CROPPING SYSTEMS AND SOIL CONSERVATION IN THE HILL AREAS OF TROPICAL AMERICA[1] /

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Resumen

La mayoría de los alimentos básicos en la América Tropical se producen en fincas pequeñas ubicadas en zonas de ladera. Un análisis de los sistemas agrícolas actuales y del pasado en esta región, indica que en la conversión del agua y del suelo influyen varios elementos, las que en conjunto promueven su estabilidad. Se sugiere que los encargados en investigación en el campo agrícola deberían enfocar sus esfuerzos hacia los sistemas de agricultura de ladera para mejorar su productividad en términos sostenidos.

Introduction

The hill areas of tropical America are characterized by small holdings, steep slopes, annual cropping and poverty. This combination of factors has created serious problems of soil erosion causing land degradation in the hills and flooding and silting in the lowlands. There has been a tendency for planners and agronomists alike to emphasize the negative aspects of hillside farming and to encourage alternative land use patterns. As a result they ignore many of the soil conserving components of present farming systems.

This paper will review some of the environmental constraints and the strategies employed by traditional farmers to modify these constraints for agricultural production on steep slopes. Careful consideration of these soil and water conservation strategies should help to improve the productivity and sustainability of on-going agricultural production programs.

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Current importance of the hill areas

A combination of geographic, climatic and historical forces has resulted in great population concentrations in the highlands of Mexico, Central America and the Andean countries. Table 1 gives estimates of the total area, arable land, the percentage of the national population, and agricultural population on the steep slopes. Posner and McPherson (49) suggest that from one-third to one-half of the farmers and from 20 to 40 percent of the arable land are on steep slopes. The major use of this arable land is for food crops and recent estimates show that 40 to 80 percent of national food crop production comes from hill farms (49, 60, 67).

Historical perspective

Historically the hill areas of tropical America were used for food production. They had numerous advantages for the aboriginal farmer. The steeply sloping areas were easy to clear since they were usually in forest and with an axe and fire the land could be made ready for planting. In contrast, the flat areas often had poor drainage and were covered with dense grasses, a difficult type of vegetation to control without animal traction (64). Also, burning on slopes was easier than on flat lands in that the updraft

Table 1. Estimated area, arable land[a] and population on steep slopes[b] of Tropical America[c].

Country	Percent of National Area	Percent of Arable Land	Percent of National Population	Percent of Agricultural Population
(1)	(2)	(3)	(4)	(5)
Mexico	45	20	15	45
Guatemala	75	30	40	65
El Salvador	75	40	30	50
Honduras	80	15	15	20
Costa Rica	70	25	20	30
Panama	80	10	15	30
Jamaica	60	50	15	30
Haiti	80	70	50	65
Dominican Rep.	80	15	15	30
Colombia	40	25	15	50
Ecuador	65	25	25	40
Peru	50	25	25	50

a Arable land includes only the land used for annual crops. It refers to cropped and/or fallow land which is part of the normal rotation. Thus, arable land includes all the land in sugar cane, cotton, and other annual crops, but excludes perennial crops such as coffee and bananas and permanent pasture lands.

b Steep slopes – slopes above 8 percent, intermontane valleys and highland plateaus.

c The data in this table are tentative. They are based on USAID, FAO and World Bank sources, discussions with a number of scientists, and personal estimates.

Source: Posner and McPherson (48) Table 1.

caused hotter burns and the fire was more easily controlled since it rarely would burn downhill (6). A further advantage of the slopes at high elevations was less danger of frosts due to better air circulation. On slopes with deep but poor soils the gradual erosion of the exhausted topsoil exposed more fertile subsoil permitting annual cropping (17, 47).

These advantages were offset by the problems of generally thinner topsoils and the greater risk of drought damage due to increased water runoff. According to Donkin (20), farmers responded to this problem by terracing, since these structures increased the depth of topsoil and reduced surface runoff. He found that 85 percent of the terraces discovered in the Americas are in areas with less than 900 mm of rainfall and have five or more dry months. Rather than out of concern with soil erosion, according to his thesis early Indian farmers terraced to increase soil moisture holding capacity and to permit irrigation.

In fact, Spores (55) suggests that the farmers of the Mixtec culture actually tried to promote erosion for the purpose of accumulating the soil as alluvial deposits behind check-dams. This "lama-bordo" terrace system which was formed with soil collected in this manner was the basis of agricultural production prior to the arrival of the Spanish. Wright (69) provides a similar example from the desert Pacific coast of Chile where erosion promoted agricultural development. He speculates that silt trapping by building check-dams transformed nomads into agriculturalists since it provided a technique of deepening soils near sweet water supplies. He further suggests that in the lowland humid tropics, where soil fertility, not moisture is the main limiting factor, terraces were unnecessary. Long rotations or erosion itself were the two simplest ways to renew soil fertility. The major exception to this generalization is in the Mayan areas of the Yucatan Penninsula where thin but fertile limestone soils were terraced with check-dams in order to deepen them (59).

Before the arrival of the Spanish, both the Inca (40) and Aztec (18) Empires were suffering from the effects of serious soil erosion. Most researchers also suggest that the collapse of the Mayan Empire some 500 years earlier had also been caused by reduced productivity due, in part, to soil erosion (19, 43). With the Conquest in the first half of the 16th Century came the "population catastrophe," significantly reducing population pressure on the land. As reported by Eckholm (22), demographers estimate that the Indian population was reduced by as much as 75 percent during the first century of colonial rule due to diseases, forced labor and warfare. Demographers estimate that the rural population in Mexico, Guatemala and the Andean countries did not again reach 1500 levels until after 1950 (61). Since that time, population has expanded rapidly, as have the urban centers, resulting in severely increased pressure on the hills for food production. A fundamental question for planners and agronomists alike is whether or not the steeply sloping areas can continue to produce the bulk of the food crops or, as has happened before, will these areas "collapse" due to erosion and overpopulation?

Global estimates of soil loss and erosion plot measurements

Numerous researchers have attempted to estimate the area severely affected by erosion [at least 75 percent of the topsoil has been lost and numerous deep gullies exist (7)] in tropical America. A selected list of these evaluations is presented in Table 2. In the Caribbean countries over 50 percent of the land suffers from severe erosion while in the Andes the estimates are higher. Even in areas that are predominantly flat such as Cuba or the Savannah of Bogota, estimates indicate that large areas are affected by erosion. While there is no doubt that erosion exists, these estimates are so general and so high that they are difficult to place in perspective. As such they have most often hindered constructive thinking about the erosion problem and persuaded government policymakers that their hill areas will soon be denuded and abandoned.

In contrast to these general estimates, close examination of experimental data from erosion plots (Table 3) have two striking features: there is a wide range in the rates of soil loss; and a large number of soil management systems have sustainable soil losses. Tosi (58) estimates that the soil loss tolerance on deep soils of the humid lowland tropics may be from 25 to 40 ton/ha/yr. This is equivalent to approximately 2 to 4 mm of topsoil a year.

Nevertheless, some cropping systems are incredibly destructive. For example, Sheng and Michaelsen (52) show that monocropped yam cultivation in Jamaica

Table 2. Global estimates of damage due to erosion.

1.	42 percent of Mexico suffers from accelerated erosion. Conservation Foundation in Baldwin (7).
2.	77 percent of El Salvador suffers from accelerated erosion. Organization of American States (1969) in Eckholm (23).
3.	30 percent of the Savannah of Bogota in Colombia has severe erosion. CEPAL (16).
4	75 percent of the land between Loja and Cuenca in Ecuador has been abandoned due to severe erosion Giroux in Portch (48).
5.	83 percent of the Peruvian Andes loses more than 10 ton/ha/yr of topsoil Low (38).
6.	50 percent of the cropland in the Dominican Republic is on steep slopes and suffers from accelerated erosion. Organization of American States (1969) in Ahmed (2).
7.	60 percent of the cropland in Jamaica is on steep slopes and suffers from erosion Wilson (67).
8.	25 percent of the declared agricultural land in Jamaica was incapable of reforestation or renewed agricultural use Blume (12).
9.	80 percent of Cuba suffers from serious erosion. Saouma Dir. Gen. of FAO in Gamma. Sept. 14, 1980.

Table 3. Summary of runoff plot measurements of erosion in Tropical America.

Location	Slope	Cover	Erosion (ton/ha/yr)	Reference
Humid Tropics				
Trinidad	25	Corn relay cowpea	3	Lindsey (37)
Trinidad	35	Pineapple on terraces	5[a]	Alleyne & Percy (4)
Puerto Rico (Mayaguez)	40-45	Annual Crops	44	Smith & Abruna (54)
		Sugarcane-burned	19	
		Sugarcane – with mulch	2	
		Pasture	5	
Jamaica (Smithfield)	30	Yams-traditional culture	134	Sheng and Michaelsen (52)
		Yams with contour mounds	27	
		Yams on terraces	17	
Peru (San Ramon)	30	Potato-fallow-potato	16	Felipe-Morales (28)
		Corn-beans-potato	119	Felipe-Morales (27)
Wet-dry Tropics				
El Salvador	30	Corn relay beans	100	Sheng (53)
		Corn relay beans on terraces	30	
High Elevation Tropics				
Costa Rica (Turrialba)	45	Annual crops	0	Ives (35)
Colombia (Chinchina)	22	Pasture	7.1	Suárez de Castro (56)
	45	Young coffee trees	1.8	
Panama (Boquete)	35	Carrots and beans	80	Oster (44)
Peru (Huancayo)	25	Potato-fallow	5	Felipe-Morales (28)

a Total soil loss per ha during 18 storms.

led to an average soil loss of 133 ton/ha/yr. Blaut (11) observed that Jamaican farmers did not attribute any of the plant nutrition to the minerals in the soil, but rather to the "juices" in the rotting fallow grasses of the previous cycle. As a result, sheet erosion is not a concern to many traditional farmers. Similar losses have been reported for potato production in the eastern Andes of Peru. In this case, a burnt fallow, on a 30 percent slope, was followed by clean cultivated corn, then beans and finally potatoes, and soil losses measured 119 ton/ha/yr (27). The previous year, however, with 25 percent less rainfall, a rotation of potato-fallow and burning-potato resulted in a moderate soil loss of 16 tons/ha/yr (28).

At higher elevations, with the exception of the work with vegetables at Boquete, Panama (44), soil loss measurements are much lower than in the lowland tropics. Under these cooler conditions Tosi (58) estimates soil loss tolerances of twelve to twenty ton/ha/yr so most of the systems reported in Table 3 would be sustainable.

Universal soil loss equation

To understand why some systems are relatively stable, even on steep slopes, it is useful to consider the Universal Soil Loss Equation of Wischmier and Smith (68):

$$A = RKLSCP$$

This identity states that soil loss (ton/ha/yr) (A) is a function of rainfall erosivity (R), soil erodability (K), slope length (L), percent slope (S), crop cover (C), and soil conservation practices or structures (P).

Environmental factors

There is a wide concensus that in the tropics, rainfall is the most important factor in promoting erosion (30, 36, 51). Table 4 lists some of the rainfall erosivity (R) measurements from the literature. As can be seen, the humid tropics have very intense rainfall activity (8, 45), as do the wet-dry tropics (56). In contrast, the storm intensities and duration are often much less at higher elevations, which is reflected in the lower "R" values. For example, measurements made in Turrialba, Costa Rica (5), Huancayo, Peru (21) and Quito, Ecuador (29) indicate that average rainfall erosivity is less than one-tenth of that on the windward side of Jamaica.

In addition to the variations in the erosivity of the climate between locations in tropical America (total R), rainfall distribution is also an important factor in soil erosion. For instance, the R-factor is uniformly distributed by month in a location like Turrialba (Table 5), while in both Jamaica and the Dominican Republic the months of June and September or October experience intense rainfall. Depending on soil cover during these months, serious erosion may or may not occur. This aspect of rainfall distribution has important implications for timing and type of soil preparation, as well as mixed and relay cropping.

Surface soil structure is measured as the K-factor. As can be seen in Table 6, tropical soils tend to be several times more stable than temperate climate soils due to the better aggregation and infiltration rates associated with oxisols, ultisols and andisols.

Table 4. Annual rainfall erosivity (R) in selected locations of Tropical America[a].

Location	R (metric)	Reference
Humid Tropics		
Jamaica – Smithfield	2603	Hutchingson and Forsythe (33)
Ivory Coast – Abidjan	2192	Roose (51)
Puerto Rico – Mayaguez	1353	Barnett (8)
Dominican Republic – Quemados	1428	Paulet (45)
Peru – Iquitos	2600	Paulet (45)
Wet–Dry Tropics		
El Salvador – San Salvador	1150	Forsythe in S. de Castro (57)
Upper Volta – Ouagadougou	750	Roose (51)
Dominican Republic – Valdesia	1123	Paulet (45)
High Elevation Tropics		
Costa Rica – Turrialba	123	Amezquita and Forsythe (5)
Ecuador – Quito	224	Flores (29)
Peru – Huancayo	100–200	Paulet (45)
Temperate Zone		
USA – Illinois	350	Wischmeier and Smith (68)
USA – Gulf Coast	950	Wischmeier and Smith (68)
Central France	100–600	Roose (51)

a Rainfall erosivity index is the product of the total storm kinetic energy times the maximum 30 minute intensity. The annual index is the sum of the R values calculated for each rainstorm during the year.

Table 5. Monthly distribution of rainfall erosivity (R) in three locations of Tropical America.

Date	Turrialba	Location Smithfield	Valdesia
(1)	(2)	(3)	(4)
		(percent)	
January	4.1	2.4	1.1
February	4.6	5.1	0.3
March	1.6	5.2	1.1
April	6.3	3.9	5.8
May	7.1	8.8	8.4
June	11.5	17.0	18.1
July	11.0	10.4	8.4
August	10.7	7.9	14.2
September	11.2	9.0	28.3
October	9.8	21.4	11.0
November	9.1	6.5	2.1
December	13.0	2.4	0.9
Total R metric	122	2600	1123.3
rainfall mm	2680	2500	1124

Source: Col. 2: Amezquita and Forsythe (5)
Col. 3: Paulet (46)
Col. 4: Paulet (45)

Table 6. Soil erodibility indexes (K) in selected tropical locations.

Location	Soil Type	K metric	Reference
USA – Hawaii	Humoxic Tropohumult	0.13	El–Swaify and Dangler (24)
	Typic Torrox	0.31	El–Swaify and Dangler (24)
	Tropeptic Eutrustox	0.22	El–Swaify and Dangler (24)
USA – Puerto Rico	Typic Tropohumult	0.01	Barnett (8)
	Vertic Eutropepts	0.02	Barnett (8)
	Typic Dystropepts	0.115	Barnett (8)
Trinidad	Orthoxic Tropudult	0.12	Lindsay (37)
	Orthoxic Tropudult	0.08	Lindsay (37)
Costa Rica – Turrialba	Alluvial	0.155	Amezquita y Forsythe (5)
	Typic Dystropept	0.103	
Ecuador – Quito	Entic Dystrandept	0.18	Flores (29)
USA – New York	Dunkirk Silt loam	0.89	Wischmeier and Smith (68)
USA – Ohio	Keene Silt loam	0.62	Wischmeier and Smith (68)
USA – Texas	Boswell fine sandy loam	0.32	Wischmeier and Smith (68)

However it would be a mistake to assume, based on Table 6, that all tropical soils are stable. The erodibility analysis (K) is only conducted on the topsoil, and often the B horizon, if it is relatively impermeable, is a more important determinant of the potential for soil erosion (1, 2, 30). Barnett's (9) work in Puerto Rico showed that 90 percent of water that infiltrated the plow layer on a Juncos silty clay soil reappeared at the end of the plots, as interflow, and not surface runoff. This interflow can cause landslides or soil slumping as it lessens the friction along the interface of the impermeable subsoil and permeable topsoil. Also the "K" indexes are based on the stability of initially dry soils. According to El-Swaify (25), with soil high in amorphous aluminum oxides (volcanic soils), previous moisture condition is important in measuring their stability in any given storm, and often the K values are under-estimated under experimental conditions.

The two main characteristics of the slope itself are "L" and "S:" slope length and percent slope. Although not mentioned in the equation, hill aspect is important and erosion problems on the leeward and windward sides of a slope are different. Simple geometry shows that a slope will receive less rainfall than adjacent flatlands if the rainfall is falling vertically. If the wind is blowing the rain away from the slope (leeward aspect) then rainfall will be much less than on the flatlands. In addition to moisture effects, slope direction and therefore wind impact can markedly increase the actual erosivity of the rainfall (1).

Farming system factors

The remaining two factors in the Universal Soil Loss Equation, crop cover (C) and soil conservation practices (P), are under the farmers' direct control. Traditional soil conservation practices include: mixed cropping and relay cropping, which improve the effectiveness of the crop cover; no-tillage and weeding with only a machete, which leaves a protective mulch on the soil; terracing, bunding and hedge rows, which serve as conservation structures; and rotations, which improve soil stability and take land out of row crops, at least for part of the cycle.

The key component of the traditional hillside soil conservation strategy is the maintenance of good vegetative cover of the soil. While often low soil fertility or potential drought stress precludes the use of high plant populations, most locally adapted varieties have both rapid growth rates and high leaf area indexes which provide protective cover for the soil. Also, rapid canopy development is usually a prerequisite for high yields, so conservation and productivity are complementary.

Hudson (32), in an experiment which demonstrated the importance of crop cover, reduced erosion from bare soil on 4.5 percent slope by over 99 percent by simply covering the plot with thin mesh wire gauze. Barnett (9), in Puerto Rico, further demonstrated the importance of the canopy as an interceptor of the kinetic energy of rainfall by clipping at soil level a grass plot (*Digitaria decumbens*). This treatment resulted in a tenfold increase in soil loss when compared with the check plot that had not been cut. In addition to the binding effect of the roots, the check plot also had leaves protecting the soil from direct rainfall.

In annual cropping areas a major soil conservation strategy is the use of rotations which not only serve to reduce the incidence of certain soil borne pests and rejuvenate fertility, but also protect the land while it is fallow. Personal estimates made in Turrialba, Costa Rica, and the coffee zone of Colombia indicate that as much as 80 percent of the land at any one time is in pasture, tree crops and sugarcane. In the annual crop producing zone of Huancayo, Peru, Werge (63) estimated that only 10 percent of the land is in crops at any one time. Numerous authors refer to the "laymi" system common in the high Andes where often five years out of seven the land is in fallow (13, 31).

In addition to the grass tops protecting the soil, fallows improve soil structure. In the warmer tropics, Hudson (32) estimates that fallows of only two years build up soil structure sufficiently to permit one year of annual cropping. In his work in southern Africa, he found that grass fallows rapidly created loose aggregates in the topsoil and the resulting organic matter reduced erosion significantly by increasing infiltration rates for one year after the land was plowed up and planted. However, this improved structure rapidly broke down and by the second crop year, erosion had increased threefold over the previous year.

Loose aggregates and large pieces of organic matter result in soils with high initial infiltration rates. This is important in the tropics where peak rainfall intensity often occurs at the beginning of rainstorms. Wilkinson (65) studied 58 storms of 10 mm or more in western Nigeria and found that peak intensities were recorded in the first minute for 26 percent of the storms; first five minutes in 56 percent of the cases and fully 75 percent of the storms within the first 13 minutes of rainfall.

In addition to rotations, which improve soil stability (K) and provides good cover (C), farmers use a number of other strategies that effectively protect their soil. Often hillside fields in the humid tropics are prepared with a minimum of tillage, leaving cut grass or tree trunks on the ground to serve as a type of mulch (39). These fields are then sown with a planting stick which according to Buchele (14), disturbs only approximately 0.04 percent of the soil. In Costa Rica another technique is the system of "frijol tapado" in which the bean seed is broadcast into a fallow field and then the tall grass is simply cut, covering the seed. These activities, in addition to reducing some pest problems, can increased soil organic matter (improve K-values) and of course improve the soil cover (C).

Another approach is to increase the density of crop canopy and the length of time it remains. Mixed cropping is an example of the former where often a slow growing crop is grown with a fast growing crop (cassava and corn) or a tall crop is grown with a short one (corn and squash). Work in Nigeria has shown that cassava cropped with corn on a 10 percent slope resulted in only 70 percent as much soil loss as when grown alone (3).

In more humid areas planting prior to the onset of the rains and using relay cropping are two further traditional means of increasing canopy effectiveness by increasing its duration. The first method creates some ground cover against the force of the beginning rains. The second, planting a prostrate bush bean into the standing corn, for example, can offer good canopy cover for the heavy late rains in areas with a bimodal season (Table 5).

Although a small point, crop canopies on hillsides are more effective in protecting the soil than on flatlands when the rain is falling vertically. Using the data generated by Wilkinson (66), a 1.8 m high corn crop (LAI = 4.9) on a 60 percent slope will permit only one-half as much direct penetration by light or rain as will the same plot on flatland.

Conservation plantings or structures (P) are less common in traditional systems, but one can observe for example grass waterways in Colombia, contour plowing with oxen in Peru and newly constructed "andens" (sloped terraces) in Ecuador. Perhaps the most important traditional conservation structures have been the use of hedge rows and walls as property boundaries. Often these barriers run across the slope and serve to trap eroding soil behind them. From the vantage point of soil conservation, land parcelization may be an advantage.

Generalized farming systems scheme

I have identified four major farming system/erosion control complexes to organize the information above.

I **Wet highlands** (Guatemalan highlands, coffee highlands of Central America, the northern Andes of Colombia and Ecuador). These are areas often with deep volcanic soils and mild precipitation (Table 4). Generally farmers have relied on good crop cover to reduce erosion either through the use of tree crops (coffee, citrus) and grasses (pasture, sugarcane) or with sophisticated relay cropping and mixed cropping methods.

II **Dry highlands** (Central Plateau of Mexico, the central Andes of Peru and Bolivia). As in I, the soils are generally stable, rainfall is mild but it is inadequate, which means that moisture is a major limiting factor in crop production. One solution historically was to increase soil depth and reduce runoff by means of terracing. Whenever possible, terracing was combined with irrigation. Another solution was to go to even higher elevations (cooler climates) where the hydric balance was more favorable to crop production. Here the low erosivity of the rainfall and a long rotation system permitted continual use of the steep, unterraced slopes.

III **Wet lowlands** (Caribbean rim and eastern Andean foothills). These are areas with highly erosive rainfall patterns (Table 4), generally deep stable soils (Table 6) and usually abundant rainfall. A long cycle of slash-and-burn agriculture has predominated in the area until recently, and this system has been successful in maintaining soil fertility (42) and in controlling erosion (26). Where permanent agriculture has been established, farmers often rely on tree crops, mixed cropping and minimum tillage techniques.

IV **"Wet-dry" lowlands** (Pacific Coast of Central America, Caribbean coast of South America, lower Andean valleys). Included among this group are areas with aggressive rainfall, generally stable soils and a well-defined often bimodal rainy season with usually 5 or more months where evaporation exceeds precipitation. Historically, they were not heavily populated but increasing population density has caused the expansion of annual cropping to the steep slopes. The lack of ground cover at the beginning of the rainy season is causing serious erosion. Often the hills are planted in local varieties of corn and sorghum, which provide good canopy cover, at least late in the season. Other areas are in cassava, one of the few crops that can produce under the low fertility equilibrium state that is established between soil losses and pedogenesis.

The above groupings serve both to classify farming systems strategies and to highlight the conditions under which soil erosion is most likely to be severe. Annual cropping in the tropical wet lowlands is risky and as the data from San Ramon (Peru) and Smithfield (Jamaica) show, high soil losses can be expected from monocropped, clean cultivated tuber crops. On the other hand, no-tillage systems and plots with hillside ditches showed a nearly 60 percent reduction in erosion losses in both cases. Also, in the wet-dry topics the combination of steep slopes, erosive rainfall and long dry spells makes this perhaps the area of greatest concern. High value crops have not yet been identified that are well adapted to the steep slopes, so terraces are hard to justify economically. In addition, the long dry season limits the possibilities of no-till planting since little mulch is available as the cropping season begins. Generally the cropping patterns in these areas are simply mining the soil.

At higher elevations, the climate is more benign, and coupled with the intensive local farming patterns, many sustainable systems have evolved. Nevertheless, these are the areas of greatest population growth resulting in shorter rotations and the cultivation of steeper slopes.

A major challenge for agricultural scientists and economic planners will be to design programs to increase food production in the threatened, but important hill lands. Over time, a relatively stable equilibrium was established between the limitations of the environment and the needs of the hill farmers. Some systems, even under increasing population pressure, have remained stable, and almost all hill systems have important elements which serve to check erosion. The current task is to evaluate present patterns and proposed innovations with a conservationist point of view.

Conclusions

Current research and development in the hill areas is often doubly handicapped as research station orientation is toward the flatlands, and hill development is left to soil conservation agents whose approach is regulatory and whose primary focus is on conservation structures. Since most farms and most of the food crops are in areas with erosion problems, crop and livestock researchers should logically focus their attention on the hill environment.

Indeed the majority of agricultural research stations in tropical America are located at low elevations on flat land. For example, the six Central American countries have 32 agricultural research stations (34) while the five Andean Pact countries have 63 (10). Few of these stations include steep sloping land where field experiments can be conducted to study cropping systems under varying soil and water conservation practices. There is also a low elevation bias in the location of these stations. In the Andean countries, over three-quarters of the stations are at elevations of less than 2 500 meters. In Central America, where elevation bias is less pronounced, the research emphasis of genetics and plant improvement (65 percent of the effort) dominates. The attention given to the concerns of the small farmer on steep slopes, namely weed control, irrigation, and soil conservation is minimal (3 percent of the effort).

Agronomists and breeders need to evaluate their development programs in terms of crop cover and intercepting rainfall. Either through increasing crop cover duration or intensifying the cover itself, improved farm systems can both increase yields and reduce soil losses.

Foresters and pasture researchers can help to convert the marginal slope cropping areas into more stable mixed systems with agroforestry or grass ley rotations. Most of the densely settled hill areas have both a firewood and forage shortage, so tree species for firewood and short grass rotations benefiting the soil and their livestock would fit into the current farming systems.

Experience with terracing throughout tropical America, certainly an important option on steep slopes, indicates that only if the structures are combined with new inputs (notably fertilizer) or new high value crops (eg., vegetables) can they become a permanent part of the farming system (15, 41). This requirement for immediate payoff with terracing further highlights the need to include agricultural research with the civil engineering task of terrace construction as, for example, is being done in northern Honduras (50) and in Jamaica (62).

While soil conservation is not the primary concern of farmers, it should be considered and evaluated in the generation of new technology. Hudson (32), in work completed in the late '50's, developed an index comparing kilos of yield with kilos of soil loss and found that the high input corn crop produced ten times as much grain per kilo of soil lost as his low input crop. Buchele (14) inverted this index in discussing a colleague's work and found that conventional tillage corn lost five times as much soil per kilo of grain as did no-till corn on a 9 percent slope. It would be useful if farming systems agronomists in Latin America gained this perspective as they work on small farmer production systems – i.e. those which are predominantly adapted to the steep sloped areas.

Summary

Most of the basic food crops in tropical America are grown on small hill farms. An analysis of the tropical environment and present and past farming systems indicates that there are many elements which help to conserve soil and water, thereby promoting the sustainability of the system. It is argued that agricultural researchers should focus on current hill farming systems and in addition to improving their productivity, evaluate them for sustainability.

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Reseña de libros

PALTI, J. Cultural practices and infections crop diseases. Berlin, Springer-Verlag Advanced Series in Agricultural Sciences No. 9, 1981. 243 p.

Rara vez se tiene la oportunidad de revisar un libro de fitopatología eminentemente práctico y ubicado dentro de las necesidades actuales, en donde se trata de racionalizar las prácticas culturales tradicionales complementándolas con las investigaciones más recientes acerca del combate integrado de enfermedades. A su vez, para dar una visión general e integral, se hace un enfoque moderno de este control al relacionarlo con los agroecosistemas. En este sentido el libro es excelente como material de enseñanza, ya que muy frecuentemente se transmite al estudiante cantidad de detalles que lo hacen perder esta clase de visión, además de que utiliza con asiduidad figuras y cuadros muy didácticos.

En la primera parte, y con el fin de ubicar al lector, se describen las prácticas de cultivo utilizadas en cada uno de los agroecosistemas y el microclima generado por la topografía, el suelo y el cultivo mismo. Seguidamente se analiza el efecto del manejo del inóculo mediante prácticas culturales en la epidemiología y el combate de enfermedades, enfocado hacia regiones o comunidades de agricultores. También enfatiza en forma concisa y profunda el influjo del suelo y la flora microbiana en la incidencia de enfermedades del suelo. Siempre haciendo énfasis en la integración de conocimientos analiza los factores de *stress* con relación a las enfermedades, principalmente aquellos provocados por alta o baja temperatura y la deficiencia o exceso de agua. La sección de la relación malezas-patógenos se discute con claridad e incluye un cuadro con el ámbito de hospedantes de patógenos comunes en diferentes agroclimas.

En la segunda parte, que es la principal, y siguiendo una secuencia lógica se analiza con sumo detalle y a nivel finca el impacto que tiene cada una de las prácticas culturales en el desarrollo de enfermedades. Comienza por destacarse la importancia que tienen estas prácticas en la relación costo/beneficio para los agricultores, pero considerando no sólo el aspecto económico en la toma de decisiones sino el político y social. Asimismo estudia lo difícil pero importante que es tomar decisiones en el combate de enfermedades cuando se tienen múltiples alternativas de escogencia, aspecto que el autor presenta en forma esquematizada y de fácil comprensión para el lector. Aunque no hay nada nuevo en cuanto a los principios y medidas de combate, se hace un enfoque tan profundo de cada uno de ellos que el lector se encontrará, por ejemplo, con cuadros en los que se presenta aquellas enfermedades en las que se puede reducir el daño con quema de residuos, calentamiento solar, suplencia adecuada de potasio y otros. Especial énfasis se da a las secciones de rotación de cultivos y sus implicaciones económicas, la incorporación de materia orgánica, uso de coberturas, preparación del suelo y buen manejo de la fertilización y el riego.

Para integrar toda esta información, en la tercera parte se analiza las interacciones que ocurren entre el control químico, el control cultural y la resistencia, con el fin sobre todo de reducir el número de aplicaciones de fungicidas utilizando para ello excelentes ejemplos presentados como figuras y esquemas.

El libro está definitivamente enfocado hacia la protección de cultivos en sistemas de explotación tecnificados, haciendo énfasis sobre la planificación de estrategias de combate, más que curar enfermedades, de ahí que destaque la importancia de educar al agricultor en este sentido. Sin embargo, el libro brinda muchas ideas que pueden ser adaptadas a sistemas de explotación poco extensivos y tecnificados, de manera que en este campo es una buena guía para investigadores, sobre todo por la amplia información bibliográfica que posee.

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