GOOD FARMERS

Traditional Agricultural Resource Management in Mexico and Central America

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Dedicado a los Señores
Don Bernardino Nophal Corona
Don Pablo Ahguech Rodríguez
Don Pedro Gonón
Don Apolinar Rodríguez
Don Juan Vásquez Santiago
Campesinos, Maestros, Amigos

y a todos los otros quienes cuidan los escasos recursos que les proporcionan el ambiente y la sociedad, y quienes con paciencia y comprensión me han revelado la utilidad y la belleza de su trabajo.

6

Slope Management

The mountainous regions of Middle America are products of primordial forces. Still-active volcanos and frequent earthquakes have created a jumble of abrupt mountains, folded hills, and steep escarpments cut by deep canyons and narrow valleys. This precipitous natural landscape contrasts sharply with the cultural landscape. Over the years traditional farmers, hardly less a primordial force, have modified thousands of hectares to permit effective use of the land.

This discussion of surface geometry is divided into two parts: slope management (covered in this chapter) and field-surface management (see Chapter 7). The distinctions are of duration, scale, and purpose. Under slope management I group relatively permanent changes made to whole fields or even entire hillsides primarily to control runoff or irrigation water. Included in such efforts are terracing and leveling. In contrast, field-surface adjustments are usually temporary, lasting no more than a season or year, and are designed to improve biological, climatic, or edaphic conditions for crop plants. They take such forms as ridges, pits, raised beds, or even individual plant mounds. The distinctions are not sharp. Field-surface features may cover a field or hillside and affect as much of the surface as permanent slope systems. Conversely, many slope-control measures have profound effects on soil nutrients and moisture levels. But a rough grouping into categories is useful, especially when reviewing labor requirements for construction and maintenance.

More than one writer has commented on the curious lack of scientific attention to agricultural landforms.[1] The few studies on the Western Hemisphere deal mostly with the pre-European period; surveys of contemporary slope or field forms are rare, and rarer still is information on the costs and benefits of restructuring the natural landscape.[2] This review does not correct these deficiencies but instead focuses on a few common features found in Middle America for which some data are available.

Slopes represent a dynamic process. On natural slopes the forces that move materials downhill are balanced by factors that resist downward movement. The impact of gravity, the fundamental degradational (erosive) force, can be seen directly in land movements such as in soil creep or slides, and indirectly in the flow of water. In the case of surface runoff, effects increase with distance. Not only does water accelerate as it travels downhill, but, in addition, sheet wash is quickly concentrated into small channels. These degradational forces are resisted by such factors as soil shear and erodibility, and vegetation.[3]

Most slope modification is aimed at controlling surface flows, either runoff or irrigation water.[4] Factors that influence surface flows include rainfall amounts and intensities, soil structure and texture, vegetation, and large and small surface features. Other than protect the surface against splash erosion, farmers can do little about rainfall. The physical characteristics of soils can be altered to a certain extent by adding organic materials or sand to improve infiltration rates or water-holding capacities. Although a complete, permanent vegetative cover is effective for controlling erosion, it is inimicable to the needs of most farming. Most important is slope management, by which the gradients over which water develops erosive power are modified.

[1]Berl Golomb and Herbert M. Eder, "Landforms Made by Man."

[2]Although focused on the pre-Spanish period, R. A. Donkin's *Agricultural Terracing in the Aboriginal New World* contains considerable information on contemporary terracing. See also J. E. Spencer and G. A. Hale, "The Origin, Nature, and Distribution of Agricultural Terracing"; A.C.S. Wright, "Some Terrace Systems of the Western Hemisphere and Pacific Islands." For a recent survey and analysis, especially of the socioeconomic aspects of hill farming, see Andrés R. Novoa B. and Joshua L. Posner, eds., *Agricultura de Ladera en América Tropical.*

[3]This concept is developed by M. A. Carson and M. J. Kirkby, *Hillslope Form and Process,* chaps. 3 and 4. The term *erodibility* includes several factors, such as particle size and permeability, that affect soil response to degradational forces. W. H. Wischmeier and J. V. Mannering, "Relation of Soil Properties to Its Erodibility."

[4]Some writers argue that moderate erosion is beneficial to crop production because it exposes fresh mineral soils. For example, Wright ("Some Terrace Systems") maintains that stabilizing slopes with terraces in the humid tropics would nullify natural soil-rejuvenation processes.

Although slope management has the control of water as its primary purpose, other benefits result from it. For example, several slope-control structures act as settling basins: check dams create level fields in streamways; surfaces of the Tehuacán *pantles* (fields) are periodically dressed with silt. Thus, by reducing gradients (slope management) and water flows, farmers increase percolation or allow irrigation (water management) and reduce erosion or induce deposition (soil management). In addition, improved fields permit other practices (mulching, manuring, fertilizing) and tolerate intercropping or multiple cropping (space management). In the final analysis, it is difficult, and perhaps pointless, to decide which purpose is paramount.

Individual decisions to modify surface geometry rest ultimately on farmers' perceptions of feasibility and on anticipated returns in relation to costs. In some cases favorable benefit/cost ratios are apparent. For example, the substantial yields from irrigated fields usually justify the costs of leveling. Less apparent are the returns from erosion control. It is testimony to the perspicacity of traditional farmers that so many are willing to devote so much effort to controlling degradational forces.

Irrespective of scale, most slope- or topographic-control measures can be reduced to the several phases of materials handling: excavation or acquisition, transfer, and deposition. But each phase requires substantial work, which in traditional farming systems must come from humans or animals. The two basic solutions to the problem are to combine sources of power or to reduce scale. For rapid, large-scale slope modification, massing human and animal power may be attractive, especially where labor is abundant. But slope control lacks the organizing tendencies of water management, and institutional requirements limit this solution to those societies that can control labor.[5] Reducing scale is the more common solution. Most traditional slope projects can be constructed and operated by a family or small group. Even so, over long periods of time the cumulative results of small-scale slope-control projects can be impressive.[6]

[5]Organization, supervision, and incentives are critical elements in large-scale labor-intensive projects. Basil Coukis, *Labor-Based Construction Programs;* World Bank, *World Bank Study of the Substitution of Labor and Equipment in Civil Construction.* Contemporary land-leveling and terracing projects in the People's Republic of China offer spectacular examples of what can be done with massed labor in a highly organized society.

[6]Many Old World terrace systems are products of centuries, even millennia, of effort. For example, the famous terraces of northern Luzon were most likely built over a period of perhaps 2,000 years. H. O. Beyer, "The Origin and History of the Philippine Rice Terraces." See also, Harold C. Conklin, *Ethnographic Atlas of Ifuqao.* Paul Wheatley ("Agricultural Terracing") argues that, despite a long period of development, some terrace systems in Vietnam are the result of preconceived and carefully executed plans.

Unable to concentrate power from either mechanical equipment or massed labor, traditional farmers accept that reshaping the agricultural landscape requires patience. Carefully scheduled stages and predetermined completion dates characterize projects in industrialized systems. In traditional slope management extensive terracing or erosion control is undertaken with little thought as to the pace of work or when it will be finished.[7]

In addition, slope modification is never permanent. Powerful degradational forces are inescapable elements in hillside environments. Once natural slope stability is disrupted, farmers must continuously manage hillside ecosystems to ensure that exposed soils and control structures remain intact. Slopes are destabilized not just by natural forces but also by most farming practices. For example, original clearing and subsequent cultivation reduce the impeding effects of vegetation on surface flows and soil erosion. Tillage loosens soils and weakens shear resistance. Successful hill farming therefore requires compensatory practices that decrease or interrupt overland flows or reduce gradients. But entire hills cannot be leveled, and if gradients are reduced on some parts, inevitably they are steepened on others. Thus, slope modification itself creates unstable conditions.

With these brief introductory remarks, we turn to a discussion of specific slope treatments. The list is not comprehensive, and it is not arranged chronologically. Although simpler forms precede more complex structures in the discussion, it cannot be assumed that they did so in history. Simple methods of slope control are still widely practiced in Middle America and serve admirably where they are appropriate to environmental and social conditions.

Check Dams

Check dams provide an excellent illustration of the interplay between natural forces and human management. Check dams *(atajadizos, bordos, presas, teceras, terrazas, trincheras)* are built in intermittent streamways *(arroyos)* in arid and semiarid regions where sudden storms and sparse vegetation combine to produce heavy erosion. The dams are constructed across smaller streams where the force of water rushing down after a storm will not destroy the rock, earth, and branch structures. Check dams reduce the speed of the flowing waters and thus their ability to carry eroded materials. As the water slows, suspended debris is deposited and forms flat, flood-irrigated and subirrigated fields behind each dam.

[7]Gene C. Wilken, "Traditional Slope Management."

Figure 6-1. Check dams (arrows) and depositional fields, southern Tlaxcala, Mexico.

Since the small dams can slow but not completely contain heavier stream flows, they must provide for overflow. This also opens possibilities for a sequence of dams, each checking the flow and capturing some of the suspended debris. In some *arroyos* check dams form continuous steps with the top of each downstream dam level with the base of the one above it (Figure 6-1).

Check dams are often built in stages. In this respect they display the process-rather-than-project approach of so many traditional management activities. A narrative account from an Otomí informant in Hidalgo, Mexico, offers insights into the process:[8]

> *Atajadizo* is the name of fields made in gullies. It is also the name used for the actual wall that is constructed to retain the water and the soil. . . . *Atajadizos* need to be strong in order to withstand the force of the water when it rushes down the gully. An *atajadizo* that is well built has a double wall: the outside wall is pitched in order to hold back the water; the inside wall holds the soil that accumulates. It also has a floodgate *(compuerta)* so that the extra water can spill over. Furthermore, the wall itself is curved in order to deflect the force of the water.

[8]Kirsten Johnson Haring, *Preliminary Report on Field Work Carried Out in Hidalgo, Mexico Between October 1973 and April 1974*, pp. 19–22.

> It may be necessary to use mortar and it is best to use the largest solid rocks possible.
>
> An *atajadizo* isn't built all at once. Usually a farmer starts with a low wall across the path of an *arroyo*. It takes a few years until the water has brought down enough debris *(basura)* and soil to level with the top of the wall. Then, the farmer will build up the wall a bit more, and so on, little by little until s(he) has built up a tall strong wall and a large level field. A well-made *atajadizo* is level so that the trapped water will cover all parts of the field evenly. It may be necessary to level the field by hand and, also, to tear down parts of the gully in order to enlarge the field. But this is only the case when the gully is very narrow and uneven. In most cases the flow of water takes care of enlarging and leveling out a field.
>
> A well-made *atajadizo* always has a wall that is higher than the field behind it. This is necessary because water must be trapped so that it can soak into the field. But if the field is at the same level as the wall, the water will just flow over it and waste.
>
> There is no need to fertilize an *atajadizo* because every rainy season the water brings down new debris and soil.

A number of variables, such as gully configuration, force of water, materials availability, and type of construction, affect the amount of labor required to build a check dam. Erasmus[9] found that during a 5-hr workday[10] one man had no trouble excavating 7 m^3 of earth with a shovel or 3.5 m^3 of rock with a steel crowbar.[11] Comparable information on the time required to place these materials in a check dam or similar structure is not available. To build single- or double-fitted stone walls of the types described here probably would take no more than twice the time spent excavating. Thus, as a first approximation, a total time (excavating plus placing) of 1 to 2 m^3 per working day seems reasonable.

But suitable materials are not always near at hand. Erasmus establishes that during a working day a man can travel a total of perhaps 10 to 12 km carrying 20 to 25 kg of earth or rock (and return with only the container) for a daily transfer capacity of 200 to 300 kg/km (Table 6-1). The volume of materials delivered to a construction site declines sharply with distance, as the table shows. Transferring bulk materials horizontally or vertically is one of the most difficult tasks faced by low-energy societies. The data here, for example, indicate that rock transfers consume as many man-hours as the excavation itself when transfer distances exceed 100 m.[12]

[9]Charles J. Erasmus, "Monument Building."

[10]A 5-hr or, more commonly, 6-hr day is reasonable for sustained, hard work. It is also a common workday in rural Middle America.

[11]A figure of 2.7 m^3 of rock per day for manual excavation from a quarry in Africa includes loading into trucks. J. Müller, "Labour-Intensive Methods in Low-Cost Road Construction."

[12]A World Bank study recommends a 30-m limit haul distance to loads carried by humans. Coukis, *Labor-Based Construction Programs*, pp. 190–92.

Table 6-1. Materials-Transfer Rates by Human Carriers

Trip Distance, One Way (m)	Material	Total Trips, 6-hr Day	Total Distance, One Way (km)	Total Weight Carried (kg)	Average Weight Carried per Trip (kg)	Total Volume Carried[a] (m^3)	Performance Index, kg/km/Day, One Way
50	Earth	234	11.7	4,716	20.2	3.63	236
100	Earth	134	13.4	2,672	19.9	2.06	267
250	Rock	39	9.8	1,088	27.9	0.76	272
500	Rock	23	11.5	575	25.0	0.40	288
750	Rock	17	12.8	586	34.5	0.41	440
1,000	Rock	13	13.0	295	22.7	0.20	295

SOURCE: After Erasmus, "Monument Building," pp. 284–87. Rock data adjusted from 5- to 6-hr day.

[a]Volumes calculated: 1 m^3 = 1,300 kg of earth or 1,440 kg of rock.

Check-dam dimensions vary enormously. A good set of measurements comes from Chihuahua, Mexico, where prehistoric *trincheras* ranged from a few centimeters to 3.5 m high, 1 to 165 m long, and 15 cm to 3 m thick.[13] Representative *trincheras* 0.5 to 1 m high, 6 to 9 m long, and 0.33 to 0.5 m thick would contain from 1 to 7 m^3 of material. The ancient builders probably did not spend much time transferring rocks because there appears to have been abundant suitable material in this volcanic region, especially in the eroded gullies where the check dams were built. I estimate that a 3- to 4-m^3 structure could be erected in perhaps 2 to 3 man-days.

Mortared check dams are rare, and I have no data on their labor costs. A few figures from other structures, including stone-faced road drains and *mampostería* (cemented-rubble) foundations and walls suggest that mortaring a fitted rock wall can be done in the general range of 0.25 to 1 m^3/man-day, depending on availability and suitability of materials and quality of work.

The calculations of labor invested in check-dam construction are based on limited data and should be considered only rough approximations. Nevertheless, it appears that even the elaborate structures are relatively inexpensive to build. Once the dams are in place, field development proceeds with little additional effort; silt deposition is induced by reducing stream speed, and the fertile fields essentially create themselves.[14] The same reduction of stream force helps control gully erosion. Because the periodically silted and wetted fields are highly productive, I suspect that check-dam farmers enjoy a high rate of return on their labor investment. Certainly on the semiarid Mesa Central of Mexico benefits from check dams must more than justify costs. In the arid north they are one of the few means by which farming can be supported.

Check dams do not directly affect general slope characteristics. But they and their associated alluvial fields are in precarious balance with stream forces. Water topping a dam or pouring through a leak can cause rapid, drastic erosion. Although some of the rock *trincheras* in Chihuahua are still intact after more than 500 years, most are susceptible to failure, especially during sudden, heavy stream flows. Frequent maintenance is necessary to prevent breaking and undercutting, and subsequent rapid erosion of deposited soils. In this regard check dams share a characteristic of all terraces. Although gradients, and thus

[13]Laurance C. Herold, *Trincheras and Physical Environment Along the Río Galiván, Chihuahua, Mexico,* pp. 90ff; William A. Howard and Thomas M. Griffiths, *Trinchera Distribution in the Sierra Madre Occidental, Mexico.*

[14]Ernst Griffin and Howard W. Dennis, "A Mexican Corporate Campaign in Conservation"; Comisión de La Malinche (Mexico), *Realizaciones en la Montaña de La Malinche.*

Figure 6-2. Debris in shifting-cultivation plot retards runoff and erosion.

debris-transport forces, are reduced on their beds, gradients on terrace faces are increased, making them highly vulnerable to erosion.

I have seen or read reports of check dams in the Mexican states of Chiapas, Chihuahua, Hidalgo, Mexico, Oaxaca, and Tlaxcala, and I suspect that they are actually found in most states and countries in Middle America. They are not simply artifacts of primitive slope management. Modern government erosion-control projects in Chihuahua and Tlaxcala include rock check dams identical to those constructed for centuries by traditional farmers.[15]

Sloping Terraces

The most extensive slope-management systems in Middle America consist of sloping terraces, on which original gradients are changed

[15]A somewhat analogous procedure is followed by Zuñi farmers, who set out rows of brush to induce deposition of wind-blown sand and dust. Frank Hamilton Cushing, *Zuñi Breadstuff*, pp. 165–66. Some central Asian people similarly create level areas of wind-deposited materials that are then flooded. Food and Agriculture Organization and United Nations Educational, Scientific, and Cultural Organization, *International Source-Book on Irrigation and Drainage of Arid Lands in Relation to Salinity and Alkalinity*, p. 510.

only slightly or not at all. In their simplest form, sloping terraces consist of nothing more than rows of logs or rocks laid perpendicular to slope gradients to partially check down-slope surface wash (Figure 6-2). In their more elaborate forms, earth or rock embankments follow hill contours. At their fullest development, sloping terraces have carefully shaped earth-and-rock or rock embankments *(bordos)* reinforced with economic plants and parallel drainage ditches *(zanjas)*.

The main functions of sloping terraces are to control erosion and accumulate moisture. Although slope angles are not deliberately changed, most sloping terraces develop modified gradients through natural processes (over time, deposition builds up behind embankments) or human intervention (in team-worked fields consistently turning furrows downhill transfers soil in that direction and reduces gradients).

There are many variations of sloping terraces in Middle America. West describes the distinctly central Mexican *metepantle*, in which low embankments are paralleled immediately down slope by drains, forming a *zanja/bordo* combination that is probably the most popular slope-control technique on the Mesa Central.[16] Characteristically grain is planted in the fields and *maguey* (*Agave* spp.) on the *bordos* to stabilize them and also to produce flower-stalk sap (*aguamiel*, from which *pulque* is fermented) and many other products.[17] Other economic plants commonly found on *metepantle* embankments are *mesquite* (*Prosopis* spp.) and the native fruit trees *tejocote (Crataegus mexicana)* and *capulín (Prunus capuli)*. West identifies *metepantles* as a form of semiterracing or incipient terracing. But their long history and extensive modern use suggest that they are not a rudimentary stage of terracing but rather a well-developed technique uniquely adapted to the physical and agricultural conditions of central Mexico.

Despite their antiquity and extensive modern use, the mechanics of *zanja/bordo* systems and their relationships to physical and biological conditions are not well understood. We do know that *bordos* act as hillside check dams that prevent surface wash from accelerating and channeling. Although some deposition occurs behind the embankments, their purpose seems more to reduce erosion and absorb moisture than to trap silt. The reinforcing *maguey* is used because, although it suffers in saturated soils, it fares well on the higher *bordos*. *Zanjas* act as small field reservoirs to catch seepage and any ponded runoff that tops the *bordos*. Although some *zanjas* are excavated up slope from the

[16]Robert C. West, "Population Densities and Agricultural Practices in Pre-Columbian Mexico, with Emphasis on Semi-Terracing."

[17]In addition to *pulque*, the plant provides fiber *(ixtle)*, building materials, roof thatching, fuel, and foods (including young leaves and edible larvae). Gene C. Wilken, "The Ecology of Gathering in a Mexican Farming Region."

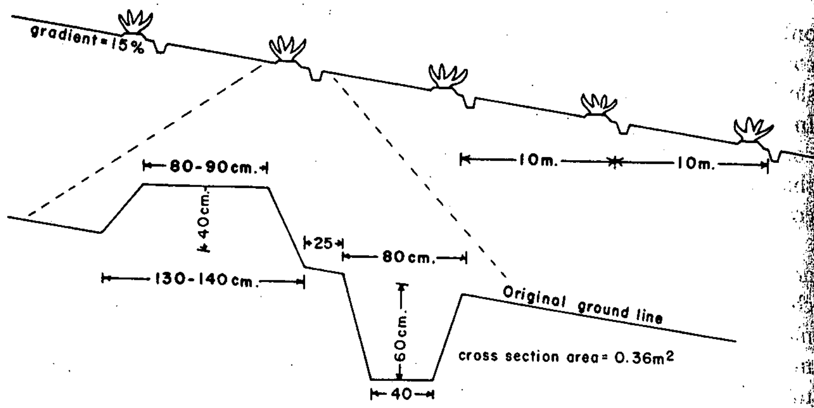

Figure 6-3. Sloping (*zanja/bordo*) terrace.

embankments, most are below, where they are less likely to fill with sediments. In porous soils water stored in *zanjas* gradually percolates into field substrates.

Sloping terraces are a method of controlling slopes at low cost, a feature appreciated by traditional farmers and modern planners alike. In 1972 an agency of the Mexican government stated that "the salvation of rainfall *[temporal]* agriculture consists in the modification of traditional systems of cultivation" and enthusiastically undertook a series of conservation projects involving *trincheras,* stone-faced terraces, and *metepantles.*[18] One such operation in western Tlaxcala provides an opportunity to corroborate field observations with government data on labor inputs in *zanja/bordo* projects.

Farming is marginal in this region. Average rainfall of 600 to 700 mm is barely adequate for grain crops, and below-normal years are hazardous. Rains come mostly in the period from May to September, often in intense, convective showers. Much of the region is gently rolling to hilly. The thin, sandy soils have little water-holding capacity and are easily eroded. These problems are common in central highland Mexico, as are sloping terraces as a solution.

With the help of government engineers, farmers and *ejiditarios*[19] laid out lines of drains along contours. Trapazoidal *zanjas,* 80 cm wide at the top sloping to 40 cm at the bottom, were cut 60 cm deep, for a

[18]Dirección General de Conservación del Suelo y Agua (Mexico), *Resumen Gráfico de Tabajos de Control de la Erosión de los Suelos y de Conservación del Agua de las Lluvias,* p. 14. See also Secretaría de Obras Públicos (Mexico), "Obras a Mano."

[19]*Ejiditarios* are those who received expropriated lands *(ejidos)* under the Mexican land-reform program.

Figure 6-4. Sloping terraces with *maguey* in *zanja/bordo* system.

cross-section of 0.36 m^2. Dividing strips 50 to 60 cm wide but only 30 to 40 cm high were left every few meters to stop movement of water in the drains. Excavated material was piled immediately up slope from the drains in geometrical *bordos* 40 cm high and 80 to 90 cm wide at the top sloping to 130 to 140 cm at the bottom (Figure 6-3). The *bordos* were not compacted except by incidental foot traffic, which is why they have a larger volume than the *zanjas* from which they came. After *zanja/bordo* construction was complete, young *maguey* was planted along embankments at 3-m intervals (Figures 6-4 and 6-5).[20] Except for the engineers' transits, the only tools used were shovels and spades, and picks when consolidated *tepetate* layers were encountered.

In addition to providing engineering assistance, the government paid workers on the basis of *tareas* (or *journales*), the fair or normal amount of work that can be done in 6 hr.[21] *Tareas* are based on type of work, terrain, and material. Table 6-2 lists representative *tareas* for this project. Within these ranges precise amounts are determined by specific

[20]Field preparations for transplanted *maguey* are reviewed by Candido Cruz López, "Estudio Agrológico Regional del Estado de Tlaxcala," especially no. 3, pp. 123ff., "El Maguey y su Cultivo"; Miguel Macedo Enciso, *Manual del Magueyero,* pp. 7–28.

[21]Workers proceed at their own pace. Energetic individuals may complete their *tareas* in 4 or 5 hr, while slower workers might take 7 or 8 hr.

Figure 6-5. Planting young *maguey* on *bordo* above down-slope *zanja*.

Table 6-2. *Tareas* for *Zanja/Bordo* Construction

Material	*Tarea* (m, linear)	Approximate m³ (cross-section = 0.36 m²)
Soft soil (*blando*)	20–25	7–9
Moderately compacted (*duro*)	10–15	3.5–5.5
Tepetate	5–10	2–3.5
Rocky (*rocoso*)	1–5	0.5–2

conditions of a particular site. For example, a worker may be expected to excavate only 5 or 6 m (linear) of *zanja* in solid *tepetate* but 10 to 12 m if the *tepetate* layer accounts for only the bottom few centimeters of a trench in otherwise loamy soil. The data on *tareas* were checked against individual farmers' estimates elsewhere in the region and against quotas set for voluntary community work (*comunidad*) in villages.[22] Correspondence was excellent. Farmers working on their own

[22] Many villages in Mexico adhere to the ancient custom of *comunidad*, in which one day each week is devoted to community projects. All adult males not otherwise occupied are expected to participate.

lands (*dueños*) are more motivated than hired workers (*peones*) and will exceed the work rates given here. But for *peones* the figures appear to be good indicators of what one man can do in a day on a sustained basis.

Those unfamiliar with hand labor may be surprised at the amount of material that one man can move and thus the relatively low cost per cubic meter. Government engineers assigned to these projects were delighted with results and soon were boasting that, given favorable conditions (moderate terrain, little rocky material), they could build a variety of public works better and cheaper with hand labor than with machinery.

To estimate labor requirements, we need to know the width of *metepantles*, or distance between *bordos;* this distance depends on slope gradient and soil texture and depth. Cruz López proposes the following general guide for *maguey* plantations: on gentle slopes (1 to 5 percent), *metepantle* width is generally 5.0 to 6.5 m; on moderate slopes (5 to 10 percent), it is 4.0 to 5.0 m; and on steeper slopes (10 to 15 percent), it is 2.5 m.[23] In western Tlaxcala, where perhaps the absorptive sandy soils reduce surface runoff, intervals are somewhat greater. Width of *metepantles* on the government-assisted erosion-control project ranged from 5 to 20 m. With examples mostly from nearby Apan, Hildalgo, West suggests a range of 12 to 30 m on moderate (5 to 10 percent) slopes down to 3 m on steeper ones (up to 25 percent).[24]

Although far from complete, the data permit some preliminary analyses of labor requirements for *zanja/bordo* slope-control projects. An average terrace width of 10 m will serve for the example. If we allow an additional 10 percent for contour sinuosities, a hectare would have a total of 1,100 m (linear) of *zanjas* and *bordos*, for a total volume of (0.36 m² × 1,100 =) 396 m³ of material to be excavated and formed into embankments. Total labor requirements would vary from 44 man-days in soft or sandy soils to more than 100 man-days in hard *tepetate*. Generally this type of work is not undertaken on rocky slopes or in pure *tepetate*. Therefore, most projects probably fall into a range of 60 to 70 man-days/ha.

These estimates are for direct labor only; they do not include time spent planning, administering, surveying, or supervising. On large communal or *ejido* projects, perhaps 20 percent more time is needed for these tasks. In individual small-farm operations the time required for planning, laying out, and supervising is inseparable from time spent during normal farm work and constructing terraces.

With the data presented here, it would be relatively easy to estimate labor costs for a *zanja/bordo* project in almost any type of material. But

[23] Cruz López, "Estudio Agrológico," no. 3, pp. 129–30.
[24] West, "Population Densities and Agricultural Practices."

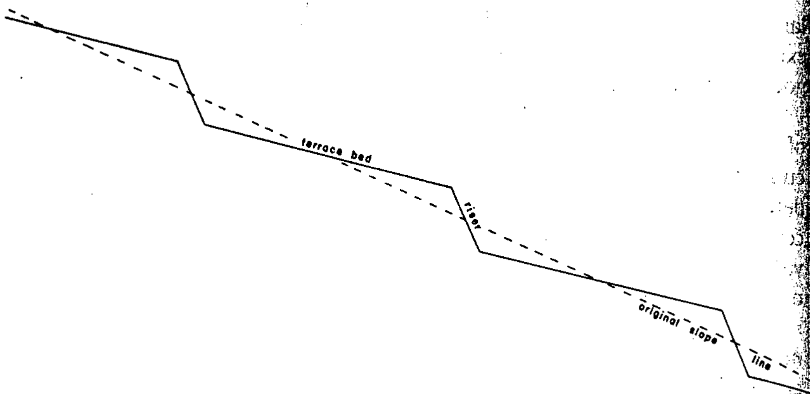

Figure 6-6. Chamula sloping terrace (not to scale).

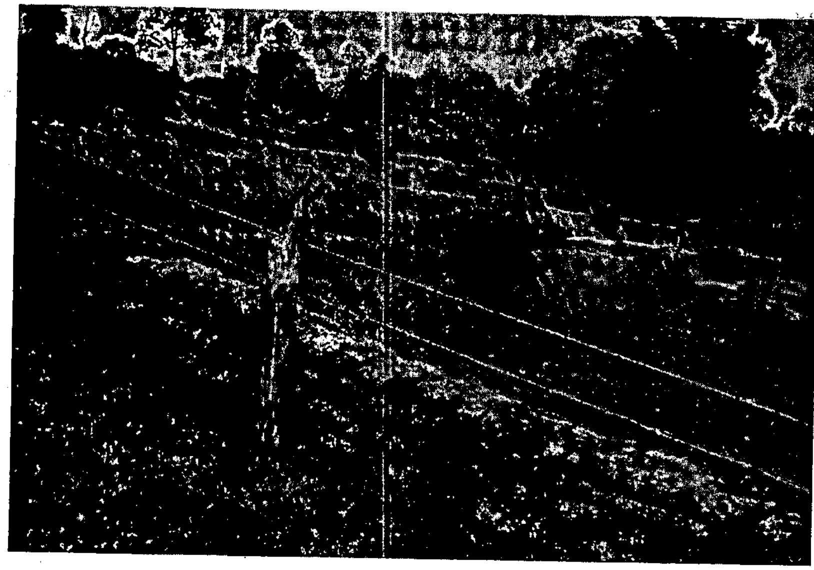

Figure 6-7. Sod-faced Chamula terraces, Chiapas, Mexico.

on individual small farms slope control is undertaken by the farmer and his family, perhaps with a few friends on an exchange-labor basis, and an occasional hired hand. The cost is more realistically represented by the 60 or 70 days it takes to treat a hectare of hill land than by a peso amount. As one Otomí farmer put it, "*bordos* don't cost money; they cost work";[25] time and effort can be spread conveniently over indefinite periods so that *bordo* construction becomes more of an ongoing process than a project.

A different approach to sloping terraces is found on rolling limestone hills near San Cristobal de las Casas in the Chiapas highlands of southern Mexico. The Chamula terraces (after the Chamula Indians of that region) typically are 5 to 10 m wide with relatively steep risers 0.2 to 1.0 high (Figures 6-6 and 6-7). Variations include rock- or sod-faced risers, small riser-edge *bordos,* and heel drains. Modifications of slope gradients are achieved by normal crop cultivation and down-slope debris transport. Unlike the team-plowed fields of central Mexico, Chamula terraces are hand cultivated with broad hoes *(azadones).* Crops such as maize, beans, potatoes, and wheat are popular. Sheep graze on grass covers that develop during fallow periods.

Not infrequently, combined forms of sloping terraces have multiple functions. For example, sloping fields in the rugged Sierra Norte del Puebla, Mexico, are bounded by *zanjas* and meter-high rock walls (Figure 6-8). Debris transport could be controlled with much lower structures. But the walls also serve as convenient depositories for rocks collected from fields and as barriers to the often carelessly herded sheep of that region.

Although sloping terraces are not as unstable as flat (bench) terraces, they are subject to accelerated erosion if not tended. West notes that "on hillsides where *metepantles* have been abandoned and where *maguey* rows have not been maintained, severe sheetwash and gullying have destroyed most of the thin soil cover."[26] Water ponded behind an embankment will pour through a break with concentrated force causing severe local erosion (Figure 6-9). Thus, like all terrace forms, sloping terraces partially destabilize hill-slope and water relationships and create potentially hazardous conditions.

So far, the discussion has treated slope as a negative element to be reduced or controlled. But sloping fields also provide some advantages, such as easily worked soils, good drainage, and the assistance of gravity in certain field tasks. On flat lands on the floor of the Puebla-Tlaxcala basin of central Mexico, high water tables and poor internal drainage make for difficult farming conditions. In addition to cutting drains,

[25]Quoted in Haring, *Preliminary Report on Field Work,* p. 23.
[26]West, "Population Densities and Agricultural Practices," p. 367.

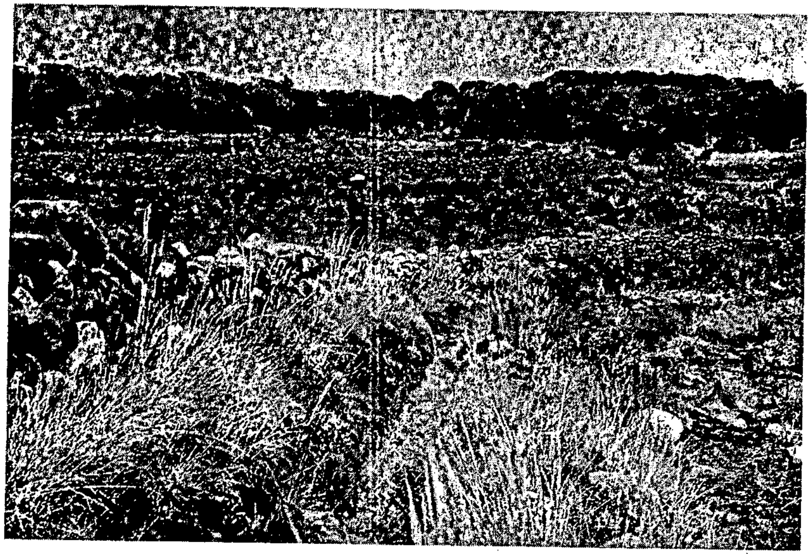

Figure 6-8. Sloping terraces with *zanjas* and high rock walls, Sierra Norte del Puebla, Mexico.

Figure 6-9. Break in *bordo* and gully erosion.

Figure 6-10. Curved fields, Tlaxcala, Mexico.

farmers create slight gradients by curving field surfaces convexly (Figure 6-10). Plowing creates this field camber. Except for passes to open small, central drains, furrows are turned toward field centers; plot surfaces thus are gradually worked into a curved form in which field centers are perhaps 20 cm higher than the edges. Once plots have been shaped, only routine plowing is required to maintain the curved form. The process is almost exactly opposite that which occurs on sloping terraces, where down-slope debris transport and transfers from plowing reduce gradients.

Flat Terraces

The ultimate in slope management is reached in flat, or bench, terraces, with which traditional farmers transform sloping hillsides into level fields.[27] An enormous range of types and subtypes is found in Middle America, which has had a terrace tradition for hundreds, perhaps thousands, of years. Some bench terraces are simply constructed, carved out of hillsides with broad hoes and periodically abandoned. Others are

[27]Gene C. Wilken, "Drained-Field Agriculture."

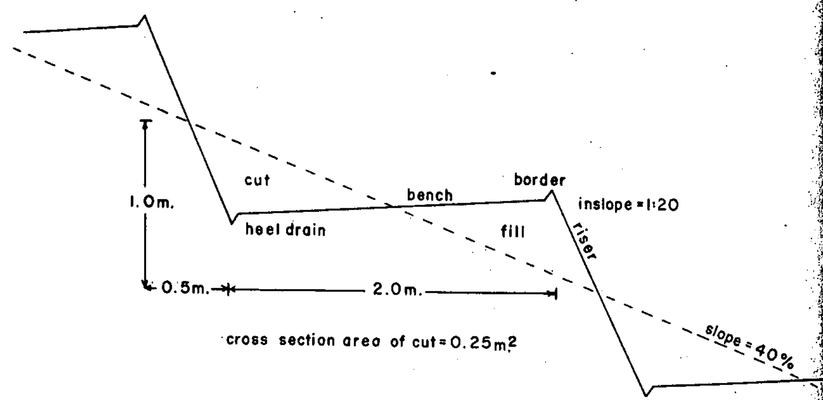

Figure 6-11. Flat, or bench, terrace.

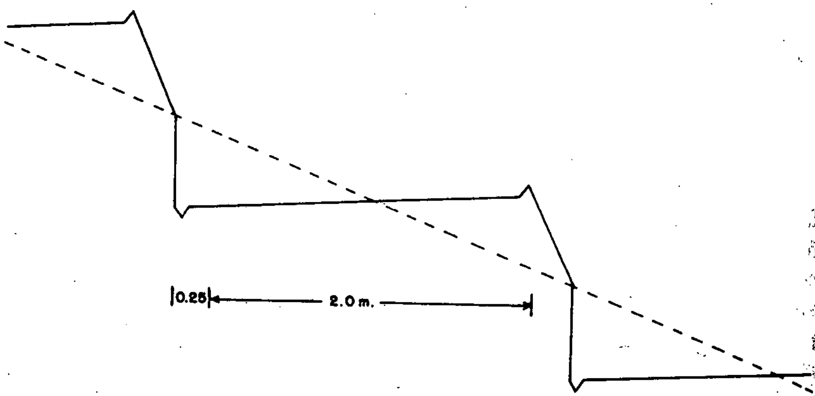

Figure 6-12. Bench terrace with vertical and sloped risers.

carefully shaped and improved over the years. Only a few details of construction and maintenance are discussed here.

Typically, bench-terrace risers, or faces, are tilted back as little as possible to maximize bed width while still maintaining some measure of stability (Figure 6-11). Benches on *temporal* terraces have slight inslopes so that surface runoff flows toward the heels, often into small drains, rather than over easily eroded risers. Irrigated versions are similar except that beds are absolutely flat. Small ridges (again *bordos*) along riser edges, rather than inslope gradients, keep water from overflowing. Ditches at the heels are larger than on *temporal* terraces to carry irrigation water.

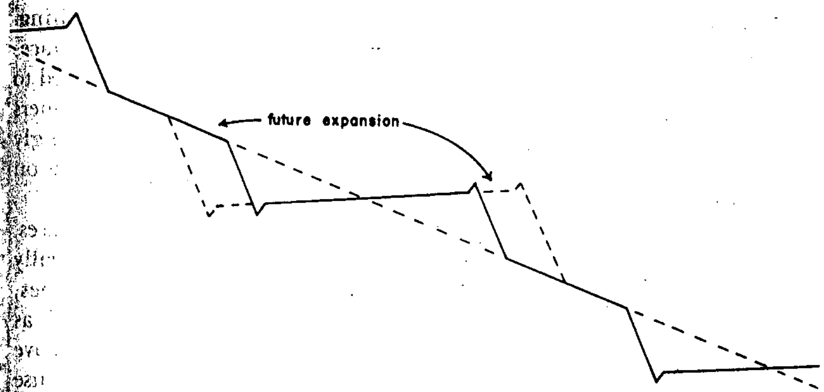

Figure 6-13. Bench terraces with unterraced space between tiers.

A variation on basic bench-terrace design suggests one way to enlarge planting surfaces without sacrificing stability. Figure 6-12 shows a terrace with the riser sloped back 0.5:1 in the fill material but with the compact, cut face left vertical. Bed width is increased by more than 10 percent with this technique.

Farmers need to take several factors into account when designing flat terraces. Slope is the primary determinant of terrace configuration. As a general rule, the steeper the slope, the narrower the bench or bed. In addition to surface geometry, however, soil types and depths and working design are important. For example, underlying bedrock limits the depth of terrace cuts. But even if soil depths are adequate, deep cuts introduce infertile subsoils onto plot surfaces. In some cases farmers leave space between terrace tiers and gradually expand them over the years so that less-desirable material is only slowly incorporated into planting beds (Figure 6-13).

In addition, farmers need to consider costs. The basic objective of bench terraces is to produce the degree of levelness needed to control surface water. Unlike check-dam fields and *metepantles*, bench terraces are not leveled to an acceptable degree by natural forces. Direct labor investments are necessary for almost all phases of construction. One way to reduce these costs is to build narrow terraces, which are less expensive than wide ones. The volume of material that must be excavated and transferred (cut and filled) to terrace a given area varies geometrically with terrace cross-section, whereas the number of terrace tiers varies arithmetically with bench width. Thus, if N terraces of bed width BW and riser height RH involve excavating and filling V m^3 of material, $2N$ terraces of dimensions $0.5BW$ and $0.5RH$ will produce the same amount of level planting beds but require only $0.5V$ m^3 of cutting and filling. Little wonder that traditional farmers often opt for narrow bench terraces even where slopes and soils would permit wider fields. With no need to accommodate cumbersome powered equipment,[28] traditional farmers can keep bench terraces narrow and labor investments correspondingly small. In the final analysis traditional terrace dimensions are based on slope angle, soil type and depth, and working-space requirements.

Although labor costs can be reduced by building narrow terraces, they are still considerable because traditional bench terraces are usually handmade. Common tools include shovels, spades, broad hoes, pickaxes, and crowbars. Only a few animal-drawn implements, such as buck *(fresno)* or drag scrapers, are useful. Although some farmers have simple bubble levels, many merely estimate slopes and angles, and use small amounts of running water to establish suitable gradients for heel drains. New terraces usually are built by parties of several men (Figure 6-14).

Labor costs are subject to two sets of variables. Bench terraces are constructed in many forms and sizes, and are found on a wide range of slopes that comprise many soil types and depths. Equally important are variations in the human labor units; individual workers differ greatly in physical and emotional states and in responses to environmental conditions (temperature, humidity). These elements are not unique to terrace construction but hold true for all estimates of production rates involving humans or animals. In the example here data distilled from a number of field observations and supported by farmers' estimates and government work quotas are applied to a typical bench terrace to illustrate construction costs.

On moderate slopes of 40 percent, benches 2 m wide are not unusual, with backslopes on the order of 0.5:1 (Figure 6-12). The cross-sectional area of such a terrace is 0.25 m^2. With soft *(blando)* soil, an experienced workman should be able to excavate, fill, and form small drains in about 20 to 25 m (linear) (5.0 to 6.25 m^3) in a 6-hr day. About thirty-seven tiers of terraces of this size are needed to cover 100 m of slope. Allowing an additional 10 percent of terrace length for contour sinuosity, each hillside hectare would require 4,070 m (linear) of terrace, or a volume of material slightly more than 1,000 m^3. At the indicated rates, a three-man work party could produce a hectare of terracing in 54

[28]Although bench terraces are not unique to traditional farming, they are not generally recommended for industrialized systems. Thus, Glen O. Schwab et al. (*Elementary Soil and Water Engineering*, p. 119) say: "The original bench terraces . . . were costly to construct and were not always well adapted to modern cultivation equipment." See also Peter Crossley and John Kilgour, *Small Farm Mechanization for Developing Countries*, pp. 14-15; Soil Conservation Service, *A Manual on Conservation of Soil and Water*, pp. 96ff.

Figure 6-14. Bench-terrace construction, Quezaltenango, Guatemala.

to 68 days, for a total of 163 to 204 man-days. In the process, they would create more than 8,000 m^2 of flat fields on what had been sloping hillside. Although bench terraces 2 m wide are not unusual, narrower terraces suffice, especially for manual-cultivation systems, and they are cheaper to build, as explained previously.

In heavier soils and clays construction rates drop to 10 to 15 m (linear)/man-day, and in rocky soils or *tepetate* to 5 to 10 m. Work rates are lower than those developed for *zanja/bordo* construction (Table 6-2), because greater care is required to shape and compact terrace fills and to form drains and borders on flat terraces. Thus, total labor investments could easily run to more than a man-year per hectare.

Maintenance of flat terraces adds to these costs. If the ultimate in traditional slope management is reached with flat terraces, so too is the ultimate in slope artificiality and instability. Maximizing terrace-bed

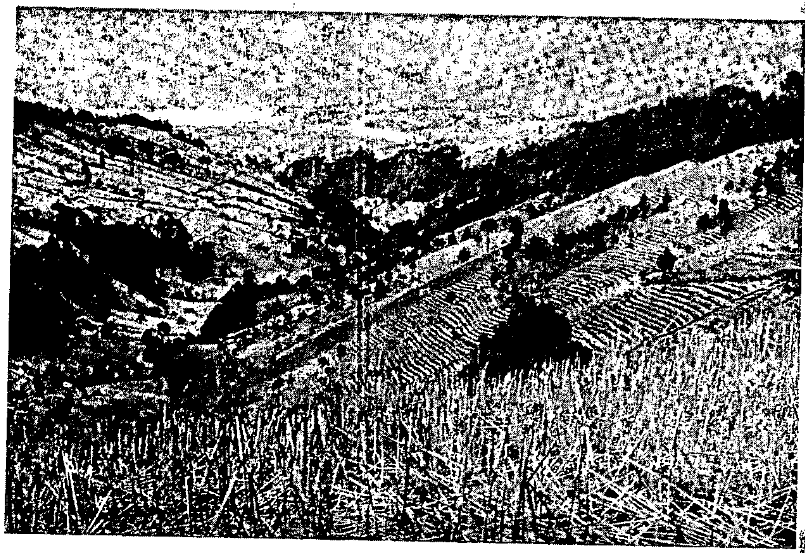

Figure 6-15. Extensive *tablón* systems, Totonicapán, Guatemala.

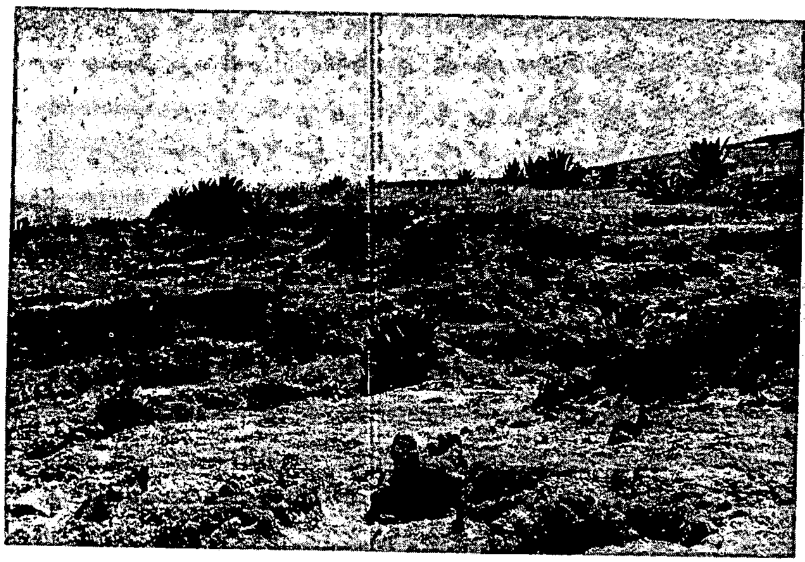

Figure 6-16. Severely eroded old terrace system near Amozoc, Puebla, Mexico.

Figure 6-17. Rock-walled bench terraces, central Mexico.

space requires that risers be as steep as possible and, consequently, highly susceptible to degradation. On terraces that cover entire hillsides, forming interdependent systems (Figure 6-15), failure in one part unleashes concentrated degradational forces that can devastate whole sections down slope (Figure 6-16).

In addition, flat terrace beds themselves are only provisionally stable because down-slope movements of soil and water are controlled only as long as risers remain intact and heel drains perform satisfactorily. Constant surveillance and maintenance are necessary continuing costs of bench terraces.

Stability can be increased by adding artificial walls, but such additions increase costs as well. Where soils are compact, risers may simply be exposed subsoil, perhaps with a protective cover of vegetation to impede erosion. But in looser soils terraces may need artificial facing such as rocks or poles, in some cases secured with mortar or lashings (Figure 6-17). The ultimate in defense is a separate structure such as a cemented-stone or even concrete wall embedded in the hillside against the slope.

Terrace-wall construction is costly, especially if materials must be brought from a distance. In addition, terrace walls are not built in increments, as are other traditional slope-control structures. Most terrace walls appear to have been built all at once, perhaps because of the need to complete a certain lineal distance or to establish proper base/top/height proportions during original construction. Consequently, the traditional farmer contemplating construction of terrace walls must be in a position to commit large amounts of time and effort to the project over a relatively short period of time.[29]

There are thus two basic reasons for the labor costs incurred in the construction of flat terraces. First, most flat terraces offer few opportunities for gravity to assist with cutting, filling, or leveling, which require much labor. Second, costs are considerable because walls are often necessary. Flat terraces must offer significant benefits—either the production of high-value crops or the creation of fields in extraordinarily space-scarce circumstances—to justify such heavy investments of labor.

Unirrigated *Tablones*

In western Guatemala narrow unirrigated hoe terraces, or *tablones*, are common wherever hillsides exceed 20 or 25 percent and are found on slopes as steep as 70 percent. Basically they are bench terraces. But their unique operation and solution to the problem of field preparation merit special attention.

Tablón dimensions do not differ greatly from those of conventional bench terraces. Flat or slightly convex beds 0.5 to 1.5 m wide rise in tiers 0.2 to 0.8 m high. Slope angle partially controls terrace design as it does in basic bench structures; generally terraces on slopes steeper than 40 or 45 percent have benches less than one meter wide, whereas on more gentle slopes they range from 1.0 to 1.5 m. Riser backslopes also vary with gradient, from near vertical on gentle slopes to 0.5:1 on steep hillsides. Wheat is the most common crop grown on *tablones*, although other *temporal* crops such as maize and broad beans *(Vicia faba)* are popular too.

But terrace design is determined also by cultivation practices. The narrow *tablones* are formed and cultivated solely with *azadones*, the universal farming tool of this region. A big 29 cm (11.5 in.) wide blade fitted to a 120 cm long wooden handle is the most popular size. Although *tablones* occasionally are broken down and reworked, by and large they are permanent forms that remain through many crop cycles and even though extended fallow periods.

[29]Of the spectacular granite vine terraces of Minho Province, northern Portugal, Dan Stanislawski says: "In the case of the low [3-4-ft] walls, the owner is probably of modest circumstances and without much capital to invest. Many small farmers of the Minho build terraces little by little on 'their own time,' that is, after the necessary work of the day is done." *Landscapes of Bacchus*, p. 38.

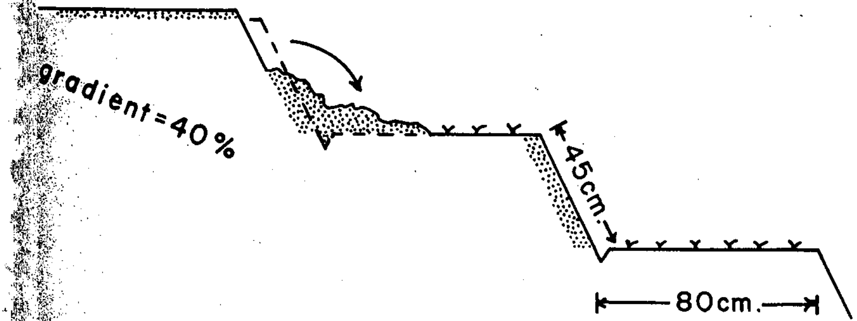

Figure 6-18. *Tablón* tillage.

A description of *tablón* cultivation will clarify the process. Prior to planting, terrace beds are not tilled; instead, risers are shaved off and the excavated material is spread over benches to establish a planting surface. Work begins at the top of the slope. Farmers, often standing on the next lower tier, swing *azadones* down to cut off an appropriate slice from the old terrace face. Swing arcs reestablish backslope angles on the newly exposed risers. Two or three swings usually are enough to cut through the risers and recut the 5 to 10 cm deep heel drains. The resulting soil is pushed and pulled across the bench with the *azadón* to bury the old surface under a layer of loosened soil (Figures 6-18 and 6-19).

For wheat, farmers strive for a layer about 5 cm deep. Thus, in Figure 6-18 about 9 cm would be cut from the riser. As soon as a few tiers have been prepared, wheat is sown and immediately covered by the same process: riser faces are again shaved and trimmed with *azadones*, and loosened soil is extracted from heels and drains to cover *(tapar)* the seed with about 2 cm of soil. Thus, a total of about 7 cm of soil is spread over the *tablón* surface. A slightly convex field surface is often developed at this stage by raking with *azadones*.

This method of plot preparation, in which old planting surfaces are buried undisturbed complete with stubble or burned residue (*basura*, literally, garbage) and root systems from previous crops, has several advantages. First, erosion potentials are greatly reduced because the basic terrace structure remains intact and only a thin layer of loose soil is exposed to splash and sheet erosion. Second, organic materials and ash are interred at root levels of the new crop. Third, layers of loosened soil may surpress weed growth. Fourth, soil from the whole riser profile is added to planting beds each year, and thus all soils are rotated on a long-term basis. For example, it will take 6 to 7 yr to work through the 0.8-m terrace illustrated in Figure 6-18 with 12.5-cm cuts each year.

Figure 6-19. Tilling *tablones.* Loose soil for planting bed secured by shaving riser with *azadón.*

Fifth, and perhaps most important, the system requires much less effort than would digging up terrace beds. With steady work, farmers expect to till, sow, and cover a *cuerda* (approximately 440 m^2) of *tablón* in a 6-hr working day, considerably more than would be possible by ordinary shovel or spade tillage.

Several features of *tablón* design make it possible to conserve labor in this way. Beds are narrow, permitting the entire operation of cutting and spreading to be done from one position. In addition, backslope angles and heel drains are reformed as part of seed preparation, not as separate operations. But most important, arduous soil lifting—an essential phase of plot preparation when using shovels or spades—is replaced by gravity-assisted downward transfers of soil, and farmers can move along rapidly without excessive physical exertion. One man-day per *cuerda* (or 23 man-days/ha) may not seem an impressive rate for field preparation. Yet in speed and efficiency, the *tablón* system must rank high compared with other methods of working steep slopes.

Irrigated *Tablones*

The irrigated *tablones* of western highland Guatemala have little in common with their dry namesakes. They are small (perhaps 10 to 30 m

Figure 6-20. High-walled, hand-irrigated *tablones,* Sololá, Guatemala.

long, 2 to 6 m wide) and rise in steps 0.5 to 2.0 m high up steep valley sides in Cakchiquel Indian areas of the department of Sololá.[30] Irrigation water led into heel canals is splashed over plot surfaces with small basins *(palanganas).* Riser *bordos* are not needed because the plots are neither flood nor furrow irrigated. Surfaces are completely leveled, however, to prevent ponding of splash-applied or rain water (Figure 6-20). To prepare fields, riser faces are not shaved; instead, plot surfaces are tilled with *azadones* at the same time that leaf mold *(broza),* manure, and field debris are worked into the soil. With complete control over slope, water, and soil conditions, farmers harvest three or four crops of vegetables each year, most of which are sold in local, regional, or national markets.[31]

[30]Kent Mathewson *(Irrigation Horticulture in Highland Guatemala)* presents a detailed review of irrigated *tablón* operations in the same general region. He reports (pp. 82–83) construction of one 3×30 m *tablón* per *tarea,* which is lower than the rates developed here for unirrigated *tablones.* However, his example includes substantial soil conditioning as well as careful plot formation in preparation for at least two years of farming with splash irrigation.

[31]T. David Johnson, "Análisis de Actividades Necesarias para la Producción de 11 Especies Horticolas (Hortalizas)"; William C. Merrill, Lehman B. Fletcher, and Michael S. Hanrahan, "Vegetable Production and Marketing in Guatemala."

Figure 6-21. Rock-faced *tablones*, Quezaltenango, Guatemala.

Equally hard-worked *tablones* cover the narrow Samala River flood plain at Zunil, Quezaltenango. Some fields occupy relatively flat land; others ascend gentle slopes as terraces. Plots are tiny, no more than 10 m wide and less than 25 m long. Like the Sololá terraces, they are hand cultivated with broad hoes and splash irrigated, although with long-handled scoops *(palas)* rather than basins. Most Zunil *tablones* are rock faced, either dry wall or mortared. Terraces are completely flat to accommodate splash irrigation and are bordered by an elaborate system of small canals so that all parts of the plots are within range of scooped irrigation water (Figure 6-21).

Discontinuous Control Structures

If crops or exposed soil are not continuous, the control structures do not need to be continuous either. In Middle America several types of discontinuous or partial terraces are used. Circular pit terraces *(cepas)* around individual trees in hillside orchards are common and illustrate the technique.

Cepas are constructed by cutting and filling just as are ordinary flat terraces (Figure 6-22). They perform all customary terrace functions

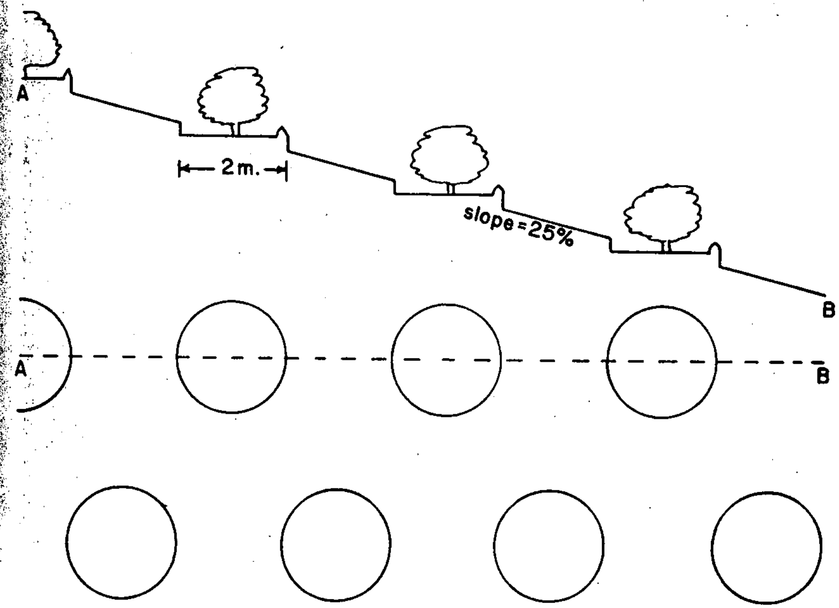

Figure 6-22. Pit terraces (*cepas*).

such as controlling erosion, conserving moisture, and facilitating cultivation. But, in addition, this form of terracing has distinct advantages. Unworked portions of slopes remain at original gradients under vegetation, thus reducing erosion potentials. And irrigation water delivered through small canals or tubes is confined to immediate tree areas, a great saving over flood irrigation (Figures 6-22 and 6-23).[32]

But most important, because reorganization of surface geometry is kept to a minimum, little labor is necessary. For example, constructing one of the *cepas* shown in Figure 6-22 would require excavating less than 0.2 m^3. At indicated spacings, each hectare would have about 922 *cepas*. Assuming construction rates similar to those for bench terraces, it would take only 23 to 58 man-days to construct pit terraces in a hectare of hillside orchard.

The process in new orchards is to level circular areas only slightly larger than seedling crowns. As trees grow, terraces are enlarged. Such phased expansion suggests the process rather than project approach.

[32]The benefits of individual tree-sized terraces in connection with irrigation by team- or tractor-drawn water tanks are reviewed by Leonardo Obregón Formoso, *Desarrollo de la Fruticultura por una Sistema Práctico y Económico de Riego en Zonas Aridas y Semi-Aridas*.

Figure 6-23. *Cepas* newly planted with avocado seedlings pock a hillside, Veracruz, Mexico.

Materials transfers from cut to fill are down slope, assisted by gravity. Once formed, *cepas* trap surface wash and debris to moisten and enrich the soil around the trees. Thus, the several principles of traditional slope control find expression in this single management form.

Summary

Reshaping natural landscapes into forms suitable for farming poses special problems for nonindustrial systems. Lacking the concentrated energy of fossil fuels, traditional farmers are limited to human and animal power for transferring volumes of material and for controlling forces that transport debris.

Animals are an important source of power, especially for horizontal transfers such as land leveling. But for many operations, such as lifting and fine excavating, animal-powered equipment is unsuitable.[33] Furthermore, to use animals efficiently may require larger plot sizes than

[33]As far as I know, there are no animal-powered soil-lifting implements that would be equivalent to back hoes or trenchers.

are feasible. For example, slope and soil conditions may not permit construction of bench terraces wide enough to accommodate animal-drawn equipment.

Massed labor offers another solution. If adequate labor supplies and appropriate sociopolitical institutions exist, most slope-control projects can be accomplished completely or substantially with human labor. But the organizations and customs necessary make this solution available to only a few contemporary societies.

Thus, power available to traditional farmers for slope management is generally limited to relatively small amounts of human labor. These constraints give rise to several distinct characteristics of traditional slope management. First, slope-control projects are generally of modest size. Although large projects may be attempted by social units such as villages or *ejidos*, most practices are scaled to families or small groups.

Second, because materials transfers pose special problems, distances are kept as short as possible. Transfers across a few meters can be accomplished without the use of containers or conveyances. But longer distances require loading and unloading, and volumes moved per unit of time decline rapidly. Traditional farmers avoid long-distance transfers or resort to powered equipment whenever possible.[34]

Third, for bench-terrace construction, beds are kept narrow to minimize the amount of material that must be excavated and transferred. Initial labor investment and working-space requirements probably are as important as slope and soil conditions in determining bench-terrace dimensions.

Fourth, gravity is used whenever possible. Check-dam fields are created almost entirely by stream-delivered and stream-deposited sediments. Gradients on sloping terraces are modified in large part by the work of surface wash. The ingenious *tablón* farmers of western Guatemala work with, not against, gravity in tilling and planting their narrow wheat terraces. Some of these management practices would be impractical if materials had to be transferred by humans or animals.

Fifth, traditional slope-management activities are processes more than projects. Because the supply of labor is severely limited, significant slope modification is accomplished in small increments. Schedules and completion dates are rare, and construction may continue for years, even generations.

[34]Prehispanic construction work in Middle America may have involved relatively long-distance transfers of earth and rock by human carriers. Angel Palerm, *Obras Hidráulicas Prehispánicas en el Sistema Lacustre del Valle de México;* Angel Palerm and Eric Wolf, *Agricultura y Civilización en Mesoamerica.* But the long lines of basket-laden workers found on some modern Chinese and Indian projects have no parallel in contemporary Middle America.

Sixth, slope management requires much labor for construction and continuing labor for maintenance. Slope control modifies original gradients and creates long-term hazardous conditions. Structural failure and environmental degradation are more likely to result from reduced rather than increased labor inputs.[35] Moreover, once modified, gradients and surface runoff patterns cannot be quickly reversed. Slope management should therefore be undertaken with extreme caution if there is a possibility that labor for maintenance may not be available in the future.

Despite these constraints and hazards, traditional farmers are capable of impressive achievements in slope management. Over the years thousands of hectares of mountainous Middle America have been molded into forms that effectively conserve moisture, control erosion, and create productive fields in areas otherwise marginal or unsuitable for farming. These achievements, as well as the occasional failures, merit our close attention.

[35]Thus, I do not agree that dense or increasing population is necessarily correlated with accelerated erosion, as is suggested, for example, by Sherburne F. Cook, *Soil Erosion and Population in Central Mexico*. More often population decline or sociopolitical disruption leads to neglect of resource management.

7

Field-Surface Management

Perhaps no other activity so characterizes traditional farming as the careful shaping of field surfaces into features that improve crop plant environments. Using plows, shovels, hoes, and sometimes bare hands, farmers laboriously mold a wide variety of mounds, ridges, pits, and beds to modify edaphic and microclimatic conditions on surfaces and in root zones. In the process they create distinctive, often striking plot surfaces that have no counterpart in the machine-worked fields of industrialized agriculture.

Farmers make microtopographic adjustments in their field surfaces in order to gain benefits they perceive for particular crops in particular environments. Local custom prescribes the specific forms that surface adjustments take; most farming regions have two or three standard forms which in turn are interpreted or modified by individual farmers. The result is a nearly infinite array of minor field forms and variations that defy comprehensive survey. This chapter describes a few common minor field forms used in Middle America, reviews their functions (especially as understood by the farmers who create them), and estimates labor costs in man-hours or man-days.

Shaping loose earth into mounds, ridges, or raised planting beds is the most common way of altering surface microtopography. Such mounding usually begins when fields are first prepared for planting and may be modified in subsequent cultivations. Rearranging planting