Ecology and Acculturation Among Native Peoples of Central Brazil

Daniel R. Gross, George Eiten, Nancy M. Flowers
Francisca M. Leoi, Madeline Lattman Ritter, Dennis W. Werner

Summary. Simple exposure to Western goods may not be a sufficient explanation of why isolated village communities increase their participation in external market economies. The degree of market participation by four native villages in central Brazil is related to the difficulty of making a living from slash-and-burn subsistence agriculture as measured by the ratio of labor input to food output.

As remote parts of the earth become increasingly accessible there is scarcely a human settlement that does not engage in exchanges beyond its boundaries to acquire goods. Among the rare communities still largely outside market systems are isolated villages of politically uncentralized peoples in such places as Amazonia. Even there, market exchange takes place in most communities. Participation in markets is often thought to be a major first step in the transformation of social systems. Some investigators treat market exchange as a consequence of contact between cultures. It is often assumed that sheer knowledge of the existence of industrialized goods is sufficient to stimulate demand for these goods. A corollary assumption is that the length of exposure to these goods is directly related to the intensity of desire for them.

In this article we explore another dimension of the question of market involvement. We suggest that a group's relationship to its natural environment is crucial in determining the extent of market participation. In Amazonia, native groups undergo circumscription and become sedentary as national frontiers encroach on their lands. This causes intensified use of local resources. A degraded habitat results in lower yield per unit area and per unit labor. Under these conditions, people turn to new techniques, tools, and activities to meet subsistence needs. All these changes lead to greater market participation to obtain tools and other essentials.

We present here some results of field studies of four native South American societies. After briefly describing the adaptive arrangements of the four groups, we discuss some of the principal environmental features that affect the productivity of native agriculture in the study areas. The natural vegetation and soils across this relatively homogeneous region have been differentially affected by varying lengths and intensities of human use. This accounts for variation in forest biomass which in turn reflects differences in soil nutrient content. These differences explain variation in crop yields in the four study sites. With low yields people must work more to meet their food needs. To express the output ratio per unit labor time we introduce a variable we call S. We then discuss the degree of market participation by the four communities, showing the relationship between our measure S and market participation. Thus we show how involvement in the market can be traced to environmental and historical factors.

The Study Communities

All of the groups studied are small, relatively isolated communities in Central Brazil (see Fig. 1 and Tables 1 and 2). All speak native languages of the Macro-Gê stock (*1*): Kayapó, Xavante (also spelled Shavante), Bororo, and Eastern Timbira. All the communities are in permanent contact with Brazilian society and are under the administration of the Brazilian National Indian Foundation (FUNAI). Agents of FUNAI generally refrain from interfering in the day-to-day affairs of the Indians, but their influence nevertheless is pervasive and extensive.

All the groups produce most of their food by slash-and-burn gardening, hunting, fishing, and gathering wild foods. All participate to some extent in the regional market, that is, an exchange system within which cash flows and goods travel over long distances. Most of the hand tools and some of the clothing used by these groups come from outside the village. The groups also have some access to Western medicine, especially pharmaceutical products. Some of the groups live on legally demarcated reservations, but all are restricted in their movements to some extent by the presence of Brazilian settlements, even where these are hundreds of kilometers away. Warfare, once frequent among all four groups, is not now practiced.

Kayapó is spoken by about 2000 people in ten settlements spread over a huge area extending from the Araguaia River Basin to the Tapajós (*2*). The Mekranoti, one of the westernmost groups of the Kayapó, live on a tributary of the Iriri River (Fig. 1 and Table 1). They are the most isolated of the four groups. Practically speaking, they are accessible only by light plane, and the trip requires 2.5 hours from the nearest Brazilian settlement of any size. FUNAI flights arrive at long and irregular intervals to bring in personnel, to evacuate sick or injured Indians, or to administer vaccines and other medical services. This region of continuous evergreen forest with dense undergrowth has abundant rainfall from August to April. During the rains, rivers overflow their banks and flood wide areas. In the dry season many streams dry up almost entirely.

The Mekranoti spend several months each year on long treks, living on game and on produce transported from outlying and village gardens. They do not consume many wild vegetables. They plant relatively small, circular gardens that are fallowed after 3 years of cultivation (Table 1). There are numerous garden sites around the present village, but much land is not used because of flooding or because people feel the ground is "too hard" or the trees "too large." The principal market involvement of the Mekranoti consists of Brazil-nut collecting trips made at the behest of FUNAI every year or two. They are paid with firearms, shells, tools, and an occasional bolt of cloth.

D. R. Gross is associate professor in the Department of Anthropology, Hunter College, City University of New York, New York 10021. G. Eiten is professor in the Department of Botany, University of Brasilia, 70910 Brasília, Brazil. N. Flowers, D. Werner, and M. Lattman Ritter are in the Ph.D. Program in Anthropology of the Graduate School, City University of New York, New York 10036. F. M. Leoi resides in São Paulo, Brazil.

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The remaining three communities are located within an ecologically distinctive region known as "cerrado." Within this large floristic province (*3*) which covers a fifth of Brazil (Fig. 1) the predominant vegetation type is an open semideciduous tree woodland, tree-and-scrub woodland, or scrub or savanna with a ground layer of grasses, herbs, and low thin-stemmed semishrubs. It is very rich in species in all layers. The trees and tall shrubs have characteristic twisted trunks and boughs and thick corky bark. Evergreen gallery forest, or occasional buriti palm groves, occur in narrow strips along streams (Fig. 2). Cerrado vegetation occurs primarily on the deep, well-drained, profoundly weathered soils of the Central Brazilian Shield. These soils are low in available nutrients, highly to moderately acid, and high in available aluminum which is toxic to the usual crop plants. In central Brazil the rainy season lasts from the end of September to April, with intense rainfall (1100 to 1600 millimeters annually over most of the region). In the dry season there is virtually no precipi-

Table 1. Background data on the four study communities.

Community	Language (family)	Population	Size of reservation (ha)	Habitat description	Average walking time to gardens (minutes)	Average fallow duration (years)	Major crops (in order of total caloric yield)
Mekranoti	Kayapó (Gê)	285	Not delimited	Evergreen tropical forest	42	Not determinable	Manioc, sweet potato, banana, maize
Xavante (Pimentel Barbosa)	Xavante (Gê)	198	205,000	Cerrado	40	20	Rice, manioc, maize
Bororo (Gomes Carneiro)	Bororo (Macro-Gê?)	104	19,000	Cerrado (bordering pantanal)	45	10	Rice, maize, manioc, beans
Kanela (Ramkokamekra)	Eastern Timbira (Gê)	538	225,000	Cerrado	105	12	Manioc, sweet potato, rice, maize, yam, beans

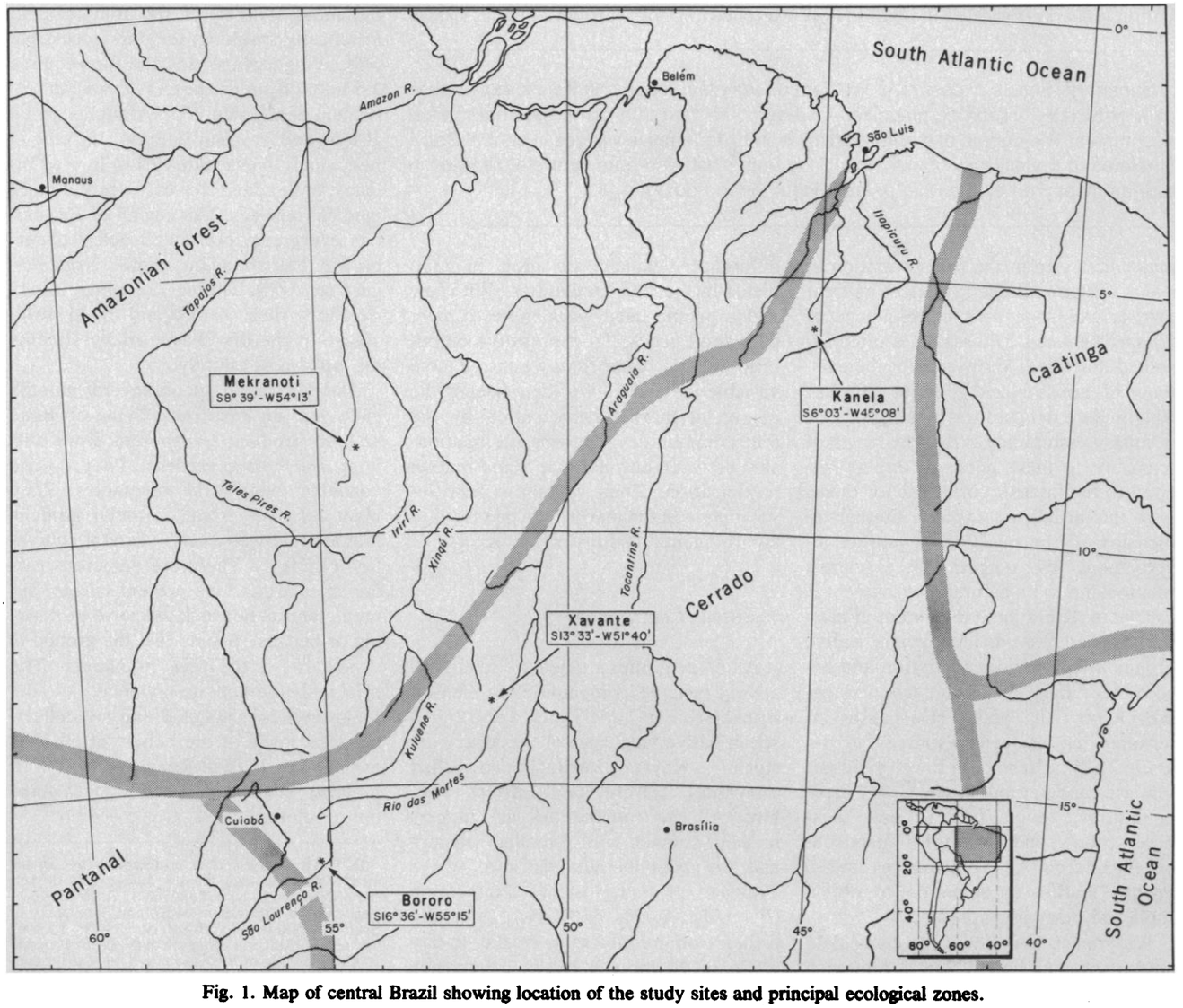

Fig. 1. Map of central Brazil showing location of the study sites and principal ecological zones.

tation. Without tractors, limestone and chemical fertilizers, or organic farming methods, cultivation in the cerrado region is limited to the narrow strips of gallery forests where soil and moisture conditions support the growth of tropical subsistence crops.

The Xavante Indians are a linguistically defined tribe of about 2000 distributed in nine villages west of the Rio das Mortes. At the study site, a FUNAI post and a single village of 198 people occupy a reservation (Pimentel Barbosa) with an area of 205,000 hectares (Fig. 1). Xavante have lived in this area for at least 100 years (*4*), but in the past 15 years Brazilian ranchers have settled the area, developing the mechanized culture of upland rice and cattle herding. The Pimentel Barbosa region is typical cerrado tree-and-scrub woodland, with some open grasslands on stony soil and gallery forests. The area abounds in game including peccary, tapir, deer, and other species, although cattle and land clearance threaten this abundance. The Indians fish in the Rio das Mortes, 30 kilometers east of the village.

Prior to their pacification in 1948, the Xavante fought frequently with Brazilians. The Xavante at Pimentel Barbosa moved to their present village site in 1972, but they had occupied the site at other times in recent decades. Thus present garden sites were probably used previously. An unpaved highway 50 km away is connected to the village by a precarious dirt track. Communications with Brazilians are fairly frequent and some Xavante men work as day laborers for a few weeks at a time on neighboring ranches.

The Xavante, like the Mekranoti, used to trek for several months of each year. Nowadays, the duration and extent of Xavante treks are limited by reservation boundaries. Formerly, the Xavante grew maize, beans, and pumpkins—all crops maturing in about 100 days—reflecting the seminomadic practices of the group. Rice recently became the principal food staple at Pimentel Barbosa. Slow-maturing manioc also entered their inventory of crops. A particularly important recent change is the planting of rice for sale by a few Xavante at Pimentel Barbosa and the expansion of the area under cultivation for this purpose.

The Bororo are a once-numerous (linguistic) tribe who formerly occupied a large portion of the present State of Mato Grosso (*5*). They speak an "isolated" language probably related to the Gê language stock common to the Kayapó, Xavante, and Kanela (*1*). The Bororo have been in continuous contact with Brazilian society for about 100 years and most of them speak Portuguese as well as Bororo. Of the seven extant Bororo communities, only a few have populations in excess of 100. One of these is the Bororo village at Posto Gomes Carneiro in Mato Grosso State (Fig. 1 and Table 1). These Bororo live in a traditional circular village about 1.5 km away from a FUNAI post. The village and post are located on a reservation of about 19,000 ha on the São Lourenço River. Most of the reservation is covered with cerrado vegetation including tree-and-scrub woodland, open grassland, small areas of closed-canopy cerrado forest, and gallery forests. Like the Xavante, the Bororo garden exclusively in gallery forests, but they have begun to reuse plots after as little as 10 years' fallow. Trekking was abandoned many years ago, but fishing on the São Lourenço is an important activity. The Bororo at Gomes Carneiro sell some fish to a merchant who visits the village weekly in a pickup truck selling items such as sugar, tea, coffee, rice, and bread.

The Bororo of Gomes Carneiro maintain extensive and frequent contact with outsiders. Some have worked off the reservation and many have become addicted to alcohol, which is available on nearby ranches. This and other aspects of life reflect a general demoralization in the village which, at times, appears to be on the verge of disintegration. Nevertheless, active ceremonial life continues. On the occasion of a death in 1976, the entire village performed the intricate and elaborate funeral rites lasting several months.

Last to be considered are the Ramkokamekra Kanela. These Eastern Timbira speakers belong to a population of perhaps 2000 people living in villages east of the Tocantins River (Fig. 1). All of the data below refer to the Ramkokamekra Kanela, who live in a village located on a reservation in Maranhão State (Fig. 1 and Table 1). The Kanela have been in close contact with Brazilians longer than the other groups in this study, about 150 years. Throughout this period they have endured hostilities with neighboring ranchers, attacks, forced migrations, and dispersions (*6*). Most adult Kanela speak Portuguese as well as their own language and some of them

Table 2. Degree of acculturation in the four study communities.

Community	Portuguese speakers (%)	Time since permanent contact established (years)	Distance to trade* (km)
Mekranoti	1	10	500
Xavante (Pimentel Barbosa)	2	25	35
Bororo (Gomes Carneiro)	98	85	20
Kanela (Ramkokamekra)	39	160	35

*Distance to nearest Brazilian settlement where trade is possible.

Fig. 2. Gallery forest partially cleared for gardens near Xavante Indian village. A stream is obscured by dense trees. Uncultivated cerrado woodland is visible in both upper corners.

have traveled far and wide across Brazil. Money flows within the village and between villagers and outsiders in numerous contexts including wage labor, handicrafts trade, purchase of foodstuffs by Indians, and FUNAI salaries.

The area of the Ramkokamekra Kanela reservation is about 225,000 ha. The circular village, with a population of 538, is about 1 km away from a FUNAI post. Although the village is accessible by vehicle, most of the outsiders who visit are peasants from neighboring estates or peddlers who travel on horses or mules. The entire reservation is located in cerrado woodland with occasional stands of closed-canopy forest (cerradão) and gallery forests. These forests show the effects of many years of use for gardens. Little primary gallery forest remains and the Kanela may reuse gardens after just 2 years of fallow (Table 1). Gardens are so widely dispersed that most villagers spend several months of each year living at their garden sites. Hunting and fishing are the primary sources of protein, but game and fish are scarce. The annual trek is no longer practiced. Neighboring cattle breeders occasionally slaughter a steer in the village to sell the meat. The Kanela pay cash.

People-Land Relationships

Soils, vegetation, and other aspects of the environment are not exogenous, but have been modified by human activity. We are not concerned with describing the "original state" of the habitats, but rather the interaction between humans and their environments through time.

Vegetation. Overall forest biomass in the Kanela and Bororo areas seems to be considerably lower than in the Mekranoti and Xavante areas. Since in the humid tropics more nutrients tend to be stored in living plants than in the soil (*7*), variation in forest biomass suggests that, after the vegetation is cleared and burned, the nutrients potentially available to cultivated plants in the Mekranoti and Xavante study areas are greater than in the Bororo and Kanela areas.

The vegetation in present and former garden areas and around the villages reflects the differences in duration and intensity of human utilization. Most of the forest cleared nowadays by the Mekranoti is primary tropical forest with very large trees, some up to 1.5 meters in diameter and 35 to 60 m tall. On former garden sites we found 10-year regrowth of fairly dense groves of cecropia 25 to 30 m tall and 30 centimeters in trunk diameter. The gallery forest utilized by the Xavante also appears to be mature forest although the Xavante on game drives burn off vegetation under large trees and in the open cerrados almost every year. This practice may have modified the gallery forest understory, which consists of a number of fast-growing invaders, especially bamboo, rather than woody species. The burning may also affect the soil (*8*).

In the most intensively exploited areas of the Bororo and Kanela we found that secondary growth is regularly cleared for gardens. During the more than 100 years of almost continual occupation of the Bororo study area by native villages much larger than the present one, nearly all gallery forest has been used at least once. Virtually no mature gallery forest remains near the Kanela village. For example, one set of gardens was stated by informants to have been cleared from land never before used. Yet trees in the remaining gallery forest in this location reached a maximum diameter of only 40 cm and a maximum height of 25 to 30 m, lower than in other presumably undisturbed gallery forest in the same general region.

Soils. An examination of some of the nutrients available in soils in the four study sites reveals a pattern similar to that of forest biomass. To determine the effect of clearing and burning, we collected soil samples from newly cleared and burned gardens and from immediately adjacent unused forest areas (*9*). Tests were conducted on four pairs of soil samples, one pair from each study area (Fig. 3). In general, the results show that soil nutrient content increases after the vegetation is cleared and burned, particularly in the Mekranoti and Xavante areas. The percentage increases for the Xavante were somewhat smaller than those for the Mekranoti, and the potassium, nitrogen, and organic matter content actually declined after burning at the Xavante site. This difference may be attributable to the fact that the Xavante, while clearing mature forests, have already degraded this forest to some extent by annual burning of the understory. The initial levels of nutrients in the gallery forests in the Xavante study area are higher than in the Mekranoti area, possibly because of the accumulation of nutrients in the soil from the annual burning. The generally higher nutrient levels on burned gardens for the Mekranoti and Xavante may be accounted for by the higher biomass of the cleared vegetation whose ashes yielded more nutrients.

Crop yields. Another important variable reflecting the abundance of resources is the yield of cultivated food per

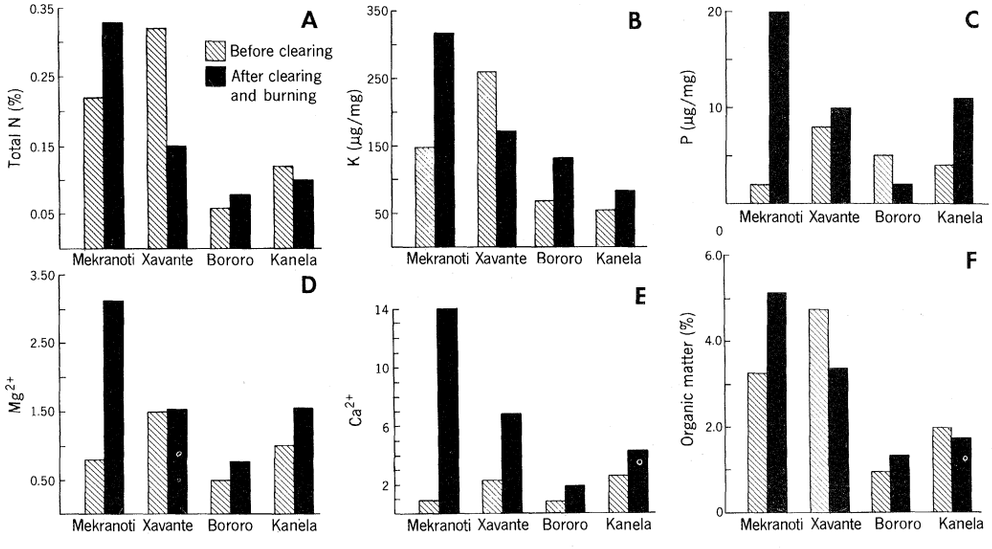

Fig. 3. Soil nutrient values for adjacent uncleared (shaded) and burned (solid) plots in four different sites in central Brazil. Nitrogen (A) and organic matter (F) were calculated as a percentage of total soil weight. Potassium (B) and phosphorus (C) are calculated as micrograms of K or P, respectively, per milligram of soil. Magnesium (D) and calcium (E) were calculated as milliequivalents per gram of soil. See (*9*).

unit area. In each study area we weighed the produce from sample plots for each crop (*10*). We converted these yields into the energy values for the edible portion of each food, using standard tables (*11*). The yields per unit area (see Table 3) in general correlate with the soil nutrient data for any particular crop. We also calculated the overall productivity of the gardens at each site by multiplying caloric content of each food by the proportion of garden area occupied by each crop. The cumulative yields for each community do not correlate with the data for soils because the crop mix is different at each site. Thus the Kanela appear to outproduce the Xavante per hectare, but only because the Kanela rely more heavily on root crops than the Xavante, whose staple is rice. In general, tubers and bananas yield more calories per unit area than crops such as maize and rice. Crop mix is influenced by knowledge of alternative crops, ethnodietetic considerations, the mobility of the group, storeability and transportability of the harvested crop, and market considerations. Thus, the variation recorded here is not simply a reflection of the state of the soils, rainfall, and other environmental variables over a particular growing season, but also is a result of numerous decisions taken consciously or otherwise by the native gardeners.

Subsistence Labor and Resistance to Swidden

Slash-and-burn (or swidden) agriculture is practiced with a very small technological inventory in most lowland South American groups (*12*). The four study groups we investigated use only the machete, ax, steel hoe, and digging stick as well as various basketry containers for transporting and storing seeds and crops. All operations are performed by hand, including slashing undergrowth, cutting down trees, firing, additional clearing, planting, fencing and weeding, harvesting, and replanting. The amount of labor expended on subsistence reflects the different garden yields (*13*) (Table 4). Where the yield of a given crop is low, farmers may clear more garden land or increase productivity, intensifying such activities as soil preparation or weeding.

The Mekranoti, who are self-sufficient in food, spend the least time of all the groups on subsistence labor. This reflects the abundance of their area in terms of both wild and cultivated foods (Tables 3 and 4). The Xavante, in contrast, although they also live in a fairly productive region, spend more time on subsistence. Gathering of wild vegetables is particularly important for the Xavante compared to other groups. The high value for garden labor reflects the Xavante commitment to rice cultivation. This crop requires more care than other tropical crops. Rice cultivation also figures in the Xavante market activities. A portion of Xavante garden labor has been assigned to the market category because about 6 percent of the rice crop is grown for sale. Bororo time allocation reflects the importance of fishing under the wild foods category and rice and manioc production under garden activities. The poverty of Bororo soils and their low garden productivity help explain why the Bororo have turned away from gardening to market activities such as catching fish for sale. The Kanela spend the most time gardening, about 17.5 hours per week per adult or twice the amount of time spent by the Mekranoti. The time spent by the Kanela in the quest for wild foods is the lowest of the four study groups, because of the poor rate of return from this activity. The difficulty that the Kanela and Bororo experience in providing themselves with food is probably a consequence of habitat degradation over a long period of time. In former times, the village would have moved to a new location where land and other resources were less depleted (*6*). Now there is nowhere to move.

The relative difficulty these populations encounter in obtaining a living from their environment may be expressed in terms of the amount of labor needed to produce a given quantity of food. The ratio L/Y, representing the total amount of time spent gardening (labor) by all village producers in a year divided by the annual yield of all gardens, expresses the labor time cost of garden food for the different areas (*14*). Table 5 shows that the Mekranoti and Xavante spend respectively 56 and 141 hours to produce 10^6 kilocalories of garden food;

Table 3. Food energy yield for different crops in the four study communities. The data are expressed as kilocalories $\times 10^6$ per hectare [see (*10*)].

Community	Maize	Beans	Rice	Manioc	Yams	Sweet potato	Overall
Mekranoti	12.39	*	5.23	42.15	*	38.72	28.84
Xavante (Pimentel Barbosa)	10.81	*	5.51	23.24	*	*	7.80
Bororo (Gomes Carneiro)	2.81	0.67	5.44	2.74	*	*	5.01
Kanela (Ramkokamekra)	0.59	0.35	4.19	17.42	0.12	7.79	15.59

*Crop not cultivated.

Table 4. Time allocated per producer (in hours) to basic productive activities over 1 year in the four study communities [see (*13*)].

Community	Subsistence activities			Market activities	Total subsistence and market activities
	Wild foods	Garden	All foods		
Mekranoti	456.6	441.8	894.4	158.0	1056.4
Xavante (Pimentel Barbosa)	437.9	705.5	1143.4	268.0	1411.4
Bororo (Gomes Carneiro)	316.5	526.2	842.7	422.9	1265.6
Kanela (Ramkokamekra)	271.0	910.2	1181.2	542.0	1723.2

Table 5. Resistance to swidden, S, and its constituent variables in the four study communities. See text for definition of variables.

Community	L	D	A	Y	L/Y	S
Mekranoti	61,410	0.512	0.333	1078.6	56.1	9.71
Xavante (Pimentel Barbosa)	77,426	0.490	0.488	549.5	140.9	33.69
Bororo (Gomes Carneiro)	34,203	0.375	0.333	53.0	645.3	80.59
Kanela (Ramkokamekra)	256,676	0.476	0.598	1318.4	194.7	55.42

the comparable values for the Kanela and Bororo are 195 and 645 hours.

There are other factors that should be taken into account in calculating the difficulty of providing subsistence needs. In our study, the groups vary in the proportion of nonproductive persons who need to be fed. In a population with many nonproducers, the food producers will have to work harder. We correct the L/Y ratio by adding a coefficient D (dependency ratio) expressing the ratio of nonproducers of food to total village population. With more nonproducers, the value of D rises, reflecting the greater difficulty for subsistence producers. Another factor, appropriate to shifting agriculture, is the ratio, represented by A, of land freshly cleared each year to the total area under production. The value for A will increase if land is reused more frequently or the area under cultivation is expanded. Either can occur when population density rises or when habitat degradation sets in. By adding these two coefficients, we take into account secular changes in population structure and land use. We may combine these variables in a formula that expresses the resistance, S, presented by the environment to swidden agriculture. This may be given as $S = LDA/Y$; S refers to a complete annual cycle but it may also be based on values averaged over several years. The formula may be used for populations depending to some extent on food produced on swiddens where the population and the particular gardens pertaining to it can be clearly demarcated.

Table 5 displays the values of S and its component variables for each of our cases taken from 3-year periods ending in 1977. The societies are ranked along this scale in a fashion that the environmental and gardening data would lead us to expect. The highest effort for subsistence occurs among the Kanela and Bororo where the vegetation is most degraded, soils are poorest, and yields for specific crops are lowest. The lowest effort for subsistence occurs among the Mekranoti where vegetation is the least degraded, soils are most fertile, and yields for specific crops are highest. The S value for the Xavante stands in the expected rank order, but is closer to the Kanela and Bororo values than we anticipated. The reason may lie in the high dependence by the Xavante on rice cultivation as compared to the other groups. Rice is a more labor-intensive crop than the other staples discussed here and the yields per unit area are lower. The Bororo and Kanela are at a critical point in their relationship to their habitats. The small size of their reservations relative to population (Table 1) and the impossibility of movement in search of better lands have evidently forced these groups to make larger and larger labor commitments simply to maintain themselves.

The use of S may be valuable for comparing relative pressure on resources among technologically similar populations. It does not require that the usual assumptions be made in determining carrying capacity, for example, nutritional needs, the amount of arable land available, and the distance people are willing to walk. If one population makes better use of its resources than another, its S value will be lower even if population density, habitat degradation, and technology are similar for both. The measure cannot, however, predict the additional labor required to produce a given increment in output. Such a ratio could be obtained only with more cross-sectional or longitudinal data. The use of S, then, is restricted to comparative studies.

Market Participation

We turn now to the use of S in explaining the behavior of native peoples undergoing acculturative pressures. Murphy and Steward (*15*, p. 353) concluded that:

> When goods manufactured by the industrialized nations . . . become available through trade to aboriginal populations, the native people increasingly give up their home crafts in order to devote their efforts to producing specialized cash crops or other trade items in order to obtain more of the industrially made articles.

A number of authors, Murphy and Steward included, allude to a process by which "luxuries become necessities" and to the disruptive influence of trading relationships on native social organization (*16*). Many investigators assume that trade occurs because of the allure of the trade goods themselves. Some observe that outsiders foster exploitative relationships by inducing dependency on externally produced goods.

Few have asked why these baubles of industrial civilization should be so attractive. Two major arguments present themselves. One holds that simple exposure to Western ideas and values instills a consumer orientation among natives. A second argument suggests that it is awareness of the existence of specific goods that creates a desire for them. Both of these arguments would predict that great length of exposure to the West leads to greater desire for Western goods. Historical data available from our groups is inconsistent with this hypothesis. During the 18th century, the Xavante and Bororo were drawn into peaceful contact with Portuguese colonizers. After periods of several decades each broke off contact and moved to isolated areas foregoing their access to Western goods (*4*, *5*). In this century, the Xavante and Mekranoti have been in contact for about the same length of time, yet there is a wide discrepancy in their degrees of market involvement (Tables 1 and 2). If Western values and ideas were of paramount importance in increasing desire for goods, we would expect the Kanela and Bororo to be far more attuned to Western ideology. However, all the villages still practice their native religions. Ceremonial activities are rich and frequent in all four. Even though all the groups have been subject to missionary influence, the only avowed converts to Christianity are found among the group least involved in the market, the Mekranoti. Use of Western clothing in the village is also not correlated with extent of market involvement.

Isolation might also be offered as an explanation, but the Kanela are about as isolated from Brazilian settlements as the Xavante and still they spend about 275 hours more per year on market activities (Table 4). The Bororo, who have more frequent contact with Brazilians than the Kanela, have a lower market involvement than the Kanela, whereas the isolation hypothesis would predict the opposite.

We suggest that the extent of market participation is closely related to the difficulty of making a living through traditional means. As native subsistence systems undergo pressure because of sedentation and encroachment, people respond by intensifying subsistence production and adopting different technologies in order to do so. Trade plays a role here in providing tools and other items that allow intensification to take place. The availability of steel axes, knives and machetes, and firearms and ammunition is especially important. These are more efficient and durable than their handmade counterparts of stone and wood, and acquiring them through trade frees the labor needed to make them.

In all four groups, most of the goods acquired in trade, such as guns, tools, and metal pots and pans have practical value. The Bororo and Kanela expend substantial amounts of their cash for food. Relatively few "luxury" items are purchased by any of the groups but, where they are, they may be a way of conserving capital because such items as radios, wristwatches, and handguns hold their value better than cash, especially in

an economy like Brazil's with chronic inflation. Clothing, while apparently superfluous, is necessary to persons who contact outsiders. Brazilians and other "civilized" peoples will not tolerate "nudity" among Indians in their midst. Thus, we think that while industrial goods may have an intrinsic allure to native peoples, practical requirements brought by sedentation, encroachment, colonization, and subsistence intensification are of greater importance.

Once commercialization has begun, certain amplifying feedbacks are observable. New tools and techniques may hasten habitat degradation and accelerate the process of dependence on the market to meet needs. The Xavante adoption of rice and their attempt to market part of this crop is a case in point. When fieldwork ended in 1977, the Xavante at Pimentel Barbosa were lobbying FUNAI for a tractor to increase their production. If granted, this tool would dramatically increase the rate of degradation of the Xavante environment as well as the dependence on the market to acquire fuel and parts. It is noteworthy that the Kanela also once exchanged food crops on the market (*6*), but that they now have a net food deficit.

We define market participation as all activities that result in the production of goods and services for exchange with non-Indians outside the village community. There are several kinds of such activity such as wage labor, or the day labor performed by Xavante men on ranches near their reservation. In the case of the Mekranoti, manufactured articles are "given" to the Indians in return for labor in Brazil-nut groves. All four groups, to some extent, make handicrafts for sale to Brazilians. Only the Xavante grow food for sale. Production for exchange within the village community among Indians is not considered market labor for the purposes of this study, even where cash payments are made.

Using this definition, we measured the extent of market involvement of our four study communities in hours per adult spent at market activities over a year's time (*13*). This value varies from a low of 158 hours per year for the Mekranoti to a high of 542 hours for the Kanela adults (Table 4). The Kanela value translates to over 10 hours per adult per week. There are other indicators of extent of market involvement, particularly in the variety and amount of goods acquired for cash. The Kanela and Bororo both derive a significant portion of their diet from the market whereas the others purchase no food at all. More than the other groups, the Bororo use Western-style clothing. The Xavante and Mekranoti have the smallest inventory of Western goods, mainly firearms, pots, and tools. The degree of market involvement as indicated both by time allocation and trade goods is higher among the Kanela and Bororo and lower among the Xavante and Mekranoti.

Comparing the extent of market involvement with our measure of resistance to swidden, we find support for our hypothesis. The societies with the lowest S values are those with the lowest market involvement. The higher values correspond to the cases where market involvement is higher (*17*). This is consistent with the view that greater market involvement is an adaptation to environmental forces. For the Kanela and Bororo, exclusive dependence on subsistence production would entail increasingly high labor costs. We think that it was not primarily choice or the allure of trade goods which led groups like the Kanela to depend so heavily on the market, but rather environmental pressure caused by the degradation of their habitat. We do not suggest that societies maximize some good under all historical conditions. Indeed, the ethnographic and archeological record is strewn with the wreckage of societies which failed to commercialize or did so under disastrously disadvantageous conditions.

Conclusions

In contrast to other models, our view does not portray all acculturative change as the superimposition of a dominant society's culture on a weaker society. Rather, expanding societies can affect others by altering environmental relationships. In our study, those aspects of culture that changed most radically were those linked to environmental parameters. Other changes also took place, but not necessarily by assimilation of traits from the dominant society. In fact, in many instances, indigenous features of religious and social life were preserved or intensified after Western contact. Even the relatively intense economic ties between the Kanela and Brazilians have not seriously disturbed native ceremonial systems. On the contrary, many Kanela utilize cash transactions to meet ceremonial obligations. Preservation of native culture seems not only to contribute to survival by maintaining group identity but also by ordering social behavior and exchange in a concretely beneficial fashion (*18*). Some evolutionists suggest that successful adaptation occurs when a form undergoes the smallest possible changes which permit an effective response to an environmental perturbation. This strategy allows a maximum amount of flexibility to encounter future perturbations and avoids the necessity for a radical (and costly) reintegration of structure (*19*). The changes documented in our case studies appear to conform to this principle.

Market involvement may eventually have erosive effects on native social systems. The Kanela village has been practically dismantled several times. Community life is perhaps most threatened in the Bororo village at Gomes Carneiro, but this seems to be attributable as much to the difficulty of making a living and surviving as to the simple influence and attractiveness of Western culture. None of the groups studied exhibits internal stratification. Nevertheless, among the Kanela and Xavante there are beginnings of unequal accumulation of wealth by individuals which may ultimately lead to clear differentiation and divisions within the community. If one can judge from their commitment to native social and ceremonial activities, none of the groups regards a fully Western life-style as more attractive than their own. The potential for increased market involvement is present in all the groups.

Twenty-five years ago, ecological studies appeared as a new approach to understanding major sociopolitical transformations in human history. Since population density and settlement size are keys to the emergence of social complexity, many studies sought to determine the maximum number of people that could be supported over time under particular subsistence regimes (*20*). Recently, writers have criticized the premises of this approach. The assumption of unchanging technological, dietary, and cultural conditions seems unwarranted (*21*). Critics object to the view that human populations invariably grow to the limits of their food supply (*22*). The difficulties of assuming a fixed carrying capacity are magnified when dealing with populations undergoing rapid change. A consequence of these critiques has been the virtual abandonment of comparative ecological studies of human societies and the downgrading of the importance of environment in sociocultural change.

Our approach preserves traditional concerns with evolution and social change, restoring comparison to its rightful place. It avoids attempting to identify particular levels of population density or nutritional adequacy as "limiting" (*23*). We suggest that a better way to view the relationship between a human population and its natural habitat is to study the

expenditure of time in subsistence and other activities. The time required to produce a given output is an immediate way in which environmental feedbacks are perceived by food producers (*24*). Many individual and communal decisions are based on the labor costs of achieving subsistence goals, costs that reflect habitat features such as weed growth, soil nutrient content, and rainfall. Labor costs are both perceptible to actors and measurable by the observer. In this study we believe we have identified a variable that helps to explain the degree of market participation among stateless societies of lowland South America and similar areas elsewhere in the world.

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9. Soil samples were collected at a depth of 0 to 10 cm. Each sample consisted of soil drawn from ten holes dug within an area of approximately 0.10 ha. From this, about 1 kilogram was extracted, air dried, and sent for testing to the Instituto Agronômico de Campinas, Campinas, São Paulo, Brazil. Complete results will be published elsewhere. The data in Fig. 3 were selected from one pair of garden locations from each of the four study areas. Where more than one pair was sampled, the values representing the highest overall soil nutrient levels were chosen to represent that area.
10. To assess garden productivity, each field worker took samples of each food crop from gardens of various ages. In most cases, an area of given size was marked off and all the food from that area was weighed or counted. If counted, the food (such as unripe ears of corn) was converted to weights, with a subsample of mature, edible produce being used as a standard. When necessary, conversions to dry weights were made by using actual comparison samples. For some crops, for example, bananas, the field worker found it more convenient to estimate yields by counting the number of plants in an entire garden and weighing the food produced by a few sample plants. By measuring and mapping gardens, they calculated the average area devoted to each crop, with appropriate adjustments for intercropping [see D. C. L. Kass, thesis, Cornell University, Ithaca, New York (1976)]. Community yields were calculated by multiplying average garden yields by the total number of gardens under production.
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13. For the time allocation studies we used the techniqu → A. Johnson [*Ethnology* **14**, 301 (1975)]. Each week field workers made visits to 12 randomly selected households at times chosen at random between 0600 and 2000 hours. For each of the communities studied, a body of 5000 to 8000 observations of individuals was built up over the period of 1 year. To analyze these data we assumed that the proportion of observations of a given activity was the same as the proportion of time actually spent on that activity during the 14-hour period used. A number of corrections had to be introduced to the data to compensate for biases inherent in the data-collection system or peculiarities of the communities themselves. To correct for variations in the number of observations made over different periods, we converted absolute values for each month into percentages for that month, then averaged to obtain year-round values. Wherever the number of observations for a given month fell to a very low level, that month's data were discarded and replaced by values interpolated from the two adjacent months. In the Kanela and Mekranoti villages, villagers spent long periods away hunting or gardening. To fill in these gaps, additional time allocation studies were conducted on treks and at garden sites and corrections were introduced to the village-based data. The Xavante grow rice both for subsistence and for market. For this group, a percentage of total garden labor was deducted from the "subsistence" category and added to the "market" category (see Table 4). In the calculation of S, however (Table 5), it was more appropriate to sum all garden labor to compare this with total garden yield.
14. The use of this ratio was suggested by R. L. Carneiro [*Proceedings, Eighth Congress of Anthropological and Ethnological Sciences* (Science Council of Japan, Tokyo, 1970). p. 431], A. Johnson (paper presented at the 73rd Annual Meeting of the American Anthropological Association, Mexico City, 24 November 1974), and M. Harris [*Culture, People, Nature* (Crowell, New York, ed. 2, 1975), pp. 229–255].
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17. The value of S for the Kanela in 1976 is lower than for the Bororo even though the latter have lower market involvement. The conscription of unpaid Kanela labor was coded as market labor and may have inflated the value in that category for that group.
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