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Intermittent Use and Agricultural Change on Marginal Lands: The Case of Smallholders in Eastern Sonora, Mexico

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Abstract

Most studies of agricultural land use tend to treat change as though it is essentially permanent. This paper argues that in some cases marginal lands are used intermittently, being brought into and taken out of cultivation frequently, rapidly, and repeatedly. Improvements to the land are made each time a parcel is brought back into use so that over extended periods permanent cultivation becomes feasible. A model of intermittent use is first outlined and demonstrated with data from northwest Mexico. The way in which permanent improvements are made is then described. Last, the theoretical implications are discussed.

Studies of agricultural land use treat change as if it is essentially permanent for the system in question. Once land is brought into or taken out of cultivation, it is considered to remain so for an extended period of time. This conceptualization threads through such diverse themes as von Thünen's agricultural land use zones (Peet 1970:181-201; Muller 1973:228-242; Norton and Conkling 1974:44-56; Ewald 1977:123-133), and Boserup's (1965) land use intensities (Brown and Podolefsky 1976:211-238; Sanders and Bein 1976: 593-610; Datoo 1978:135-144; Grossman 1984: 135-144).

For the most part, studies have tended to ignore the role of intermittent agricultural land use, a circumstance in which land is brought into and taken out of cultivation frequently, rapidly, and repeatedly for reasons other than fallow. The paucity of attention to intermittent use is probably due to several factors. In some cases it may not be recognized because it involves lands that are perceived to be of little importance--lands of marginal quality, small plots interspersed among larger, permanently cultivated fields, or segments of a zone on the margin of cultivation. In cases where it has been recognized, intermittent use has not been deemed significant in the larger scheme of agricultural change. For example, in his discussion of agricultural expansion, Peet says, "with the resulting increase in supply, prices may fall and the (von Thünian) zones contract again, but in the final equilibrium all zones are wider and the whole system of zones larger"(Peet 1970:187-188).

Understanding intermittent agricultural land use is important for at least two reasons. First, it affects the elasticity of land supply and results in greater land use variability. Second, it can involve the accumulation of capital improvements over a lengthy period of time so that marginal land is transformed into permanently cultivated land. Intermittent use of agricultural land is demonstrated here through the case of smallholders in eastern Sonora, Mexico. The example study is preceded by a overview of the concept of intermittency and is followed by a discussion of its implications.

The Concept of Intermittency

Just as food production varies by place, so does the elasticity of the supply of agricultural land. Where land-extensive circumstances prevail, supply tends to be highly elastic to increased demands (Renne 1947:18). This is so because it is generally less costly and more efficient to expand agriculture than it is to intensify it (Grigg 1976:133-176, esp. 149); expansion increases production while intensification increases output per unit area and time (Turner and Doolittle 1978:297-301). Where land is limited, on the other hand, agriculture is typically intensified as demands increase because the supply tends to be inelastic. Differences in elasticity become less distinct as demands decrease. Regardless of the amount of land that can be brought into use, land can always be taken out of production. The supply of agricultural land is, therefore, always highly elastic to decreases in demand.

Not only can land supply be elastic, it can be so with differential parameters per plot or section. Agricultural land is rarely of uniform quality for cultivation and, as such, has different input requirements, economic rents, and usages. If demand is low, land thought to be marginal may not be used for cultivation. But if demand reaches sufficiently high levels, technological adjustments may be employed to make this land usable (Denevan 1981:217-244, esp. 219); that is, the input costs to use them become acceptable (Johnson 1983:1-8, esp. 1-2).

These conditions exist for both large-scale, commodity or market production and for smallholder, consumption or subsistence production. Where choices exist, optimal lands tend to be used first and more permanently than are marginal lands. Where large-scale commercial and smallholder consumption productions coexist, the latter tend to be forced to more marginal lands and the intermittency of land use may become significant.

The intermittent use of agriculturally marginal land is related conceptually to agricultural expansion as first proffered by David Ricardo (1817). His ideas have been refined by numerous scholars, (Samuelson 1959:1-25; Hansen 1979:611-627), and recently agricultural change has been elucidated as occurring in a step-wise fashion (Stryker 1976:347-358; Doolittle 1980:328-342; Robinson and Schutjer 1984:355-366). Ideally, farmers first practice extensive, cost- or labor-efficient agriculture on optimal land to satisfy production demands (figure 1A). As production pressure increases, agriculture is expanded throughout the optimal land without technological change (figure 1B). When demands no longer can be met within this option, agriculture is

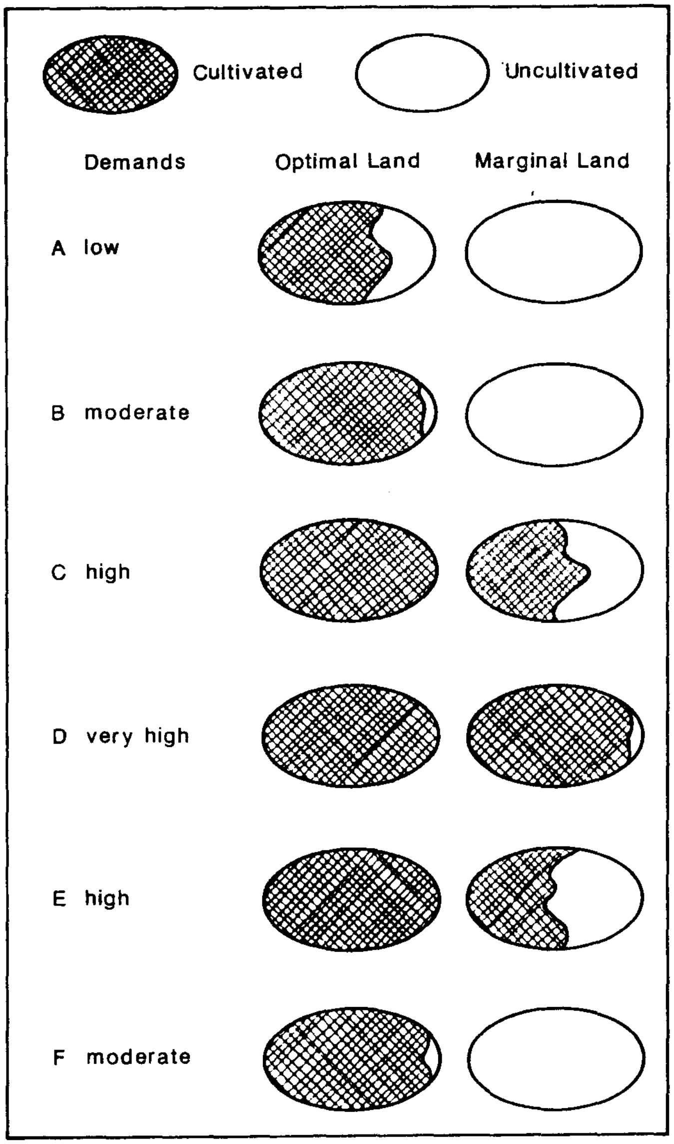

Figure 1. Schematic Map of Intermittent Agricultural Land Use

intensified to increase output on land already under cultivation, expanded onto marginal lands, or intensified and expanded coevally in some combination (figures 1C, D). Land of optimal agricultural quality is typically under complete cultivation before land of marginal quality is brought into use (Grigg 1974:275; Camm 1976:173-181; Grigg 1980:65).

As demands decrease, contraction of agriculture from lands of varying quality follows a sequence opposite that for expansion (figures 1D, E, F). Because they require greater inputs to produce comparable yields, lands of marginal quality are taken out of production prior to lands of optimal quality (Brookfield 1972:30-48). Marginal lands, therefore, not only are the last to be brought into use, but they tend to be the first to be affected by contraction.

Many seemingly marginal areas have, of course, been continuously cultivated for a long time. In such cases, agriculture has persisted largely because increases in demand have been paralleled by capital or technological improvements, such as terraces and canals (Grigg 1970:51). These improvements, however, have in many cases taken decades to complete (Serpenti 1965), perhaps because land was used intermittently. Under such conditions new features can be added and existing ones upgraded each time a field is reused (Geertz, 1963:34). Presumably, as demands increase, and as more improvements are made, intermittency becomes less common, the periods of cultivation increasingly longer, and the periods of nonuse increasingly shorter. Eventually the field has been sufficiently modified to be permanently and continuously cultivated (MacNab 1965:279-290, esp. 280). Once completed, a field system becomes an investment that is not quickly abandoned (Woodbury 1961:42).

The degree of intermittent use to changing levels of demand and the speed of conversion to permanent cultivation vary by specific case. In areas where stark dichotomies in land quality exist, such as arid zones, intermittency can be most pronounced. Similarly, agricultural change can be rapid where demographic and economic forces are great.

The Eastern Sonora Example

Referred to locally as the serrana, eastern Sonora is a semiarid transition zone between the coastal plain of the Gulf of California and the Sonoran

Desert on the west, and the pine-covered Sierra Madre Occidental mountains on the east (Brown 1982:59-65, 100-106). Forming the extreme southern end of the Basin and Range physiographic province of North America, the region is composed of a series of generally parallel north-south trending ranges approximately 30 kilometers apart. Partly controlled by structure, the valleys between these ranges are filled with thick Quaternary-aged alluvium. These deposits have been incised by southward-flowing perennial rivers that have formed floodplains varying in width up to 4 kilometers, and by numerous arroyos or ephemeral tributaries of varying length and width. Rainfall is temporally, spatially, and quantitatively variable, but averages approximately 350 millimeters annually, most of which falls during the late summer. The region has a long growing season, more than 300 days in the lower elevations (Garcia 1981:181-185).

Agriculture has long been practiced on both the floodplains and the bottoms of the large arroyos. In both places, the soils are deep, fertile, and rock-free. Other areas have soils that are too thin and rocky for cultivation, or have steep slopes that are subject to extremely rapid runoff and erosion. These areas are used only for grazing. Because of the dependability of water, which allows for irrigation and hence the production of two crops per year, floodplain lands near the river are preferred for cultivation and therefore are classified as optimal agricultural lands (Hewes 1935:284-292; Meyer 1984:128; Bahre 1984:57-66, esp. 62), even though flooding can result in catastrophic losses.

This criterion for designating lands of high quality has a long history of use throughout Latin America (Eckstein et al. 1978). Floodplain lands distant from the river and arroyo lands are considered to be agriculturally marginal. Peripheral floodplain lands are so considered because of the lack of easily obtainable water, and the arroyos because they are dependent principally on runoff which is sparse and erratic, and as often as not results in flash floods that destroy crops (Hewes 1935:289; Meyer 1984:127; Bahre 1984:62). On both types of lands, one crop per year is all that is possible.

Given the large number of arroyos in eastern Sonora, it is impossible to determine with any degree of accuracy the amount of marginal agricultural land (Bahre 1984:62). Arriving at a reasonably accurate estimate of optimal lands, however, is considerably less difficult. These lands stand out rather distinctively on black and white stereoscopic aerial photographs and topographic maps, both provided by DETENAL, the Mexican federal mapping agency, at the scale of 1:50,000.

The amount of lands of each type cultivated at any one time varies considerably. Time-series data are, therefore, essential in order to assess agricultural change. Very good current land-use data are available through the Secretaría de Agricultura y Recursos Hidráulicos (SARH), Dirección General de Economía Agrícola. These data, however, are available only for the past few years, and then not for every municipality; they are not of sufficient time depth to monitor long-term changes. The best available information on long-term land use in Mexico comes from the censuses of agriculture for 1950, 1960, and 1970 (Dirección General de Estadística 1957, 1965, 1975) and, because the 1980 census data are unavailable at this time, the state agricultural statistics for 1982 (Gobierno del Estado de Sonora 1984). These data are presented by municipality, a political division that is often considered the equivalent of the county in the United States because of the manner in which data are enumerated. Municipalities function, however, more like New England townships (Brand 1951:97). Although these data may not be as robust as those available from SARH, they do have the advantage of showing land-use changes over long periods of time.

Although agricultural censuses are usually reliable and, accordingly, are often used without reservation (Clark, Knowles, and Phillips 1983:115-120), those for Mexico must be used with caution. The greatest problem with these censuses is that aberrant figures sometimes appear, usually a result of poor enumeration practices, careless tabulation, typesetting error, or some combination of the three (Yates 1981:271-279). For example, the municipality of Aconchi was recorded as having a fortyfold increase in nonirrigated hectarage between 1960, and 1970 followed by a comparable decline by 1982. Nonirrigated land reportedly under cultivation in Aconchi involved 66 hectares in 1950, 60 hectares in 1960, 2,475 in 1970, and 250 in 1982. Field reconnaissance revealed, however that there are not 2,500 hectares of land suitable for any type of agriculture in the municipality.

Because there is no way of correcting problems of this nature, Aconchi and seven other eastern Sonoran municipalities with similar data discrepancies are not included in this study. Another seven are excluded because they do not contain any land classified as optimal. Inclusion of these municipalities would bias the analysis because virtually all land-use change involved marginal land. Three municipalities are excluded because they have land areas that extend well beyond the serrana, including large tracts on the coastal plain where mechanized agriculture and technological developments are widespread. In these cases it is no more possible to delimit optimal land than it is to delimit marginal areas. Finally, one municipality is excluded because a large reservoir constructed during the period involved removed much land from cultivation, thereby breaking the continuity of the land-use record. Data on irrigated and nonirrigated hectarage from the remaining 17 eastern Sonoran municipalities are used here to assess intermittency (figure 2).

Permanent Use of Optimal Lands

The approximately 8,500 hectares of optimal agricultural land in the study area have a long history of intensive cultivation. Prehistoric residents built the canal irrigation system and cultivated maize, beans, squash, and other crops on these lands (Doolittle 1984b:246-262). The Spaniards later farmed the same lands using the same canals (Pennington 1980:64-67). Those farmers, however, improved the agricultural base by introducing a number of new tools and crops, not the least of which was wheat (Treutlein 1939:289-311). Present-day cultivators continue to use the canals and plant many of the same crops on the optimal lands. The emphasis today, however, is on growing fodder, mainly alfalfa, for sale to neighboring ranches and dairies (United States Department of Agriculture 1969b: 5), high-yielding varieties of grains, and vegetables for market in the capital, Hermosillo. The average yield per hectares of optimal land is difficult to calculate because of the variety of crops produced, the large number of holdings, and because more than one crop per year is grown on many parcels. However, yields do tend to be high with great predictability and dependability. The perennial alfalfa, for example, can be cut and baled several times each year.

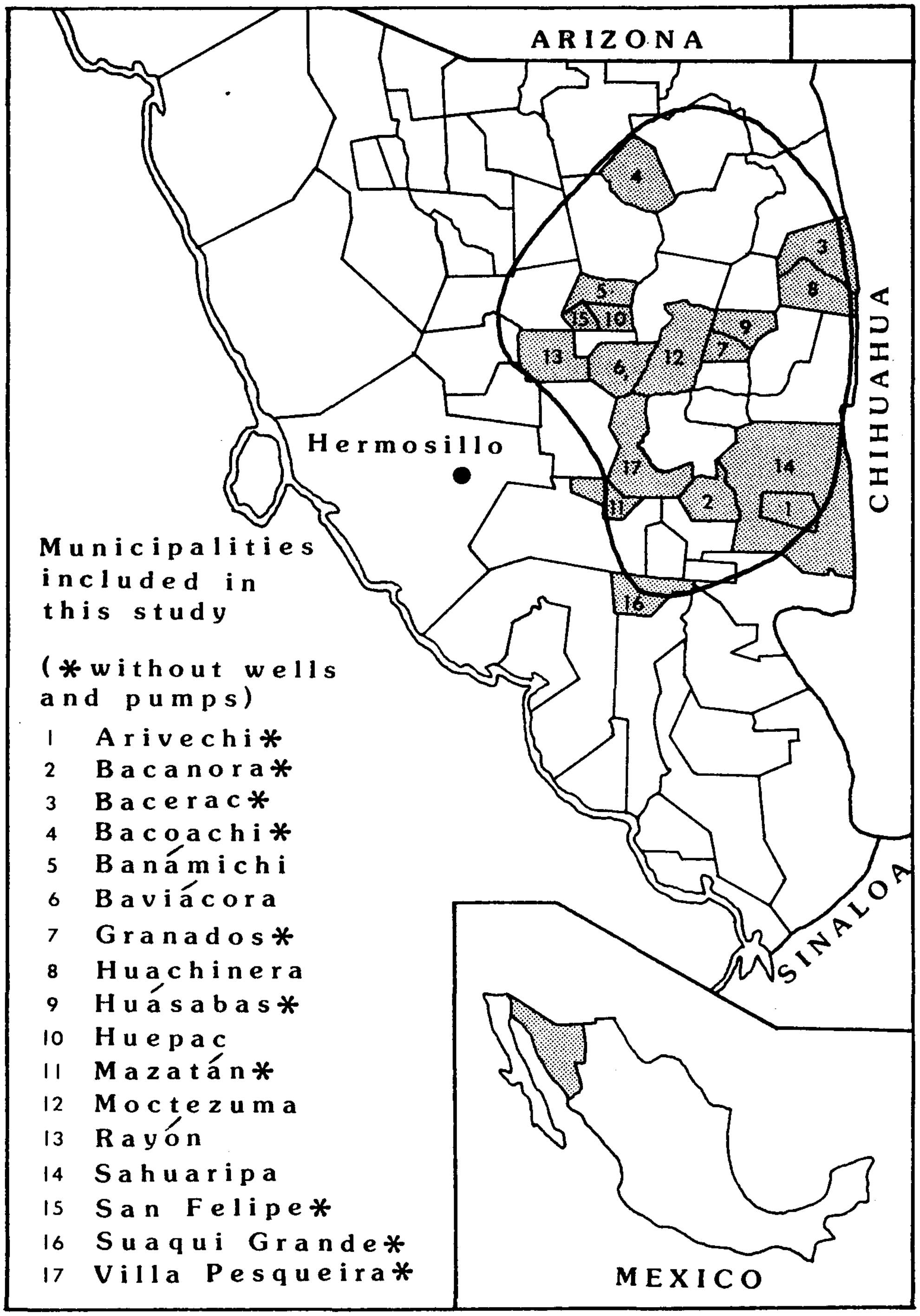

Figure 2. Sonora, Mexico, the serrana and Its Constituent Municipalities

Although the total irrigated area was much less than the optimal land area in 1950, the norm has been for the optimal lands to be completely under permanent cultivation (Table 1 and figure 3). The continued and persistent cultivation of these lands is especially evident in the total disaggregated differences--the sum of all differences regardless of whether they were increases or decreases--between optimal and irrigated hectarage. On the whole, such difference ranged between 12.7 and 42.1 percent and averaged less than 25 percent (table 2). More important, however, disaggregated differences averaged only about 17 percent for those municipalities without technological improvements such as tube wells and pumps; for the 1950s, 1960s, and 1970s disaggregated differences averaged only about 12 percent (table 2). The principal cause for the 1950 discrepancy was flooding of significantly greater than average frequency and magnitude in 1949 (Dunbier 1968:95). Flood damage, which was most severe in Bacerac, Banamichi, Huepac, and Rayon, accounted for the irrigated hectarage being less than the optimal land area.

Intermittent Use of Marginal Lands

In contrast to the optimal lands, marginal lands have a long history of intermittent use. Arroyo bottomlands were the first to be cultivated, as early as A. D. 1000 (Doolittle 1980:338-340). The Jesuit missionaries who arrived in the early 1600s promoted the almost exclusive use of irrigation, the result being that marginal lands were rarely cultivated. During the 18th century, the growing number of Spanish settlers led to the recultivation of these lands (Pineli 1709). The Mexican Revolution, 1910-1917, was extremely harsh on agriculture (Carr 1969:151). The marginal arroyo lands fell out of use again, mainly because the number of farmers decreased (Doolittle 1983:301-313, esp. 304-305). By the early 1930s, only a few marginal tracts were being cultivated (Hewes 1935:288); there was a surplus of land in eastern Sonora, just as there was in other parts of Mexico (Lentnek 1969:65-84).

The principal factor underlying the intermittent use of these lands is water, or, more correctly, water deficiency. Arroyo fields are dependent on runoff, which is sparse and unpredictable; cultivation is, therefore, limited to a drought-resistant summer crop. As throughout the country (Argüellas 1978:21-24), maize is the principal and, in many municipalities, the only

TABLE 1

OPTIMAL FLOODPLAIN LAND, IRRIGATED HECTARAGE, AND DIFFERENCES BETWEEN THE TWO FOR EASTERN SONORAN MUNICIPALITIES, BY DECADE

Munici-pality	Opt. Land (est. ha.)	Diff.	1950 Irr. ha.	Diff.	1960 Irr. ha.	Diff.	1970 Irr. ha.	Diff.	1982 Irr. ha.
Arivechi*	175	- 3	172	+ 3	178	- 50	125	+325	500
Bacanora*	125	- 14	109	+ 26	151	- 1	124	+ 44	169
Bacerac*	650	-180	470	- 70	580	+ 4	654	+ 50	700
Bacoachi*	825	+ 4	829	- 45	780	+ 20	845	+ 2	827
Banámichi	1,000	-252	748	-277	723	+ 89	1,089	+784	1,784
Baviácora	1,100	- 83	1,017	- 40	1,060	+ 269	1,369	- 32	1,068
Granados*	325	- 32	293	- 14	311	+ 31	356	+185	510
Huachinera	200	- 66	134	- 17	183	+ 63	263	- 40	160
Huásabas*	550	+ 12	562	- 6	544	+ 149	699	+ 86	636
Huepac	600	-383	217	+ 12	612	- 3	597	- 44	556
Mazatán*	100	+ 32	132	- 26	74	- 41	59	+210	310
Moctezuma	550	+ 22	572	-114	436	- 80	470	+145	695
Rayón	1,000	-181	819	+208	1,208	+ 370	1,370	+992	1,992
Sahuaripa	800	+ 9	809	- 31	769	+ 831	1,631	+452	1,252

Table 1, continued

Munici-pality	Opt. Land (est. ha.)	Diff.	1950 Irr. ha.	Diff.	1960 Irr. ha.	Diff.	1970 Irr. ha.	Diff.	1982 Irr. ha.
San Felipe*	300	+69	369	+9	309	-32	268	+37	337
Suaqui Grande*	125	-18	107	+28	153	-18	107	-44	81
Villa Pesqueira*	125	-39	86	+157	243	-56	69	-125	0
Total	8,550	-1,103	7,445	-197	8,314	1,545	10,095	3,027	11,577
Mean	502.9	64.9	437.9	11.6	489.1	90.9	593.8	178.1	681.0
Percent of Opt. Land		-12.9		-2.3		+18.1		+35.4	

*Municipalities without wells and pumps

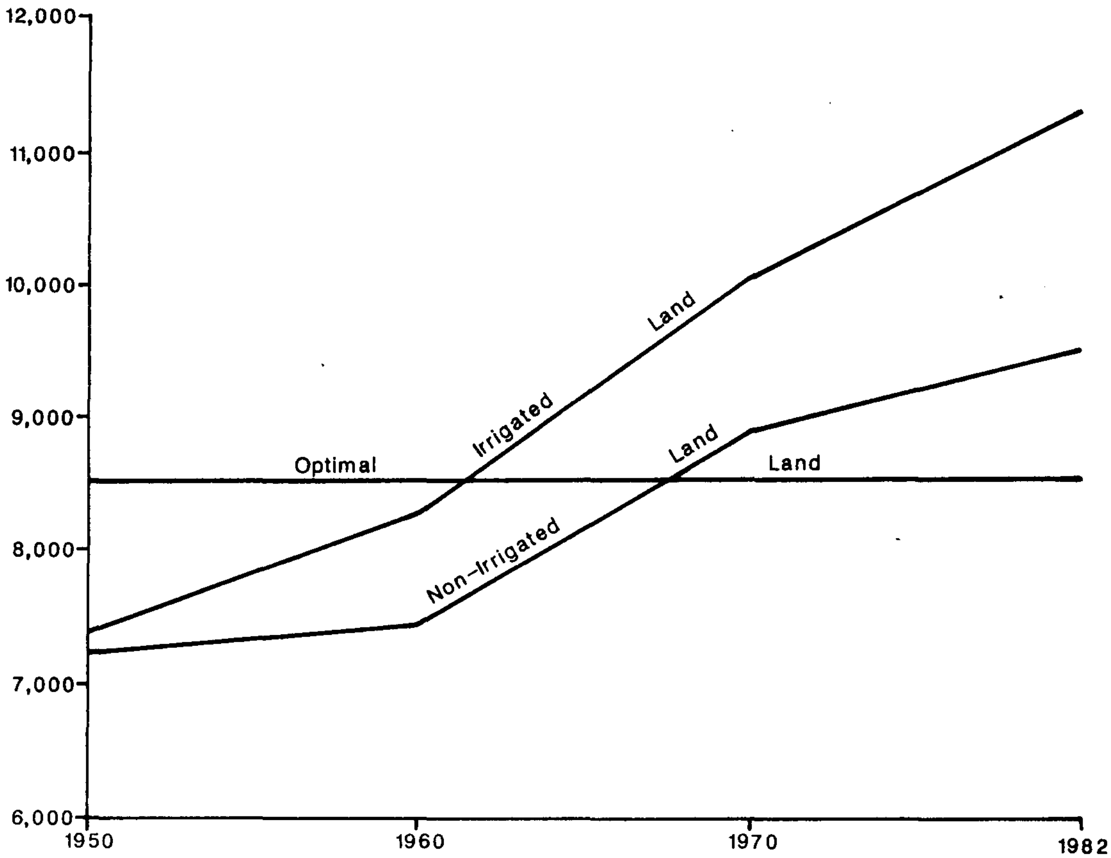

Figure 3. Agricultural Hectarage of Seventeen Eastern Sonoran Municipalities by Enumeration Period

Table 2

DISAGGREGATED DIFFERENCES BETWEEN OPTIMAL LANDS AND IRRIGATED HECTARAGES, BY CENSUS PERIOD

Municipios	1950	1960	1970	1980
All				
Total ha.	1,399	1,083	2,107	3,597
Mean	82.3	63.7	123.9	211.6
Percent	16.4	12.7	24.6	42.1
Without wells				
Total ha.	403	384	402	1,108
Mean	40.3	38.4	40.2	110.8
Percent	12.2	11.6	12.2	33.6

Source: Table 1.

cultivar produced on these marginal lands. A few farmers sell their crop, most frequently to the poultry industry (USDA 1969a:8). Unfortunately, however, they have to deal with intermediaries, which are "local monopolizers," (Levi de Lopez and Tamayo 1981), so rarely do they get a fair price. Because these farmers have few economic opportunities (Soto-Mora 1981), the greatest single use for their crop is personal consumption. Yields which vary considerably, are extremely low in most years.

Since 1950 the overall trend in eastern Sonora, as throughout Mexico (Walsh 1983:825-826), has been for cultivation to increase on marginal lands, albeit at varying rates (figure 3). This increase is not, of course, a universal phenomenon throughout the region. For example, for the ten municipalities with no technological improvements in irrigation in the 1950s nonirrigated land tended to decrease because of large population decreases due to emigration resulting from increased participation of the region's residents in the <u>bracero</u> program (Hancock 1959; figure 4). On a local basis, the history of marginal land-use and change has been one of even greater variety and complexity (table 3). Only one municipality, Sahuaripa, has shown a continuous increase during recent decades. In most cases, increases and decreases followed each other, and rarely did two municipalities experience similar trends.

Intermittent use of agriculturally marginal land is most clearly evident in the total disaggregated change in hectarage by decade for each municipality (table 4). Although these changes are not as great in those municipalities without technological improvements as they are overall, disaggregated changes in nonirrigated hectarage have been consistently and markedly greater than differences between irrigated and optimal lands (compare tables 2 and 4).

In the 1950s disaggregated change involved 2,169 hectares, or the equivalent of nearly 30 percent of the total nonirrigated hectarage in 1950. In ten cases these changes were increases; in seven, they were decreases (see table 3). In only four cases--Bacerac, Granados, Huepac, and San Felipe--were these changes minor, less than 43 hectares, or 10 percent of the 1950 mean hectarage. Two municipalities, Banámichi and Moctezuma, experienced increases in nonirrigated hectarage contemporaneously with major losses (at least 50 hectares and 10 percent of the optimal land area) in irrigated land (see table

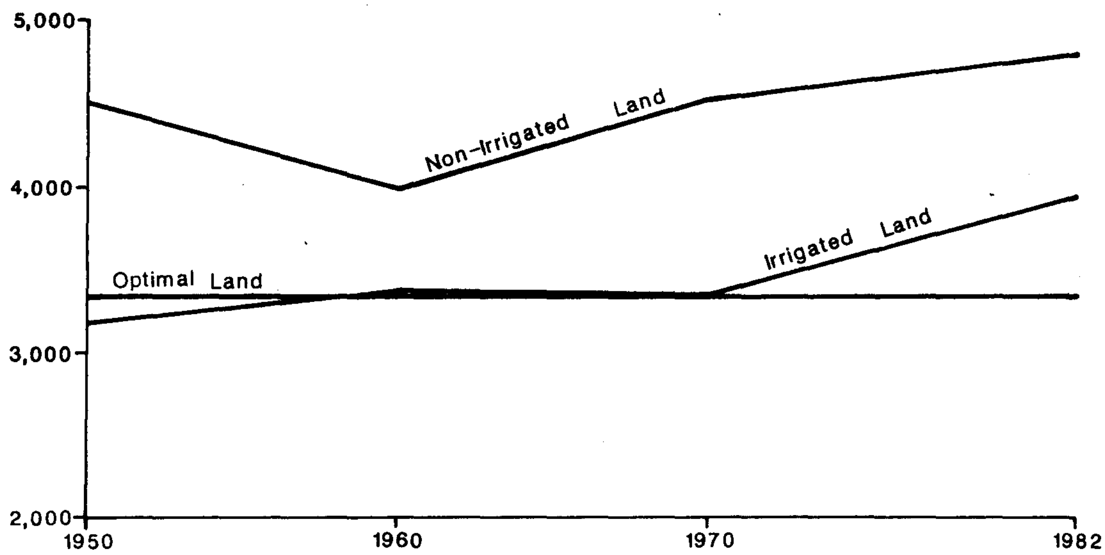

Figure 4. Agricultural Hectarage of the Ten Eastern Sonoran Municipalities without Wells or Pumps, by Enumeration Period

TABLE 3

CHANGES IN NONIRRIGATED HECTARAGE

BY DECADE FOR EASTERN SONORAN MUNICIPALITIES

Municipality	1950 ha.	Change	1960 ha.	Change	1970 ha.	Change	1982 ha.
Arivechi*	1,108	- 385	723	- 215	508	+ 225	733
Bacanora*	385	+ 148	533	- 94	439	- 150	289
Bacerac*	279	+ 13	292	- 61	231	- 231	0
Bacoachi*	201	- 70	131	+ 167	298	+ 471	769
Banámichi	93	+ 56	149	- 20	129	- 129	0
Baviácora	235	- 167	68	+ 89	157	+ 222	379
Granados*	0	+ 6	6	+ 18	24	- 24	0
Huachinera	100	+ 303	403	+ 374	777	- 492	285
Huásabas*	22	+ 90	112	- 36	76	- 20	55
Huepac	380	- 19	361	+ 132	493	- 324	169
Mazatán*	896	- 56	840	+ 539	1,379	+ 271	1,650
Moctezuma	495	+ 115	610	- 88	522	- 180	342
Rayón	295	+ 146	441	+ 213	654	- 425	229
Sahuaripa	1,154	+ 307	1,461	+ 268	1,729	+ 1,669	3,398
San Felipe*	21	+ 13	34	+ 16	50	- 18	32
Suaqui Grande*	132	- 61	71	+ 183	254	- 174	80
Villa Pesqueira*	1,453	- 214	1,239	+ 24	1,263	- 13	1,250

Table 3, continued

Municipality	1950 ha.	Change	1960 ha.	Change	1970 ha.	Change	1982 ha.
Total	7,249	+225	7,474	+1,509	8,983	+678	9,660
Mean	426.4	13.2	439.7	88.8	528.4	39.9	568.2
Percent		+3.1		+20.2		+7.5	

*Municipalities without wells and pumps

TABLE 4

DISAGGREGATED CHANGES IN NONIRRIGATED HECTARAGE, BY DECADE

	Disaggregated Change		
Municipios	1950s	1960s	1970s
All			
Total ha.	2169	2537	5039
Mean	127.6	149.2	296.4
Percent	29.9	33.4	56.1
Without wells			
Total ha.	1056	1353	1598
Mean	105.6	135.3	159.8
Percent	23.5	34.0	35.3

Source: Table 3.

1). Flooding destroyed lands in these cases and forced farmers to relocate parts of their operations on marginal lands. In the remaining cases, increases in nonirrigated lands tended to occur in municipalities that had population increases or above-average rainfall during the previous few years (Hastings, 1964) while population decreases and below-average rainfall appear to be in large part responsible for the decline of nonirrigated hectarage in others.

During the 1960s, 2,537 hectares or approximately one-third of the total nonirrigated hectarage, was involved in change, with a mean of nearly 150 hectares. Eleven of the 17 municipalities experienced increases, and in only five cases, Banámichi, Granados, Huásabas, San Felipe, and Villa Pesqueira, were changes of less than 44 hectares or 10 percent of the 1960 mean hectarage. Flooding and its resultant land-use changes do not seem to have been significant during this decade. In approximately three-quarters of the municipalities, however, intermittent use of marginal lands does appear to be closely related to changes in demographics. Municipalities with population increases tended to have increases in nonirrigated hectarage, while those with population decreases tended to experience reductions in nonirrigated land. Rainfall during this decade tended to be less erratic than usual. Accordingly, few land-use changes can be attributed to climatic factors (ibid.).

Between 1970 and 1982, 5,039 hectares were involved in change, with a mean of almost 300 hectares per municipality, or the equivalent of well over one-half the total nonirrigated hectarage. The upward trend in nonirrigated hectarage continued, reaching its all-time high during this 12-year period. Unlike in the past, however, when most municipalities experienced increases, 12 of the 17 actually had decreases. Increases tended to be few but great, whereas decreases were numerous and small. In the five municipalities that had large increases--Arivechi, Bacoachi, Baviácora, Mazatán, and Sahuaripa--the Mexican government, through the Secretaría de Agricultura y Recursos Hidráulicos, identified large arroyos with expansive, potentially arable bottomlands and assisted in opening them in hopes of attracting farmers from areas with land shortages. In many cases, bulldozers were brought in to clear large tracts. This scheme was modeled after the most successful one in the 1940s and 1950s which attracted workers to the irrigation districts on the coastal plain (Henderson 1965:300-312, esp. 310). Indeed, many migrants to the coast came from eastern Sonora (Hewitt de Alcántara 1976:247), and it was hoped that many of these people would be lured back by the promise of developed land. Although a few people did move to these municipalities, most of the cleared lands were taken over illegally and farmed by people who already were cultivating the maximum number of hectares allowed under the _ejido_ usufruct system, a practice not uncommon in Mexico (Levi de López and Tamayo 1981). Only four eastern Sonoran municipalities during the 1970s had nonirrigated hectarages that did not change more than 10 percent from the 1970 mean, that is, 53 hectares. Changes in the amount of floodplain land (losses due to flooding or increases due to reclamation) do not appear to have been responsible for the changes that did take place on marginal lands. Changes in the size of the population are similarly not significant.

The factors that might be most responsible for limiting the value of population changes for understanding agricultural trends during this period are increases in mobility and nonagricultural economic opportunities. During the 1970s and early 1980s, the Mexican and Sonoran governments developed a highway system in which nearly every municipality was served by a maintained and, in some cases, paved, road. Increased traffic has facilitated the departure of many able-bodied men during times when they otherwise would have turned to farming marginal lands. Furthermore, although the total labor force and the agricultural labor force have both increased (from 10,094 in 1970 to 13,153 in 1980, and 7,184 in 1970 to 7,893 in 1980, respectively), the percentage of workers employed in farming declined from 71.2 to 60.0 percent. The opening of new stores and small factories or workshops, often with government assistance, has resulted in shifts in employment. Many people who would otherwise be farming marginal lands are now employed in various commercial and construction industries along with people who recently migrated into the region.

Overall, since 1950, marginal arroyo bottomlands have tended to be cultivated intermittently. Optimal floodplain lands, on the other hand, have been cultivated continuously and to their maximum extent. In fact, the irrigated hectarage has increased well beyond the limits of optimal lands.

Expansion of Irrigation

Recognition of and hence understanding intermittent use of agriculturally marginal land in eastern Sonora over the past 30 years are obscured somewhat by the expansion of irrigation (compare figures 3 and 4). By virtue of the land-classification scheme and the limited amount of optimal land, expansion of irrigation has axiomatically involved areas of marginal quality. This expansion has largely been the result of improvements in technology, specifically tube wells and electrical and diesel-powered pumps, and of concrete-lined canals. The introduction of wells and pumps created a new, dependable, and controllable water source--groundwater. Pumping began in the 1950s, and then only after years of government aid being directed to other parts of Sonora (Sanderson 1981:118-119). During that decade, only two municipalities, Rayón and Villa Pesqueira, had land-use changes in which the irrigated area increased substantially over the optimal area (table 1). A third, Huepac, had a marked increase in the irrigated area which might have been due to reclamation of land damaged by floods in the previous decade.

The increase in irrigated hectarage in Villa Pesqueira might well be more apparent than real. Given that the recorded size of the 1960 land area is so much larger than for any other period, enumeration error cannot be totally ruled out. For Huepac and Rayón, however, the story is much clearer. Although not documented, verbal reports by farmers indicate that Huepac might have had wells and pumps as early as the 1950s; there is no question that they were in use during the early 1960s. The earliest recorded use of wells for agricultural purposes was in Rayón (Sheridan and Nabhan 1978:1-16, esp. 9), the municipality closest to both the capital and the irrigation districts on the coastal plain (figure 2).

This new technology proliferated where it began and from here irrigation spread to other parts of the region. Between 1960 and 1970, additional wells were drilled in Rayón and Huepac; the municipalities of Banámichi, Baviácora, Huachinera, and Sahuaripa also received the new technology. Not surprisingly, each of these municipalities, with the exception of Huepac, experienced substantial increases in irrigated hectarage (figure 3). Indeed, during the 1960s, only seven municipalities had land-use changes in which the irrigated land area increased substantially (more than 10 percent) over the optimal area, but six of these were where wells and pumps were introduced (table 1).

Wells and pumps were brought into use in the municipality of Moctezuma sometime after 1970. During this decade, the improved technology contributed to the expansion of irrigation there and in only two other municipalities, Banámichi and Rayón. By the late 1970s, wells had become common-place. Over 40 are now found in Rayón alone, and agriculture there is almost entirely dependent on the pumping of groundwater (ibid.:10). The possibility of overdraft now exists and, therefore, the future of both the water supply and agriculture is in danger (ibid.:15-16).

The small increases in irrigated lands recorded in nearly all of the remaining municipalities during the 1970s (figure 4, table 1) are largely due to improvements in the existent gravity-flow canal system (Alcaraz 1977). Through the 1960s, most acequias madres, or main canals that carry water directly from the rivers, were small, unlined earthen ditches with no means of preventing loss due to seepage. During recent years, many of these canals have been enlarged, lined with concrete, and extended. More water is, therefore, carried through the system, thus facilitating the cultivation of lands that previously were without adequate and dependable water (Espinoza 1982:18-20).

The expansion of irrigation into marginal areas should not be construed as having involved previously unused land. Indeed, expansion, whether by means of wells and pumps or by enlarging, lining, and extending canals, principally involved lands where nonirrigated agriculture had long been practiced. Between 1960 and 1970, over 85 percent of the land area involved in this expansion was previously dry farmed (table 5). More than 90 percent of this land was in municipalities where wells were drilled. During the 1970s, nearly two-thirds of the land involved in irrigation expansion was converted from dry farming. That only a little more than one-half of this change took place in municipalities with wells verifies that canal improvements have been gaining importance recently.

The expansion of irrigation has actually been facilitated by intermittent dry farming on marginal lands. Under precultivation conditions, both arroyo bottoms and floodplain lands are heavily forested with mesquite (Prosopis sp.).

TABLE 5

EXPANSION OF IRRIGATION ONTO MARGINAL LANDS

(HECTARES)

Municipality	1960-1970 Converted from Dry Farming	1960-1970 Previously Unused	1970-1982 Converted from Dry farming	1970-1982 Previously Unused
Arivechi*	0	0	325	183
Bacanora*	0	0	44	0
Bacerac*	4	0	46	0
Bacoachi*	20	0	0	0
Banámichi	89	0	129	566
Baviácora	68	201	0	0
Granados*	6	25	24	130
Huachinera	63	0	0	0
Huásabas*	112	37	0	0
Huepac	0	0	0	0
Mazatán*	0	0	210	0
Moctezuma	80	0	145	0
Rayón	370	0	622	0
Sahuaripa	831	0	0	0
San Felipe*	0	0	37	0
Suaqui Grande*	0	0	0	0

Table 5, continued

Municipality	1960-1970 Converted from Dry Farming	1960-1970 Previously Unused	1970-1982 Converted from Dry farming	1970-1982 Previously Unused
Villa Pesqueira*	0	0	0	0
Total	1,643	263	1,582	879
Percent of Newly Irrigated Land	86.2	13.8	64.3	35.7
Total*	142	62	686	313
Percent of Newly Irrigated Land	8.6	23.6	43.4	35.6

*Municipalities without wells and pumps

These lands must be cleared of trees and they must be fenced. Arroyo lands are flood-prone and require the construction of soil-conservation devices such as weirs, water spreaders, bunds, and, frequently, low terraces. In many cases, canals to divert runoff also have to be excavated. Floodplain fields often have to be bunded and girded in order to retain water after infrequent rainstorms.

All of these activities take substantial investments of time and labor. They also are undertaken at great risk. Dependence on direct rainfall and runoff is risky and flash floods often damage fields in which improvements are incomplete and inadequate. In order to spread out the inputs and minimize possible losses, farmers tend to develop their field systems incrementally (Doolittle 1984a:124-137). In so doing, they make small annual improvements to features built earlier. They get a very small yield during the early years, when improvements are few and small. As more improvements are made and the field is upgraded, yields increase in both size and dependability. Geertz (1963:34) noted that such improvement raises productivity per hectare and per person. Potential flood damage is also increasingly minimized.

During the course of incremental change, farmers often abandon their fields out of frustration or because of better opportunities elsewhere. Indeed, because the process can take more than a decade, few prospective farmers actually complete their original plans. Their efforts, however, are not lost. By law (Codigo Agrario 1934), a field can be claimed by another member of the community after it has been abandoned--that is, not farmed for three consecutive years (Chávez Padrón 1981). Because some work has already been completed, abandoned fields are quickly claimed by farmers who would otherwise have to start improving previously unused lands. Some individual plots are claimed to have been used, improved, and then abandoned by as many as three farmers, thus resulting in intermittent use.

There is no guarantee of a good harvest even after fields are completely cleared and the necessary water-control and soil-conservation features constructed. Yields depend on water that is sparse and erratic. It is at this point that the drilling of wells becomes both possible and common. Prior to this time, the land was not adequately prepared and farmers had not accumulated sufficient cash or credit to make this final and most costly improvement. Once in place, the wells, combined with the other improvements, result in fields that are nearly as productive as fields on optimal lands that have long been irrigated. In a few cases, these new fields are even more productive because after 600 years of continuous cultivation some irrigated floodplain fields have experienced significant reductions in soil fertility. In effect, in the conversion of nonirrigated to irrigated land, lands previously considered marginal actually become optimal. Because of technological changes, permanent agriculture replaces intermittent farming. Upon completion, field systems become investments that tend not to be abandoned; they have a momentum of their own (Geertz 1963:34).

Successful agricultural change on marginal lands in eastern Sonora is painfully slow. The pace is easy to understand, however, because the amount of labor needed to clear a field and bring it up to the level of existing ones tends to discourage rapid expansion (ibid.:36). Prospective farmers in the region are not necessarily reluctant to begin cultivating. However, when they spread their efforts out over several years, and frequently abandon their fields, the high labor inputs and cash investments result in a long period of intermittent use prior to permanent and complete cultivation.

Theoretical Implications

This assessment of agricultural changes in eastern Sonora, Mexico, since 1950 illustrates two things about land-use where environmental constraints are great and land of optimal quality is permanently and completely cultivated. First, lands of marginal quality tend to be farmed intermittently, being brought into and taken out of cultivation periodically as conditions change and demands warrant. Second, the introduction and expansion of new technology and, hence, increases in the permanently cultivated area, are facilitated by the accumulation of numerous small improvements made periodically on marginal lands used intermittently. Although the process of change, as seen in this case, is slow, and is occurring on a small scale, it does have broad implications for understanding agricultural land-use.

Two examples, one ecological and spatial, the other economic and social, illustrate the importance of intermittency.

Because it was conceived in and subsequently modified for areas with well-developed market economies, von Thünian agricultural land-use theory contains no provisions for subsistence or consumption production. Holding environmental and cultural factors constant, the only economic explanation posited thus far for the existence of such farming is that it lies outside or beyond the sphere of commercial production (Norton 1984:137). Such was undoubtedly the case in the 19th century when there remained vast tracts of unused land (Norton and Conkling 1974:44-56). It is not so much the case today, however, because even the most remote areas are used for commercial purposes. For example, with the exception of the cultivated areas, virtually all of the north Mexican desert lands are used for cattle grazing, however sparsely.

In a von Thünian sense, subsistence farming can only be found at or past the economic margin of commercial agriculture (Thoman, Conkling, and Yeates 1968:153). By definition, it would have to be either on the line between the zones of the most extensive cultivation and grazing, or scattered in parcels within the zone of grazing. It would not be found beyond the grazing lands in the wilderness because no such land remains. In dynamic or evolutionary situations, increases in the amount of land devoted to producing subsistence crops would have to be at the expense of grazing lands (Peet 1970:181-201).

Both of these conditions exist in Sonora today. Subsistence plots are scattered throughout grazing lands surrounding towns located in proximity to irrigated lands. As demands increase, subsistence-oriented dry farming is expanded onto formerly communal pasturelands. The inverse is also true in certain places and at certain times. As the number of farmers producing for reasons other than cash decreases, the amount of land farmed in the marginal zone decreases. When plots are converted back to pasture rather than modified by improved technology and hence permanently cultivated, intermittency is undoubtedly occurring. If intensive commercial agriculture replaces subsistence farming, agricultural intensification is occurring and, indeed, markets are being expanded.

The shift from consumption to commercial production has long attracted a great deal of attention. Research to date clearly indicates that the process is not simple, straightforward, and clear-cut. Furthermore, there exist many factors that remain poorly understood and some even unrecognized. One such point is the changes in the production orientation of individual farmers. It is usually assumed that farmers produce for either consumption or market. The basis of this assumption lies in their behavioral attitudes. The production strategy of farmers who produce for consumption is typically one of averting risks and uncertainties. Subsistence farmers tend to be conservative, forego-ing changes that involve risks in favor of protecting what they have by doing what they know works (Ortiz 1973; Scott, 1976). Farmers involved with commer-cial production, on the other hand, often take considerably greater risks in order to obtain higher desired returns (Roumasset, Boussard, and Singh 1979).

Many smallholders, of course, produce principally for consumption, but market their surpluses. These "dual farmers" (Brush and Turner, in press) are risk averting with one aspect of production and risk taking with another. What has only been recognized on a large, national scale, and therefore needs further investigation on the small or local scale, is that some farmers might produce entirely for consumption one year and for commodity the next. They also might produce in any one of a variety of combinations some years and go completely out of production, taking cash jobs, during others. This appears to be the case with smallholders in eastern Sonora. For the most part, these farmers want to be involved in full-time commercial production. Given their land constraints and limited economic resources, however, they cannot make the transition from consumption to commodity production in a brief period of time. Furthermore, environmental and economic vagaries, such as droughts and variable prices, require that these farmers behave in a most paradoxical manner--by minimizing risks while simultaneously taking chances. The solution to this dilemma has been constantly to practice proven traditional techniques and occasionally adopt new technologies that have been proven successful by their neighbors (Cancian 1979; DeWalt 1979). Smallholders in eastern Sonora are neither efficient in their minimization of risk, nor are they profit maximiz-ers. Rather, they probably should be considered "proficient" (Schulter and Mount 1974). These farmers are in the process of expanding commercial produc-tion (Doolittle 1983:301-13). They are doing it very slowly, however, and by an ecologically and economically sound incremental process (ibid. 1984a:124-137). The key to their successful expansion in the face of adverse environmental and economic conditions is to cultivate marginal lands intermittently. When conditions become unfavorable, they take land out of production. When conditions become favorable once again, they not only bring formerly used lands back into production, but they often make improvements that result in more land being farmed, higher yields per unit area, and more land under permanent cultivation.

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