But a coherent description of the manner in which the various ecological components of a terrace interrelate to form a functioning productive system remains noticeable by its absence. So far as I am aware, a genuinely detailed and circumstantial analysis of any actual wet-rice field (or group of fields) as a set of "living organisms and nonliving sub-

[29] See Ormeling, 1956.

[30] For an encyclopedic summary of such researches, see Grist, 1959.

stances interacting to produce an exchange of material between with living and the non-living parts" does not exist in the literature.[31]

The most striking feature of the terrace as an ecosystem, and the one most in need of explanation, is its extraordinary stability or durability, the degree to which it can continue to produce, year after year, and often twice in one year, a virtually undiminished yield.[32] "Rice grown under irrigation is a unique crop," the geographer Murphey has written,

> . . . soil fertility does affect its yield, as does fertilization, but it does not appear to exhaust the soil even over long periods without fertilization, and in many cases it may actually improve the soil. On virgin soils a rapid decline in yield usually takes place, in the absence of fertilization, within the first two or three years, but after ten or twenty years the yield tends to remain stable more or less indefinitely. This has been borne out by experiments in various parts of tropical Asia, by increased knowledge of the processes involved, and by accumulated experience. On infertile soils and with inadequate fertilization the field stabilizes at a very low level, as is the case now in Ceylon and most of South Asia, but it does stabilize. Why this should be so is not yet entirely understood.[33]

The answer to this puzzle almost certainly lies in the paramount role played by water in the dynamics of the rice terrace. Here, the characteristic thinness of tropical soils is circumvented through the bringing of nutrients onto the terrace by the irrigation water to replace those drawn from the soil; through the fixation of nitrogen by the blue-green algae which proliferate in the warm water; through the chemical and bacterial decomposition of organic material, including the remains of harvested crops in that water; through the aeration of the soil by the gentle movement

[31] The quotation is the formal definition of an ecosystem given in Odum, 1959, p. 10.

[32] Gourou, 1953b, p. 100; and 1953a, p. 74.

[33] Murphey, 1957.

of the water in the terrace; and, no doubt, through other ecological functions performed by irrigation which are as yet unknown.[34] Thus, although, contrary to appearances, the paddy plant actually requires no more water than dry-land crops for simple transpirational purposes, "the supply and control of water . . . is the most important aspect of irrigated paddy cultivation; given an adequate and well-controlled water supply the crop will grow in a wide range of soils and in many climates. It is therefore more important than the type of soil." [35]

This primary reliance on the material which envelops the biotic community (the "medium") for nourishment rather than on the solid surface in which it is rooted (the "substratum"), makes possible the same maintenance of an effective agricultural regime on indifferent soils that the direct cycling pattern of energy exchange makes possible on swiddens.[36] Even that soil quality which is of clearest positive value for paddy growing, a heavy consistency which irrigation water will not readily percolate away, is more clearly related to the semiaquatic nature of the cultivation process than to its nutritional demands, and paddy can be effectively grown on soils which are "unbelievably poor in plant nutrients." [37] This is not to say that natural soil fertility has no effect on wet-rice yields, but merely that, as "paddy soils tend to acquire their own special properties after long use," a low natural fertility is not in itself a prohibitive factor if adequate water resources are available.[38] Like swidden, wet-rice cultivation is essentially an ingenious device for the agricultural exploitation of a habitat in which heavy reliance on soil processes is impossible

[34] In addition to the mentioned Grist (esp. pp. 28–49), Gourou, and Murphey references, useful, if unsystematic, material on the micro-ecology of irrigated rice can be found in Pelzer, 1945, pp. 47–51, and especially in Matsuo, 1955, pp. 109–12.

[35] Grist, 1959, pp. 28, 29.

[36] For the distinction between "medium" and "substratum," see Clarke, 1954, pp. 23–58, 59–89.

[37] Pendleton, 1947; quoted in Grist, 1959, p. 11.

[38] Murphey, 1957.

and where other means for converting natural energy into food are therefore necessary. Only here we have not the imitation of a tropical forest, but the fabrication of an aquarium.

The supply and control of water is therefore the key factor in wet-rice growing—a seemingly self-evident proposition which conceals some complexities because the regulation of water in a terrace is a matter of some delicacy. Excessive flooding is often as great a threat as insufficient inundation; drainage is frequently a more intractable problem than irrigation. Not merely the gross quantity of water, but its quality, in terms of the fertilizing substances it contains (and thus the source from which it comes) is a crucial variable in determining productivity. Timing is also important: paddy should be planted in a well-soaked field with little standing water and then the depth of the water increased gradually up to six to twelve inches as the plant grows and flowers, after which it should be gradually drawn off until at harvest the field is dry. Further, the water should not be allowed to stagnate but, as much as possible, kept gently flowing, and periodic drainings are generally advisable for purposes of weeding and fertilizing.[39] Although with traditional (and in some landscapes, even modern) methods of water control the degree to which these various optimal conditions can be met is limited, even at its simplest, least productive, and most primitive this form of cultivation tends to be technically intricate.

And this is true not only for the terrace itself, but for the system of auxiliary water works within which it is set. We need not accept Karl Wittfogel's theories about "hydraulic societies" and "oriental despotisms" to agree that while the mobility of water makes it "the natural variable *par excellence*" in those landscapes where its manipulation is agriculturally profitable, its bulkiness makes such manipulation difficult, and manageable only with significant inputs of "preparatory" labor and at least a certain

[39] Grist, 1959, pp. 28–32. One of the primary functions, aside from nutrition, of irrigation water is, in fact, the inhibition of weed growth.

amount of engineering skill.[40] The construction and maintenance of even the simplest water-control system, as in rainfall farms, requires such ancillary efforts: ditches must be dug and kept clean, sluices constructed and repaired, terraces leveled and dyked; and in more developed true irrigation systems dams, reservoirs, aqueducts, tunnels, wells and the like become necessary. Even such larger works can be built up slowly, piece by piece, over extended periods and kept in repair by continuous, routine care. But, small or large, waterworks represent a level and kind of investment in "capital equipment" foreign not only to shifting cultivation but to virtually all unirrigated forms of premodern agriculture.

This complex of systemic characteristics—settled stability, "medium" rather than "substratum" nutrition, technical complexity and significant overhead labor investment—produce in turn what is perhaps the sociologically most critical feature of wet-rice agriculture: its marked tendency (and ability) to respond to a rising population through intensification; that is, through absorbing increased numbers of cultivators on a unit of cultivated land. Such a course is largely precluded to swidden farmers, at least under traditional conditions, because of the precarious equilibrium of the shifting regime. If their population increases they must, before long, spread out more widely over the countryside in order to bring more land into cultivation; otherwise the deterioration to savannah process which results from too rapid recultivation will set in and their position will become even more untenable. To some extent, such horizontal expansion is, of course, possible for traditional wet-rice agriculturalists as well, and has in fact (though more slowly and hesitantly than is sometimes imagined) occurred. But the pattern of ecological pressures here increasingly encourages the opposite practice: working old plots harder rather than establishing new ones.

The reasons for this introversive tendency follow directly from

[40] Wittfogel, 1957, p. 15.

the listed systemic characteristics. The stability of the rice terrace as an ecosystem makes the tendency possible in the first place. Because even the most intense population pressure does not lead to a breakdown of the system on the physical side (though it may lead to extreme impoverishment on the human side), such pressure can reach a height limited only by the capacity of those who exploit it to subsist on steadily diminishing per capita returns for their labor. Where swidden "overpopulation" results in a deterioration of the habitat, in a wet-rice regime it results in the support of an ever-increasing number of people within an undamaged habitat. Restricted areas of Java today—for example, Adiwerna, an alluvial region in the north-central part of the island—reach extraordinary rural population densities of nearly 2,000 persons per square kilometer without any significant decline in per-hectare rice production. Nor does there seem to be any region on the island in which wet-rice growing was employed effectively in the past but cannot now be so employed due to human overdriving of the landscape. Given maintenance of irrigation facilities, a reasonable level of farming technique, and no autogenous changes in the physical setting, the *sawah* (as the Javanese call the rice terrace) seems virtually indestructible.

Second, the "medium-focused" quality of the regime limits it fairly sharply to those areas in which topography, water resources, and soluble nutrients combine to make the complex ecological integration of sawah farming (whatever that may turn out in detail to be) possible. All agricultural regimes are, of course, limited by the environmental conditions upon which they rely. But wet-rice cultivation, particularly under premodern technological conditions, is perhaps even more limited than most and, within Indonesia, certainly more than swidden, which can be carried out over the greater part of the archipelago, including, as it once was, most of those parts now pre-empted by sawah. Swidden can be pursued on rugged hillsides, in wet lowland forests, and in relatively dry monsoon country where, at least without the assistance of modern methods of water control, conservation, and regulation, sawah cannot. Exact data are difficult to obtain but the great extension of irrigated rice-farming in Indonesia and the rest of Southeast Asia during the last hundred years or so as a result of the application of Western technology ought not to obscure the fact that before the middle of the nineteenth century such farming was restricted to a few, particularly favorable areas. In 1833, when Java was just on the eve of her most disastrous period of social change, the island, which today has about three and a half million hectares of sawah had only slightly more than a third that much.[41]

Yet there is another introversive implication of the technical complexity aspect of traditional wet-rice cultivation. Because productivity is so dependent on the quality of water regulation, labor applied to the improvement of such regulation can often have a greater marginal productivity than that same labor applied to constructing new, but less adequately managed, terraces and new works to support them. Under premodern conditions, gradual perfection of irrigation techniques is perhaps the major way to raise productivity not only per hectare but per man. To develop further water works already in being is often more profitable than to construct new ones at the established technical level; and, in fact, the ingenious traditional water-control systems of Java and Bali can only have been created during a long period of persistent trial-and-error refinement of established systems. Once created, an irrigation system has a momentum of its own, which continues, and even increases, to the point where the limits of traditional skills and resources are reached. And, as the gap between the first rainfall, stream-bank, or swamp-plot sawah and those limits is usually great, economic progress through step-by-step technological advance within a specifically focused system can be an extended process, as shown in the following description of a Ceylonese system:

[41] The contemporary figure is from Statistical Pocketbook of Indonesia, 1957, p. 46; the 1833 figure (1,270,000 ha.) from van Klaveren, 1955, p. 23.

> . . . the Kalāwewa canal system—now has a giant tank at its head which leads into a fifty-five mile long watercourse, which in turn feeds into three large tanks which provide water for the ancient capital of Anuradhapura. It all looks like a colossal and highly organized piece of bureaucratic planning, the work of one of Wittfogel's idealised Oriental Despots. But if so, the planning must have been done by a kind of Durkheimian group mind! The original Tissawewa tank at the bottom end of the system was first constructed about 300 B.C. The Kalāwewa tank at the top end of the system was first constructed about 800 years later and elaborations and modifications went on for at least another 600 years.[42]

However, as mentioned, it is not only with respect to ancillary waterworks that wet-rice agriculture tends toward technical complexity, but on a more microscopic level with respect to the individual terrace itself. In addition to improving the general irrigation system within which a terrace is set, the output of most terraces can be almost indefinitely increased by more careful, fine-comb cultivation techniques; it seems almost always possible somehow to squeeze just a little more out of even a mediocre sawah by working it just a little bit harder. Seeds can be sown in nurseries and then transplanted instead of broadcast; they can even be pregerminated in the house. Yield can be increased by planting shoots in exactly spaced rows, more frequent and complete weeding, periodic draining of the terrace during the growing season for purposes of aeration, more thorough ploughing, raking, and leveling of the muddy soil before planting, placing selected organic debris on the plot, and so on; harvesting techniques can be similarly perfected both to reap the fullest percentage of the yield and leave the greatest amount of the harvested crop on the field to refertilize it, such as the technique of using the razor-like hand blade found over most of inner Indonesia; double cropping and, in some favorable areas, perhaps triple cropping, can be instituted. The capacity of most terraces to respond to loving care is amazing. As we shall see, a whole series

[42] Leach, 1959.

of such labor-absorbing improvements in cultivation methods have played a central role in permitting the Javanese rural economy to soak up the bulk of the island's exploding population.

Finally, independently of the advantages of technical perfection, the mere quantity of preparatory (and thus not immediately productive) labor in creating new works and bringing them up to the level of existing ones tends to discourage a rapid expansion of terraced areas in favor of fragmentation and more intensive working of existing ones. In developed systems, this is apparent; a people who have spent 1,400 years in building an irrigation system are not likely to leave it readily for pioneering activities, even if the established system becomes overcrowded. They have too much tied up in it, and at most they will gradually create a few new terraces on the periphery of the already well-irrigated area, where water resources and terrain permit. But this reluctance to initiate new terrace construction because of the heavy "overhead" labor investment is characteristic even of areas where irrigation is still undeveloped, because of the inability or the unwillingness of peasants to divert resources from present production. In contemporary Laos, for example,

> Most villagers are only semi-permanent and forest land is still available. The irrigated rice fields have become fragmented because their yields are more reliable than those of the [swidden]. The creation of new [sawahs] is not easily done, for it involves the extension of irrigation ditches and major investment of labor. This labor must be hired or supplied by the family itself, and implies existing fluid capital or a large extended family containing a number of able-bodied workers. Neither of these situations commonly occurs among Lao peasants, and therefore the progressive division of existing [wet rice] land and cultivation of [swidden] which requires less initial labor.[43]

Therefore, the characteristics of swidden and sawah as ecosystems are clear and critical: On the one hand a multicrop, highly diverse regime, a cycling of nutrients between living forms, a

[43] Halpern, 1961.

closed-cover architecture, and a delicate equilibrium; on the other, on open-field, monocrop, highly specialized regime, a heavy dependency on water-born minerals for nutrition, a reliance on man-made waterworks, and a stable equilibrium. Though these are not the only two traditional agricultural systems in Indonesia, they are by far the most important and have set the framework within which the general agricultural economy of the country has developed. In their contrasting responses to forces making for an increase in population—the dispersive, inelastic quality of the one and the concentrative, inflatable quality of the other—lies much of the explanation for the uneven distribution of population in Indonesia and the ineluctable social and cultural quandaries which followed from it.