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SUN VERSUS SHADE COFFEE: TRENDS AND CONSEQUENCES

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Sun versus Shade Coffee: Trends and Consequences

Introduction:

The issue of shade use in coffee has long been a hotly debated topic among producers and coffee agronomists. Venerable reference texts on coffee, such as Uker's *All About Coffee* from 1922, or, from 1961 (a particularly good year for coffee reference texts), Wellman's *Coffee: Botany, Cultivation, and Utilization* or Haarer's *Modern Coffee Production* all have sections devoted to the use, advantages, and disadvantages of shade in coffee. The United States Department of Agriculture had found the shade issue of sufficient interest well to these reference texts when it commissioned a Professor Cook to write a Division of Botany Bulletin in 1901. Cook's *Shade in Coffee Culture* runs for seventy-nine pages. More recently, books like the one by Wrigley in 1988, simply entitled *Coffee*, also includes discussion on the importance of shade.

It is only in very recent years, however, that the issue of shade coffee (that is, coffee produced beneath a canopy of moderate to heavy shade of diverse plant species) has begun to be seen from a slightly different perspective. Specifically, considering the fact that a) the focus of conservation of biodiversity has shifted from highly visible, charismatic species to smaller organisms and to "hot spots" of biological diversity, and b) 95 percent of the present-day terrestrial ecosystems are managed ones, including agricultural systems (Western and Pearl, 1989), we need to examine coffee production through a refocussed optic.

In addition to the usual advantages of providing soil building and soil protecting characteristics, shade coffee is now recognized as human-manipulated land use type that maintains biodiversity. Migratory birds, resident birds, small mammals, arthropods, and reptiles are some of the animal groups that show higher levels of species richness in shade coffee than in sun coffee or other agricultural lands. In short, shade coffee can serve as a refuge for biodiversity.

In this paper I will first present a short historical overview of shade use in coffee. The region of my focus--which derives from the orientation of the work in our office, the Smithsonian Migratory Bird Center--is that of "northern Latin America". Thematically, our focus has been one of comparing shade and sun coffee as useful habitats for birds. Geographically, our focus embraces Mexico, Central America, the Caribbean, and Colombia. These areas are important destinations and/or stopover areas for many of the songbird species studied by the ornithologists and ecologists in our office. Furthermore, the coffee produced throughout the region represents some of the highest quality, highest value coffee sold on the world market. The rapid changes recently seen in the coffee sector throughout northern Latin America warrant investigation from various perspectives. As many roasters attest, for instance, shade coffee tends to be better quality than sun coffee. The second part of my paper examines the recent shade reduction trends of the region. The third and fourth sections direct attention to the forces behind the trend and the consequences of these changes in shade cover, respectively. The consequences, it should be noted, are not region-specific; indeed, the ramifications of technification may apply to any number of production regions around the globe. Finally, I explore how the industry might employ a market place solution for the protection of shade coffee habitats.

Shade and Sun in Coffee: A Short Historical Overview

The forests of Ethiopia provided the raw materials for coffee's cradle of domestication. Within these forests' structural profile, the genus *Coffea* evolved as an understory species. Sylvain (1955) named the plant community the Ethiopian "coffee forest". Along with Meyer's account (1965), we find the ecosystem organized into a four-tiered forest. The main canopy is sandwiched between a taller emergent layer above and the shrub layer below. At ground level we find an herbaceous layer. Coffee occupies the lowest woody species level, that of the shrubs.

To understand the role of shade under natural conditions, a passage from Sylvain's observation in Ethiopia provides food for thought:

> In some places the coffee is so dense that several plants may be found per square meter while in others there are only a few specimens per hectare. Yields are generally low so that the plants are not weakened by over-bearing... In places where the upper stories of the forest have been removed the yield usually rises but the plants, by the fact of this increased production and/or direct exposure to rapid fluctuations in temperature, become weakened and are more susceptible to some diseases (1955:41)

Sylvain's observations were foreshadowed some 80 years prior to his 1955 conclusions by young Marshall Ward. Ward, commissioned by Kew Gardens to study the devastating effects of coffee leaf rust in Ceylon's coffee industry during the 1870s, came to similar conclusions about the usefulness of shade.

In the New World tropics, coffee represents an introduced species, non-native to the region. As a novelty crop in the 1700s, growers throughout the region experimented with coffee. Some were successful, others were not. Aside from the correct ecological zone being selected to attempt a planting, farmers also had to discover the optimum amount of shade needed by trial and error process (Cardoso, 1977:184-185; Cambranes, 1985:75-76; Dunkerley, 1988:22). No one had the luxury of observing first-hand the coffee plant in its native habitat in Africa as Sylvain did more than a century later. But as coffee's role in the regional and world economy grew in importance, the shade levels for different areas were established.

For high elevation cloud forest habitat, little to no shade was needed, given the constant protection provided by cloud cover. Sometimes the original forest was thinned just enough to "insert" coffee plants beneath the natural canopy (Coyner, 1960). For much of northern Latin America, however, moderate to heavy shade was found to suit coffee production best. With time, an array of tree species evolved to become the principle shade species used, depending upon the local conditions and the collective coffee history of a particular zone.

Today, shade trees belonging to genera such as *Gliricidia, Erythrina, Grevilea,* and *Inga* tend to dominate, with a range of fruit and other hardwood species often mixed in as well. Small producers, usually more dependent than their larger neighbors upon the production of several products from a relatively small plot, tend to manage a greater diversity of shade species. It is not unusual, in fact, to find upwards of twenty different shade species associated with coffee produced under traditional peasant practices (Rice, 1990). In the Antigua, Guatemala area, small coffee producers on average may obtain as much as 30 percent of their annual income from non-coffee products derived from the shade tree species (Rice, field notes and personal observation).

Compared to many other crops, agricultural changes associated with modernization of the food production sector have been slow in coming to coffee. The intensification of production seen in basic grains beginning in the 1940s was not mirrored in this traditional cash export crop. Attempts in the 1950s in some countries garnered little favor among producers, large or small. Those who did choose to modernize their holdings early on usually did so by removing or thinning the overstory, introducing high-yielding coffee cultivars, and introducing relatively heavy use of the agrochemicals that had proven so productive in the "green revolution" associated with basic grains. For the most part, however, coffee production technology did not change significantly until the 1970s in northern Latin America.[1]

Recent decades show increases in coffee area, production, and yields for northern Latin America. Data from the United Nations Food and Agriculture Organization's Production Yearbook for various years emphasize the extent to which the coffee sector has grown. Percent change in production between 1950 and 1990 reveals an increase of nearly 200 percent for the region. By the early 1990s, northern Latin America produced just under one third of the world's coffee (see Table 1).

One manner in which to increase production is by expanding the coffee area. Areal expansion has surely occurred (Table 2), increasing by as much as 326 percent in the case of Mexico for the period from 1950 to 1990. Another way to crank up yields, of course, is through intensifying the production process to increase yields. This, too, has occurred in the northern Latin American region (Table 3), with some Central American countries showing yield increases greater than 200 percent for this period. Such production, area, and yield increases, however, are not without their tradeoffs, many of which are ecological.

Trends in Shade Use in Northern Latin America

Shade coffee in northern Latin American has been disappearing. The trend over recent decades has been one of changing from traditional shade coffee to that of reduced shade or, in extreme cases, coffee that is completely open to the sun. The transformation is dramatic. It generally entails the reduction of shade, the introduction of varieties like *caturra, catuaí,* or *catimor,* the increase in planting density, and the use of agrochemicals. This shift toward a more intensified production system is known as "technification", "modernization", or "renovation". In terms of habitat loss, this shift qualifies as deforestation. The contrasting characteristics of traditional and technified systems are shown in Table 4.

As a result of this technological shift, coffee farms characterized by their forest-like nature are changed into manicured hedgerows of uniform size and shape. As a transformed agroecosystem, the impact of the modifications as they relate to soil protection, nutrient recycling, organic matter production and mulching characteristics, as well as to the use of agrochemicals to suppress weed growth and confront diseases and insect pests can be serious. Ecological interactions can be disrupted. Natural processes, such as soil erosion,

[1]Costa Rica is the exception, with some of the most consistently high yields in coffee in the world.

can be enhanced. Moreover, farmers may be placed at greater risk when they abandon a system that provides coffee plus an array of non-coffee products for one that relies solely upon the coffee harvest, as is the case with a technified system.

Map 1 and Table 5 show, with the best data available to date, the extent of this coffee area transformation. Of the total 2.7 million hectares of coffee found throughout the northern Latin American region, about 1.1 million hectares have already been technified. A country like Colombia has embraced the technification process whole-heartedly, as is reflected in the fact that nearly 70 percent of the coffee lands are now technified, a process that took place with impressive rapidity (FEDERACAFE). At the other extreme we find El Salvador or Haiti, countries with coffee sectors showing around 10 percent technification. For these two countries in particular, and others in general, the "forest" cover provided by traditional shade coffee represents a significant portion of the total land area with any type of canopy. Reduction of this cover will essentially deforest such countries.

The attraction that technification holds for policy makers has yet to run its course. Mexico, for instance, currently has a program known as "Alianza Para El Campo", with scheduled activities that target coffee holdings under 10 hectares for improvement and renovation, among other actions (SAGAR, 1996). The focus is upon the smallest of growers, those with fewer than 5 hectares, who represent 90 percent of Mexico's coffee producers. The plan calls for the renovation of 338,000 hectares nationally by the year 2000, an area that represents 44% of the country's total coffee area. If successful, this plan would launch Mexico into second place behind Colombia in terms of total coffee lands technified.

Forces Behind the Trends

What is pushing or has pushed this shift toward intensification of the production process. The rationale behind any given country's tendency to technify its coffee area derives from a range of causes. For countries with significant portions of the foreign exchange tied to coffee, it certainly makes economic sense to attempt to increase production. Efforts to bring capital to the rural sector are also cited as reasons for the attraction that governments have for a technified coffee industry. Colombia's efforts began in earnest after the Brazilian freezes of the 1970s, perhaps revealing FEDERACAFE's strategy to position the country to take advantage of future problems with Brazilian production.

A secondary concern may be employment, though this has never been cited by policy makers as a reason for technification. The image of being "modern" however, may in fact play a role in the zeal with which many government officials have embraced the newer coffee technology. Modernizing a traditional export sector represents an attractive alternative to having to depend upon a "backward" industry. Technification for many officials or producer organizations surely serves as an entry into the modern era for many rural producers. As happened in the US grain sector earlier this century, a push to modernize may be linked with being "professional", "up-to-date", and, indeed, serious about one's production.

Such transformations have their tradeoffs, however. Agrochemical contamination of ground water supplies, soil erosion, increased sediment runoff, and fuelwood issues are examples of environmental disruptions that may be associated with coffee technification. Human health concerns with pesticide poisoning are also an issue. Economically, increased production by an array of countries can potentially lead to a crisis of over-production, creating problems with the supply and demand interactions of the coffee market. Moreover, the long-term social costs linked to these environmental disruptions rarely figure into the economic equations that promote production increases. Such externalities must be included if we are to address coffee's relationship to the environment.

There have been some agronomic reasons for technification, especially during the early years of the technology adoption. In Central America, for instance, the push to renovate coffee holdings region wide came on the heels of coffee leaf rust's (*Hemileia vastatrix*) appearance in Nicaragua in 1976. The disease had destroyed some of the Old World coffee area last century, and the American coffee industry awaited the inevitable landfall of the rust with fear and anxiety. When the rust finally did reach the Western Hemisphere in Brazil in 1970, the New World coffee industry was desperate to take measures to stem its advance.

With coffee leaf rust's arrival, the efforts to intensify production that had fallen on deaf ears in the 1950s had new reason for notice. Technification was seen as a way to combat the rust. Removal of the shade cover, completely or in part, would allow the plantation to dry off more easily during the course of the day, eliminating the "free water" necessary for the fungal dispersion. Nowhere was the new production technology embraced as a remedy for rust control as readily as it was in Central America and the Caribbean. The attraction to the technification process in this region, however, has an institutional tie. The United States Agency for International Development, working in conjunction with the Inter-american Institute for Agricultural Sciences (IICA) in Costa Rica, funded a regional program known as Promecafe (Coffee Improvement Program).

From the 1970s to the 1990s, USAID has funded coffee projects throughout the region by funneling upwards of $80 million into a variety of country-specific and regional programs (see Figure 1). Whereas these efforts initially focused upon rust control, they eventually evolved into small farmer technification projects. Coffee leaf rust, in fact, never presented the problems to production that were originally anticipated. It currently exists at various levels of incidence, periodically flaring into an obstacle to production on a local basis.

National institutions have also played a role in the technification process. The National Federation of Coffee Producers (FEDERACAFE) in Colombia served as the motive force in that country to technify the coffee sector. Within some twelve years between 1980 and 1992, Colombia's technified coffee area climbed from about 20-25 percent to nearly 70 percent. In Mexico, the now-defunct Mexican Coffee Institute (INMECAFE) carried out a technification program in various parts of the country during the 1970s and 1980s. The present day efforts to technify Mexico's coffee lands are being directed through the newly-announced "Alianza Para El Campo" program mentioned above, which targets growers with fewer than 5 hectares of coffee (SAGAR, 1995).

Consequences of Technification

The dichotomy often presented in the issue of sun vs. shade coffee is a clear-cut one. The problem is that it is misleading. While thinking of the issue in terms of shade or sun, we must understand that there exists a continuum of shade associated with coffee that goes from a densely shaded, coffee-in-the-natural-forest setting to one of no shade at all. Much coffee area in northern Latin America falls somewhere along this continuum, between the two extremes. Figure 2 shows this shade gradient. "Rustic" coffee is that found in a natural forest setting which has been modified by the insertion of coffee beneath the existing canopy. A traditional polyculture is a much more disturbed habitat, but has a profile very similar to a forest, with discernible layers in the overstory. The commercial polyculture also has a relatively diverse shade in both species and structure, but is more controlled than the traditional polyculture. Specialized shade usually consists of a single species of shade that is intensely pruned, often with a resulting laminar look. Along with coffee that is devoid of any shade cover, the specialized shade habitat represents a particularly poor vegetation complex for bird diversity.

Obviously, there are both physical and ecological considerations related to the shade gradient in coffee. For purposes of comparison, it is useful to contrast the two extreme ends of the continuum. From my own work in Central America, we see that traditional shade coffee produces more leaf litter, has higher levels of carbon (an indicator of organic matter content), and shows a greater cation exchange capacity than technified coffee (Rice, 1990; 1991).

The buffering effects of a shaded environment are intuitive. A canopy acts to insulate the micro-environment beneath it, dampening the temperature and humidity fluctuations that would other occur (Graph 1 and 2).

In terms of bird populations, we now have data that point to a decrease in bird populations over the last two decades. The Northern Oriole, for instance, displays a definite downward trend in its numbers between 1978 and 1994 as calculated from the U.S. National Biological Service's collection of bird counts on the Breeding Bird Survey routes. Other species, such as the Tennessee Warbler and the Cape May Warbler show even sharper declines for this same period. It should be noted that these declines correspond temporally with the intense period of coffee technification in northern Latin America, a fact that in part may be related to the population changes observed a continent away.

Findings from work conducted on birds in coffee show that the diversity and abundance of birds in "rustic" coffee (those production units in which coffee has been inserted into the existing natural forest) and traditional polycultural holdings, in which coffee is grown in association with an array of different shade trees, are surpassed only by natural forest habitats. At the other extreme, an unshaded coffee plantation is the most depauperate habitat. The middle levels of shade within the gradient tend to show intermediate species diversity and abundance. There is a positive correlation, then, between bird diversity and shade complexity.

We can identify a series of factors associated with the shade gradient. In general, yields increase as the shade is removed and agrochemicals are used at the prescribed doses. Income for the farmer may indeed increase also, but the unpredictable nature of the international market price of coffee can place a grow at greater risk economically. For many small producers, complete dependence upon a single crop, the price of which is determined far away by factors beyond his control, does not represent a viable strategy for year-to-year survival. The use of shade trees, by contrast, provides products aside from the coffee which can be consumed by the household or sold on the local market. Initial studies in the Antigua, Guatemala area suggest that small farmers on the average gain around 30 percent of their yearly income from the non-coffee products derived from the overstory.

Other ecological factors associated with the shade gradient can also be identified. A canopy produces more leaf litter, as mentioned, resulting in greater amounts of organic matter. The soil enhancement properties of organic matter are known, as is the soil protection characteristics of a mulch layer. Together, the mulch and incorporated organic matter allow for better water infiltration into the soil, as well as enhanced soil moisture retention. The shade cover, acting to break up what might otherwise be desiccating winds during the dry season high above ground level, also undoubtedly adds to the soil moisture levels. Without shade, obviously, the effect of the wind's action and evapotranspiration reach the coffee. The spread of diseases, such as fungi like coffee leaf rust, may also be accelerated by removing the overstory (Rice, field notes; personal observation).

A shade plantation generally has a longer productive life span than a sun plantation. In the sun, coffee's productive period lasts for 12 to 15 years, at which time the plantation is renovated. Renovation entails the removal of the coffee plants, which disturbs the soil base. In areas characterized by heavy seasonal rainfall and highly dissected terrain, such disturbance can result in increased erosion (Rice, 1990; 1991). At higher levels of shade, coffee's longevity tends to be greater. Shade plantations have productive life spans that generally last for 25 to 30 years, with farms as old as 80 years still in production (albeit reduced).

A significant trade factor associated with the shade gradient concerns coffee quality. Many roasters maintain that shade coffee yields a better cup. While the shade in itself may play a role in this quality difference, we should not overlook the fact that today, due to widespread technification efforts, it is the small growers with mixed shade tree canopies who have retained the traditional coffee varieties such as *bourbon* and *tipica*. So, at least in part, these vintage varieties may be responsible for the empirical shade/quality observation.

A final factor associated with the shade gradient is that of biodiversity. We have seen the role that shade plays with respect to bird diversity. Not surprisingly, other organisms, such as arthropod groups, also show high levels of diversity in shade coffee. Perfecto et al (in review). Sampling of two trees of the same genus (*Erythrina spp.*) in traditional shaded coffee yielded 126 species ("morphospecies") of beetles in one, and 110 species in another less than 200 m distant. Such findings are in the same order of magnitude as that beetle diversity found on individual trees in undisturbed tropical forest (Erwin, 1982). More impressive yet, however, is the low level of overlap shown by the samples from the two trees, which totaled only 14 percent (Perfecto et al, in press).

It is worth noting that the majority of coffee producers throughout the region of northern Latin America qualify as small growers. The definition of "small" coffee producer varies from country to country--indeed, from zone to zone within a single country--but if we take 10 hectares of coffee as the cutoff for a small producer, we find upwards of 750,000 producers in the region.

A Role for Shade Coffee in the Market?

Shade coffee obviously can play a role in agricultural policy and environmental policy. In many countries, where forest cover has been removed at astounding rates in recent years, the agro-forestry characteristics of shade coffee land represents some of the little remaining "forest" cover. As others have pointed out (Perfecto et al, in review) tropical agroecosystems like shade coffee might be more important to conservation of biodiversity and general ecological well-being than previously thought.

On the one hand we find that shade coffee areas involve a managed biodiversity, represented by the shade tree species acting as a canopy for the coffee below. These species provide a host of non-coffee products for the producer's direct consumption, as well as potential income at the local market level. Moreover, though, we find an associated biodiversity that occurs within the shade system *because* of the managed or deliberate biodiversity that is there. For bird diversity, shade coffee provides a habitat rivaled only by natural forest. For other organisms, such as arthropods, diversity at the level of individual trees ranks within the same order of magnitude as that found in undisturbed tropical forest.

Additionally, the protection of the soil base that seems to be associated with shade coffee makes this traditional agricultural system an example of good land stewardship.

Considering the well-established and ever-growing "green market" in the industrialized world's consumer circles, there is a logical linkage between the market place and conservation that can be addressed through shade coffee. The coffee industry-- and that includes growers, processors, exporters/importers, roasters, and retailers, as well as national and international institutions concerned with coffee-- needs to explore ways in which connections can be made between producers and consumers.

Today, there are hundreds of thousands (perhaps millions) of producers growing coffee with what can only be called good land stewardship practices. They do not necessarily use these production methods out of a deep concern for the fate of the earth. Rather, the traditional coffee agroecosystem has evolved as a risk-avoidance approach to land management and family survival. Regardless of the rationale behind these land management practices, however, there should be way to link shade coffee producers to environmentally sensitive consumers *because* of the land stewardship practices and the ecological benefits associated with them.

Table 1: Coffee Production (1000s metric tons) and Position Within Global Production for Countries in Northern Latin America, 1991

Area or Country	Production	% of World Total
World	**6088**	**100%**
Mexico	299	4.9
Central America	**663**	**11.0**
Guatemala	195	3.2
Honduras	122	2.0
El Salvador	149	2.4
Nicaragua	28	0.4
Costa Rica	158	2.6
Panama	11	0.2
Caribbean*	**125**	**2.1**
Cuba	26	0.4
Dominican Republic	46	0.8
Haiti	37	0.8
Jamaica	2	0.03
Puerto Rico	13	0.2
Trinidad/Tobago	1	0.02
Colombia	870	14.3
Northern Latin America Total	**1957**	**32.1**

*Dominica, Guadeloupe, Martinique, Saint Lucia & Saint Vincent all produced less than 1000 metric tons during the 1980s.

Source: FAO Production Yearbook (1991)

Table 2: Area Devoted to Coffee Production in Northern Latin America (1000s hectares)

	1950*	1960**	1970	1980	1990	%Change 1950-1990
World	**5270**	**9963**	**9014**	**9847**	**11,501**	**118%**
Mexico	157	316	339	455	669	326
Central America	**469**	**567**	**655**	**776**	**755**	**61**
Costa Rica	51	54[a]	95	82	95	86
El Salvador	121	130	124	185	173	43
Guatemala	162[a]	170	229	250	244	51
Honduras	63	107	101	125	144	129
Nicaragua	56	87	85	110	74	32
Panama	16	19	21	24	25	56
Caribbean	**272**	**270**	**287**	**304**	**298**	**10**
Cuba	89	60[b]	50	50	100	12
Dominican Rep.	76	100[a]	140	160	103	36
Haiti	30[b]	30	30	34	34	13
Jamaica	5[b]	7	6	5	6	20
Puerto Rico	62	63	51	45	46	-26
Trinidad/Tobago	10	10	10	10	9	-10
Colombia	647	818	817	1084	1000	55
Northern Latin America Total	**1545**	**1971**	**2098**	**2619**	**2722**	**76.2**

*1948-52 average; **1961-65 average
[a] extrapolated; [b] estimated

Source: FAO ProductionYearbook (various years)

Table 3: Coffee Yields in Northern Latin America, 1950-1990 (kg/hectare)

	1950	1990	% Change
World	**427**[a]	**546**	**28**
Mexico	400	658	65
Central America			**(average) 152**
Costa Rica	450	1591	254
El Salvador	620	904	46
Guatemala	360	830	131
Honduras	210	825	293
Nicaragua	350	583	67
Panama	180	406	126
Caribbean			**(average) 6.5**
Cuba	350	272	-22
Dominican Rep.	360	574	59
Haiti	1235*	1094	-11
Jamaica	336*	262	-22
Puerto Rico	160	280	75
Trinidad/Tobago	354*	213	-40
Colombia	540	845	56
Northern Latin America Average	**421**	**667**	**58**

[a] World average yield value calculated from FAO coffee area for continents, assuming that about 10% of the coffee area was not reported. (production=2.25 million mt; area=5.27 million hectares)
*Data from 1961-65 (no yield data available for 1950)

Source: FAO Production Yearbook (various years)

Table 4: Distinguishing Characteristics of Traditional and Modern ("Technified") Coffee Production Technologies

	Traditional Coffee System	Modern Coffee System
Varieties used:	arabiga (tipica), borbón (bourbon), maragogipe	caturra, catuaí, Colombia (in Colombia), Garnica (in Mexico), catimor
Size (meters):	tall (3-5m)	short (2-3 m)
Shade:	moderate to heavy, covering 60% to 90% of ground area	none to moderate, covering up to 50% of ground area
Shade trees used:	tall (25 m) natural forest species, fruit trees, bananas	short (5-8 m), selected leguminous species
Density of coffee plants (number per hectare):	1000 to 2000	3000 to 7000, with some areas up to 10,000
Years until first harvest:	4 to 6	3 to 4
Plantation life span:	30 years (and more)	12 to 15
Agrochemical use:	none to low	high
Pruning:	sometimes not pruned at all; otherwise, individualized treatment of plants	standardized stumping back after first or second year of full production (*soqueo* or *recepa*)
Labor requirements:	seasonal for harvest and pruning	year-round maintenence with higher demands at harvest

Source: based on Junguito and Pizano (1991) and personal field observations

Table 5: Coffee Area as a Function of Technology Level in Selected Countries of Northern Latin America (thousands of hectares)

Country	Technology Level: Traditional	Intermediate	Technified	Total Coffee Area	Percent Technified
Mexico	64.9	489.7	114.4	669.0	17
Costa Rica	10.8	54.0	43.2	108.0	40
El Salvador	152.4	0.0*	13.2	165.6	8
Guatemala	110.1	85.6	49.3	245.0	20
Honduras	30.0	100.0	70.0	200.0	35
Nicaragua	53.0	14.0	27.1	94.1	29
Dom. Republic	77.2	0.0*	25.8	103.0	25
Haiti	30.6	0.0*	3.4	34.0	10
Colombia	357.3	n/s	791.9	1149.2	69
Total	886.3	743.3	1138.3	2767.9	41.1†

*figures are probably greater than 0.0; no reliable data on intermediate technology level available
†average for region, calculated from regional totals; average of countries' technified area is 28.1%
n/s=information not supplied

Sources: Mexico-FAO Production Yearbook (1991) and Nolasco (1985); Costa Rica-correspondence with Instituto del Café de Costa Rica (1993); El Salvador-correspondence with Patricia Valdivieso of the Consejo Salvadoreño del Café (1993); Honduras-correspondence with Fundación Banhcafé (1993); Guatemala-correspondence with Anacafe (1993); Nicaragua-Gariazzo (1984); Dominican Republic-personal communication with World Bank economist/coffee expert Panos Verangis (1993); Haiti-estimated from information from USAID (1990); Colombia-Federación Nacional de Cafeteros de Colombia (1993)

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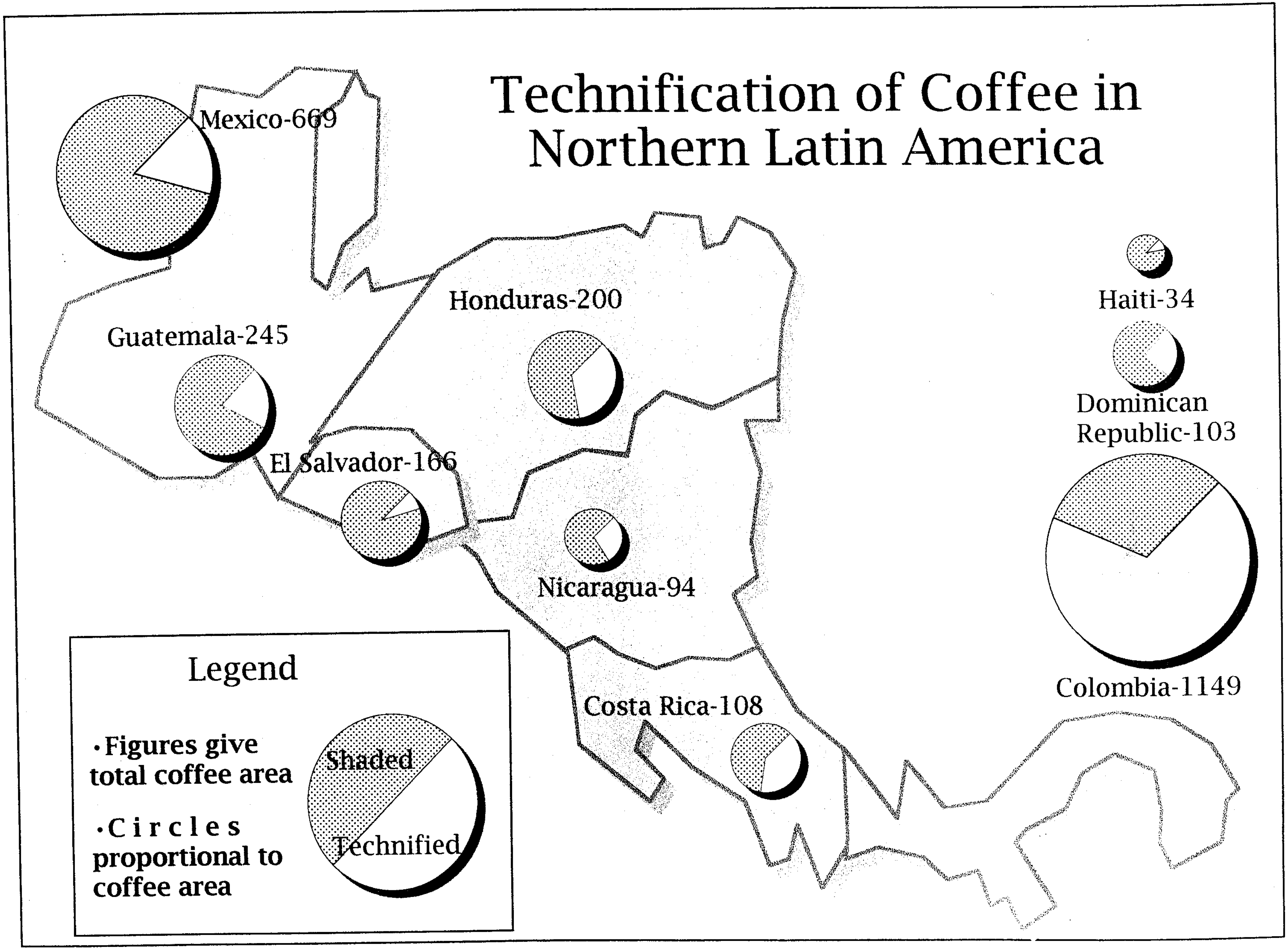

Technification of Coffee in Northern Latin America
Mexico-669
Guatemala-245
El Salvador-166
Honduras-200
Nicaragua-94
Costa Rica-108
Haiti-34
Dominican Republic-103
Colombia-1149
Legend
·Figures give total coffee area
·Circles proportional to coffee area
Shaded
Technified

Daily Fluctuations in Temperature in Sun and Shade Coffee

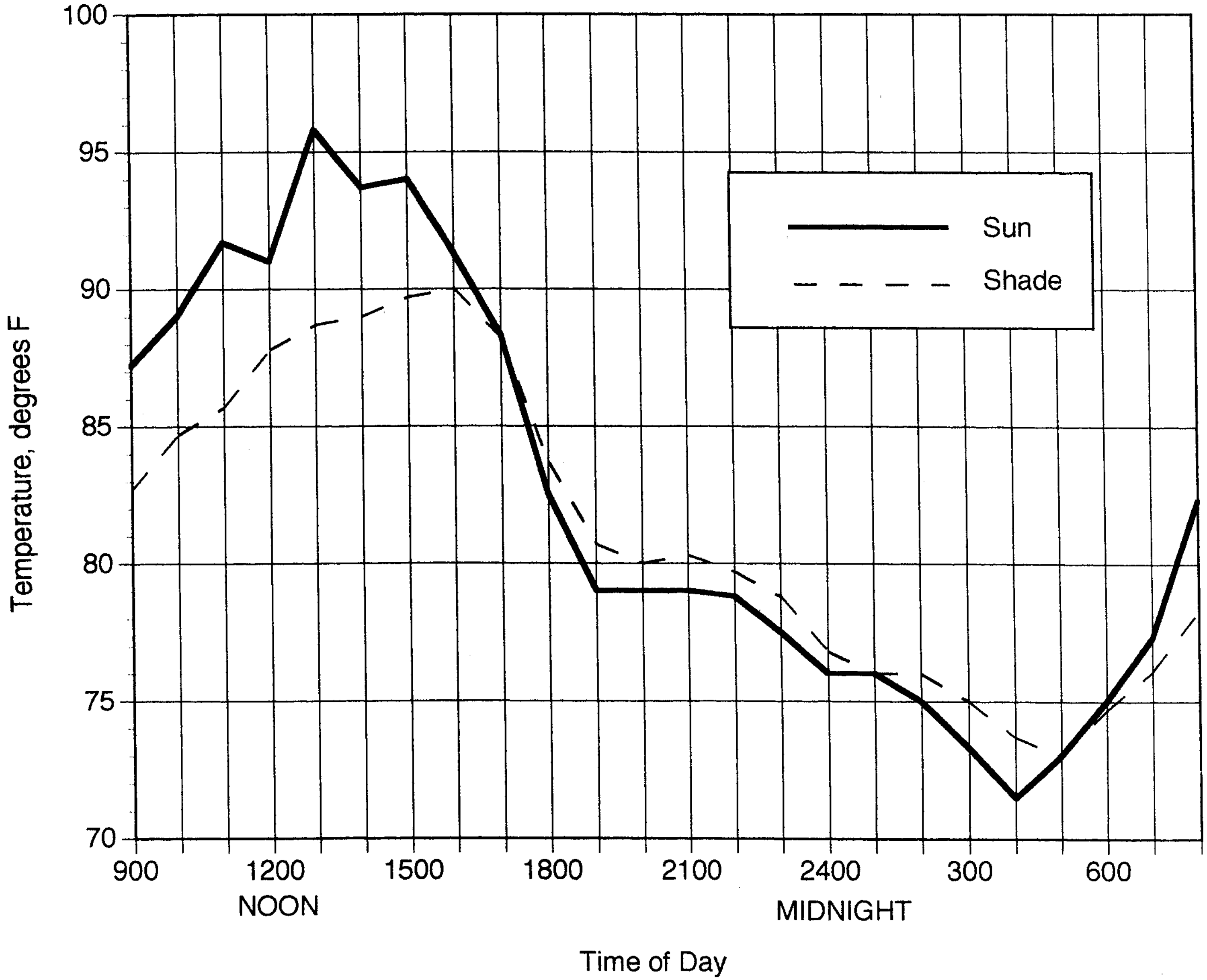
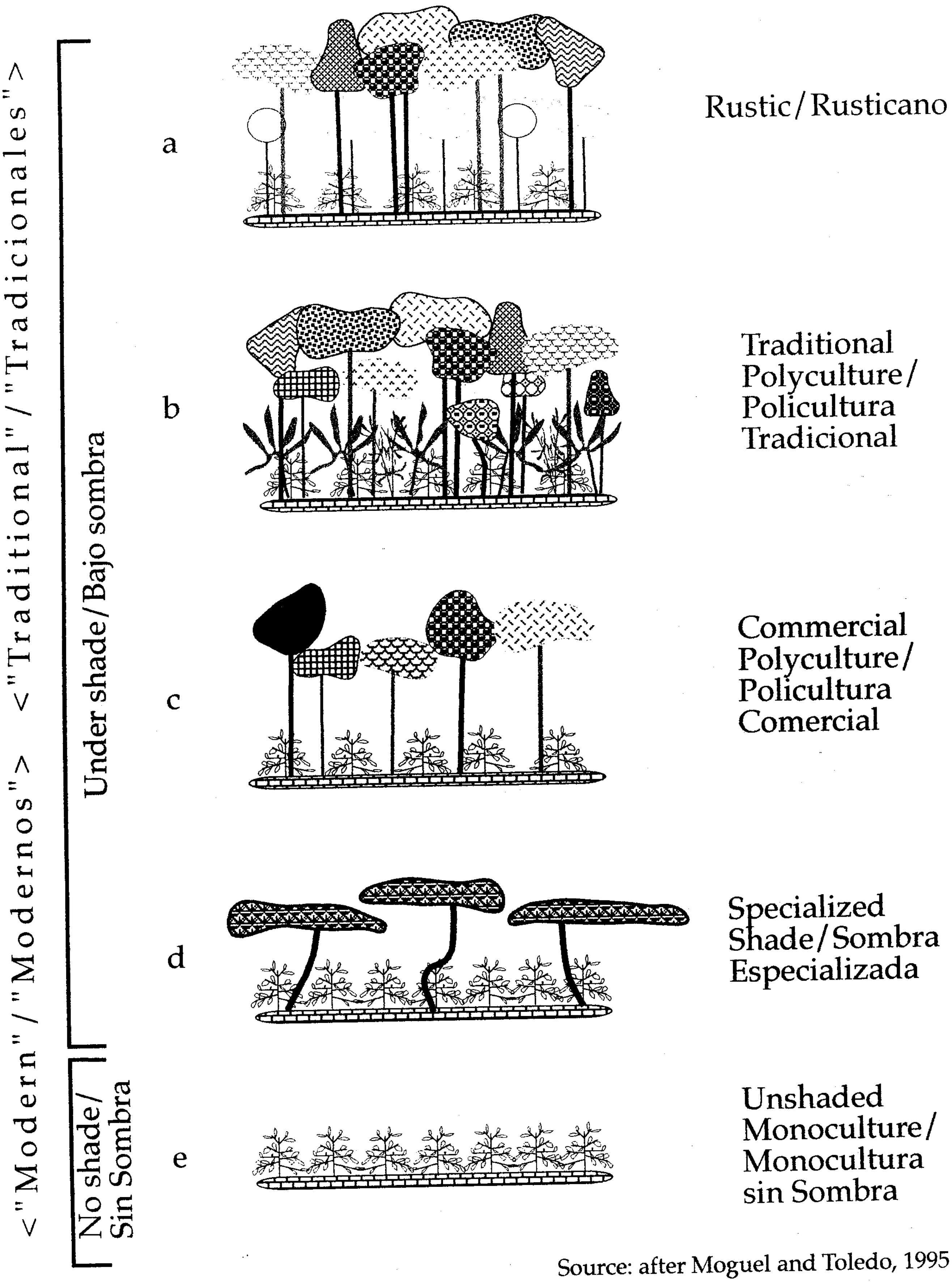
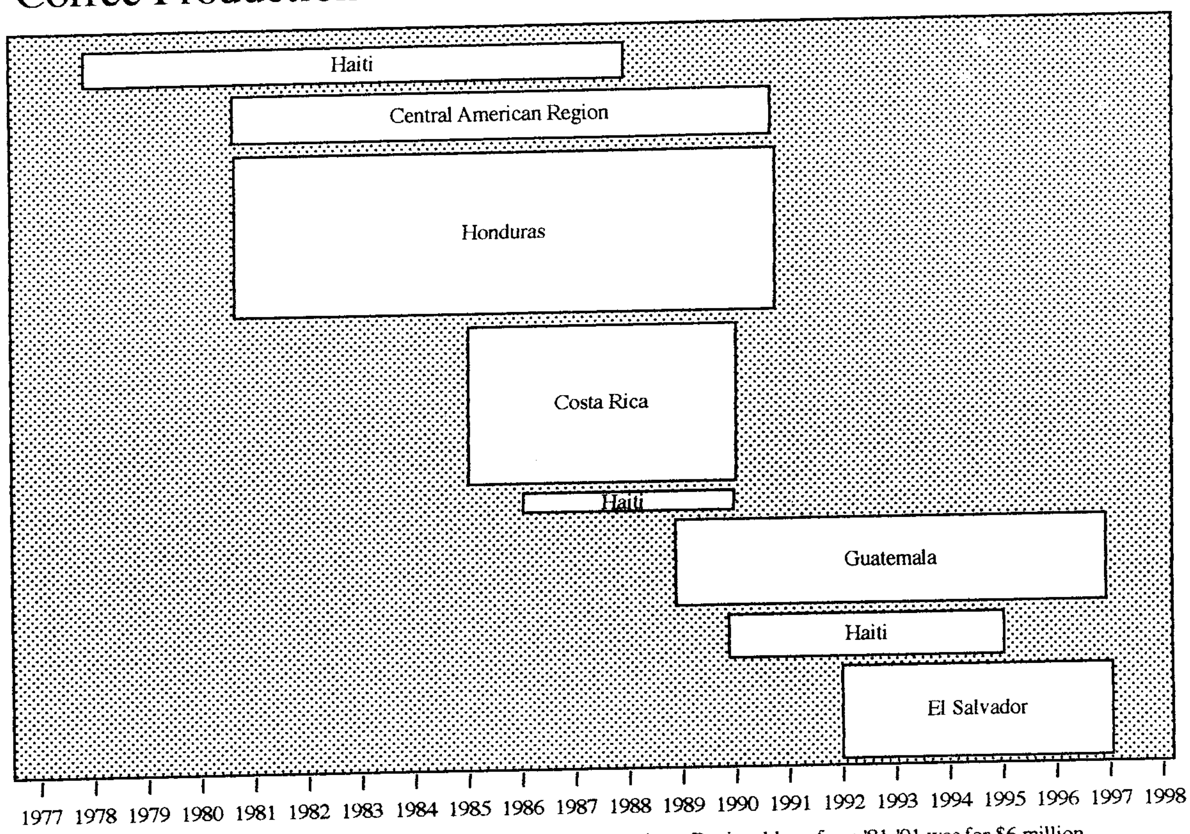


Figure 2: Shade gradient in coffee production systems



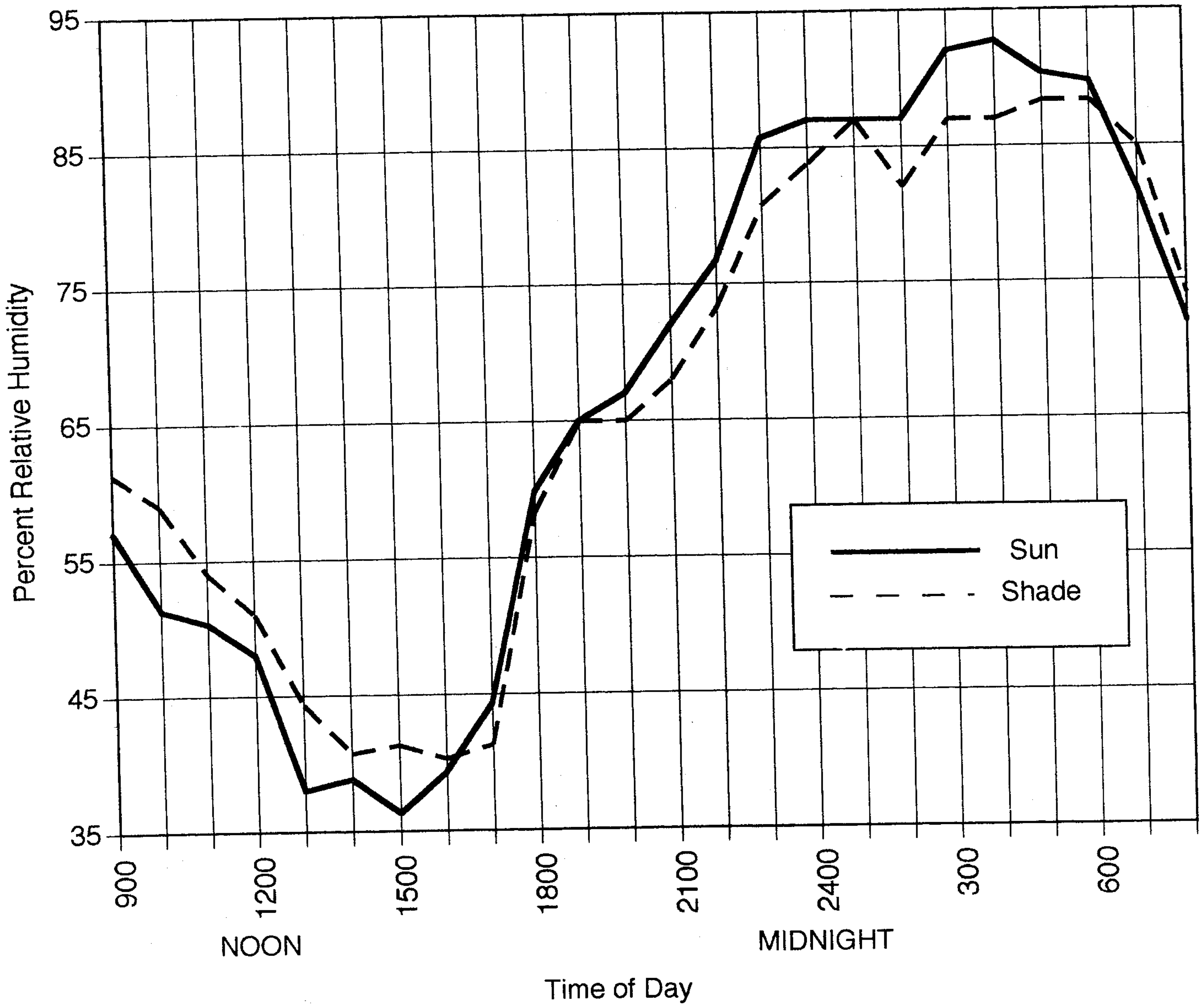
Source: after Moguel and Toledo, 1995

Figure 1: Life Span of Various USAID Projects Directed at Coffee Production Modernization in Northern Latin America



Note: Height of box proportional to the amount of loan. For comparison, Regional loan from '81-'91 was for $6 million.

Daily Fluctuations in Percent Relative Humidity for Sun and Shade Coffee



Various Factors Associated with the Shade Gradient in Coffee Farms