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Judith Carney

TRITICALE PRODUCTION IN THE CENTRAL MEXICAN HIGHLANDS:

Smallholders' Experiences and Lessons for Research

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CIMMYT is an internationally funded, nonprofit scientific research and training organization. Headquartered in Mexico, the Center is engaged in a worldwide research program for maize, wheat, and triticale, with emphasis on improving the productivity of agricultural resources in developing countries. It is one of 13 nonprofit international agricultural research and training centers supported by the Consultative Group on International Agricultural Research (CGIAR), which is sponsored by the Food and Agricultural Organization (FAO) of the United Nations, the International Bank for Reconstruction and Development (World Bank), and the United Nations Development Programme (UNDP). The CGIAR consists of a combination of 40 donor countries, international and regional organizations, and private foundations.

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Abstract

Triticale, a cross between wheat and rye, yields more than its parent species under two kinds of marginal conditions: highland areas where acid soils and foliar diseases are a problem and semiarid areas where drought stress frequently affects crop production. This paper examines triticale utilization patterns among smallholders in one tropical montane region, the central Mexican highlands, where farmers have cultivated triticale for over 20 years. In the central Mexican highlands, smallholders' interest in triticale originally derived from their experiments with the crop as animal forage and feed, and only briefly shifted to triticale's potential as a food crop when markets appeared to be developing. Future research to meet smallholders' needs for forage and feed triticales may necessitate a reconsideration of the current emphasis on complete triticale types. The diversity of microenvironments sown to triticale in the central Mexican highlands, and the decades-long experience of smallholders in growing the crop and collaborating with researchers from several disciplines, will continue to make the area a valuable location for work on forage and feed triticale.

Acknowledgements

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Acronyms

CIDA	Canadian International Development Agency
CIMMYT	Centro Internacional de Mejoramiento de Maíz y Trigo International Maize and Wheat Improvement Center
CREFAL	Centro Regional de Educación de Adultos y Alfabetización Funcional para América Latina
FAO	Food and Agriculture Organization of the United Nations
IDRC	International Development Research Centre
INI	Instituto Nacional Indigenista
SARH	Secretaría de Agricultura y Recursos Hidráulicos
UNAM	Universidad Nacional Autónoma de México
UNESCO	United Nations Educational, Scientific, and Cultural Organization

1989 Currency exchange rate: 2,400 Mexican pesos (MN) = US$ 1.00.

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Introduction

CIMMYT's involvement with triticale breeding began in 1965 when the Rockefeller Foundation provided start-up funds to CIMMYT's predecessor organization for a large-scale research program to explore the cereal's potential as a food crop (Varughese et al. 1987). In later years, additional support came from donors such as IDRC and CIDA, interested in the promise of triticale as a wheat substitute for stressed growing environments. Triticale yielded better than wheat in two stressed environments: semiarid environments and highland areas characterized by acidic and phosphorus-deficient soils (CIMMYT 1986).

While triticale research was getting underway, another development was taking place which was to have considerable bearing on CIMMYT's research. In 1964 an international organization for Latin American literacy, CREFAL, based in Pátzcuaro, Michoacán, embarked upon a joint program with the University of Montana to introduce improved rye varieties to Michoacán cultivators. Seed distribution and farmers' experiences were monitored by the local government agency responsible for agriculture and by an agronomist trained through the Oficina de Estudios Especiales (the predecessor of CIMMYT) of the Mexican Agricultural Program. Two years later the agronomist communicated the farmers' positive experience with sowing rye for animal forage to Norman Borlaug, director of CIMMYT's Wheat Program, who apprised the extension agent of the work with triticale. Thinking triticale might well meet local cultivators' needs, Borlaug released some seed for farmer experimentation, and thus inaugurated the collaboration between CIMMYT triticale researchers and the smallholders of Erongarícuaro County, Michoacán (SARH 1986; Borlaug, Kohli, and Skovmand, pers. com.).

More than two decades have passed since those initial trials in CIMMYT's experiment stations and in the fields of Erongarícuaro's farmers, and much has been learned. Interest in triticale continues to be high. It is presently receiving attention at CIMMYT for its relevance to three interrelated issues which are current priorities in the agricultural development community: the development of *sustainable* production technologies for the *rural poor* who often live and farm in *marginal environments* (Tripp and Winkelmann 1985; CIMMYT 1989a). Although giving priority to improving triticale as a food crop demonstrates sensitivity to the concerns of the development community, the discussion on directions for triticale research has not fully taken into account smallholders' experience with the crop. This paper, a case study of triticale utilization among smallholders in one marginal environment--the tropical highlands--seeks to bridge that gap by relaying the cumulative experience of Erongarícuaro's triticale farmers back to CIMMYT researchers to be used as they set breeding priorities.

Objectives of the Study

The *municipio* (county) of Erongarícuaro, carved out of the central Mexican highlands and located in the state of Michoacán, is representative of many tropical highland regions where smallholder farming systems predominate. An altitudinal gradient that spans 1,000 meters above sea level (masl) fundamentally shapes land use, but intramontane valleys contribute to the diversity of microenvironments encountered in the municipio. The farming system is adjusted to both altitudinal and microenvironmental variation. Households typically cultivate parcels scattered on volcanic slopes, valley flats, and in special areas where the soil has high moisture-holding capacity. Triticale is planted in each type of environment.

Research on triticale cultivation in Erongarícuaro got underway in 1978 when Tapia (1979) examined triticale diffusion patterns and adoption rates. His report on triticale's rapid expansion in the municipio led Hansen, the following year, to examine the ways that smallholders were using the crop. Although both Tapia and Hansen drew attention to the socioeconomic characteristics of triticale farmers, they placed little emphasis on the ecological and agroclimatic conditions affecting adoption. That concern was more squarely addressed in Biggs' (1982) research on triticale cultivation among smallholders in the Himalayas. Biggs emphasized the importance of understanding both socioeconomic and agroclimatic circumstances in generating production technologies appropriate for smallholders, but he focused on triticale's potential as a *food* crop, a priority established by the development community.

This study builds upon Hansen's (1981a, 1981b) and Biggs' (1982) concern with developing appropriate production technologies for smallholders in marginal environments, using the experience of Erongarícuaro's farmers to consider the potential role of triticale. This study has two objectives. The first is to illuminate the niche that triticale occupies in the farming systems of Erongarícuaro. The second objective, an examination of the adoption process over the past 20 years, focuses on farmer experimentation with triticale. These experiments provide a basis for understanding the significance of crop-livestock interactions in the farming systems, and offer important insights for researchers interested in the varietal development needs of smallholders living in marginal, tropical montane environments.

Organization of the Study

Empirical data for this study were collected from September 1988 through May 1989. The study involved three distinct but overlapping phases and emphasized a variety of research techniques. The first phase established the population of all triticale cultivators, former and current, in Erongarícuaro Municipio. Informal household surveys and group and key informant interviews enabled the delimitation of three farmer groups: adopters, disadopters,[1] and nonadopters, as well as the socioeconomic circumstances characterizing adoption decisions at different times (see Chapter 4).

In the second phase, the research examined the temporal and spatial dimensions of triticale cultivation. Field observations concentrated on identifying the primary agroclimatic zones in the municipio, specifying the major land use areas within each zone, and locating the production systems that included triticale. Meteorological data were collected for the municipio and the soil sampled in each triticale production zone. Interviews with adopters and disadopters had revealed which crops triticale replaced or had been replaced by and, thus, the significance of changing household land use strategies for its cultivation. The strategies guiding smallholder production practices were placed in a broader perspective through a review of secondary geographical, historical, and anthropological sources, agrarian censuses, and archival materials from the 1940s. These secondary sources brought into relief the agropastoral system that regulates land use patterns in the municipio. Chapter 3 provides an overview of these crop-livestock linkages.

The third and final part of this study, presented in Chapter 5, interweaves the insights from the historical and geographical research with the results from formal and informal farm-household surveys of triticale producers to examine farmers' innovations and experiments with the crop. This discussion provides the basis for the identification of the research needs on triticale for Erongarícuaro's smallholders, discussed in Chapter 6.

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[1] Disadopters are those who no longer sow triticale.

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Triticale: A Crop for Marginal Enviroments

Development of Triticale Research

Triticale (X. *Triticosecale* Wittmack) is the product of a cross between wheat and rye and is the first successful human-made cereal. Although the first fertile triticale was developed in 1888, the hybrid remained a taxonomic anomaly until the 1930s, when European plant breeders initiated research to evolve triticale into a species with commercial potential. To do so, however, required overcoming three major obstacles: the need to produce large numbers of hybrids as well as the hybrids' persistent infertility and tendency to set shrivelled seed. While progress on the third objective was to await the attention of CIMMYT breeders, the first two barriers had been overcome by the 1940s with the discovery of the colchicine treatment and embryo rescue techniques.

The establishment of a research and breeding program at the University of Manitoba in 1954 carried triticale research to the Americas. The University brought together for the first time primary triticales from all over the world, which enabled researchers to make an unprecedented number of secondary crosses. When the University hosted the first international wheat symposium just four years later, Norman Borlaug of the Mexican Agricultural Program was able to review the materials and discuss triticale's potential with researchers. This contact resulted in experimental material being sent to Mexico as early as 1961. Collaborative research, however, did not get underway until 1963 (Zillinsky and Borlaug 1971).

Support from the Rockefeller Foundation in 1965 enabled Borlaug and his colleagues to join with the University of Manitoba to develop a full-scale, field-oriented breeding program in triticale. Mexico provided an ideal laboratory for triticale research: scientists had access to diverse materials from the bread and durum wheat germplasm development programs; and two cropping cycles each year (each at a different location) were possible, thus doubling the number of plant generations annually as well as the number of climatic zones for testing triticale. Finally, and of significance for future research directions, the donor community was quite interested in triticale's potential in developing countries. Because broadly adapted triticales for the tropics--which encompass most developing countries--required daylength insensitivity such as that possessed by the Mexican semidwarf wheats, developing this characteristic in triticale was one of the first research objectives (Varughese et al. 1987).

In 1968, the third and final year of Rockefeller Foundation funding for triticale research, CIMMYT breeders benefited from an unforeseen event: the discovery of the Armadillo strain. Armadillo was a spontaneous outcross of triticale with an unknown Mexican semidwarf bread wheat which resulted in one rye chromosome being substituted by a chromosome of wheat. The "substitute" triticale proved to have several desirable agronomic traits, including high fertility, daylength insensitivity, earlier maturity, one dwarfing gene, improved test weights and yields, as well as good nutritional quality. (Whereas in "substitute" triticales one rye chromosome is replaced by a wheat chromosome, "complete" types possess all seven rye chromosomes.)

Armadillo increased interest in the potential of triticale as a bread wheat substitute in rainfed, marginal wheat-producing areas of developing countries (Borlaug pers. com.), and led IDRC and CIDA in 1971 to provide a five-year grant to further CIMMYT's work. This funding established the basis for emphasizing triticale's yield performance, endosperm development, and flour-milling properties. By the mid-1970s CIMMYT triticale finally yielded as well as the best available bread wheats. Progress on both substitute and complete types of triticale enabled researchers to investigate each type's yield potential under differing agroclimatic conditions. Results from international testing in five growing environments in 1982/83 yielded two findings of consequence for current CIMMYT research directions:

- Triticale yielded more than bread wheat in several stressed environments (such as semiarid areas and tropical highlands); and

- Within these marginal environments, complete triticales yielded better than substitute types.

As a consequence of these findings, complete triticales--of which the variety, Eronga, was among the first released (1983)--now receive more attention than substitute types in triticale breeding at CIMMYT.

Triticale's performance in difficult production environments thus prompted a gradual shift in emphasis at CIMMYT from developing triticale for highly productive, wheat-producing areas to improving triticale for rainfed stressed environments (Varughese 1987). While research remains focused on improving grain type to overcome the low test weights that reduce milling and baking quality (Varughese et al. 1987), the low gluten content of triticale flour limits its use as a substitute for wheat flour in making bread. Triticale flour, however, is quite suitable for soft wheat products, such as cookies, cakes, waffles, noodles, chapatis, and flour tortillas. The development of triticale with flour-milling properties similar to those of bread wheat remains a major challenge (Amaya and Skovmand 1985).

Even though CIMMYT focuses on triticale's potential as a food crop, triticale also exhibits special qualities as a feed and forage crop. It has a higher lysine content than wheat and better protein digestibility and mineral balance than rye (Varughese et al. 1987). The phosphorus content of triticale is higher than either of its parent species, which makes it a desirable addition to feed for pigs and chickens, whose phosphorus needs are significant (Varughese 1987). As a forage crop triticale also shows considerable potential. Its protein content is higher than oats, and it has higher forage and silage yields than wheat, oats, barley, or rye (CIMMYT 1986). Trials record greater average daily weight gains for animals grazed on forage triticale compared to rye (Skovmand et al. 1987), and there is also evidence that under grazing pressure triticale regenerates better than several other cereals (Zillinsky 1985).

Finally, triticale exhibits growth characteristics which may make it particularly advantageous as a forage or feed crop in certain agroclimatic and socioeconomic situations. It tolerates low temperatures better than spring wheat and oats, a quality which can enhance flexibility in crop rotations for the tropical highlands (Singh et al. 1979; Gamboa et al. 1980). Because triticale can be planted as a forage or feed crop during the autumn or winter in many tropical montane areas, it has considerable potential in smallholder farming systems.[2] For Mexican smallholders triticale provides a high quality protein for animals during the late winter and spring seasons when draft power and feed demands peak. Triticale also provides smallholders a means to intensify land use by adding to a rotation another crop that can be used on the farm or sold.

While CIMMYT does not work directly with forage or feed triticale, its research does have indirect application for animal feed, which accounts for 90% of world production of triticale (Varughese 1987). Quality requirements for feed triticale are, however, different from those for human food since test weights and breadmaking characteristics are unimportant in animal rations, although yield, protein content, and protein quality remain essential (CIMMYT 1986). Breeding for one objective consequently reduces progress in crop research for the other. Of the 32 countries currently cultivating triticale commercially, one-third could be considered developing countries (Table 1). While these countries only account for some 6% of total land planted to triticale, they are the areas where triticale is used as both feed and food. Pockets of smallholder production occur only in China, Tanzania, Mexico, India, Madagascar, and Tunisia. Data for the tropical production zones are scant but studies in Mexico (Tapia 1979; Hansen 1981a, 1981b), India (Biggs 1982), and Madagascar (Jarosz, pers. com.) suggest that smallholder cultivation is concentrated in tropical montane environments.

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[2] Crop-livestock relations are an important component of many smallholder farming systems. As an example, the average farm size in Kenya is just 1 ha, but more than 85% of farms have livestock, usually two or more species (McDowell 1988).

Table 1. World distribution of triticale

Country[a]	Area (ha)
Developed countries	
Australia[c]	160,000
Austria[d]	1,000
Belgium[b]	5,000
Bulgaria[b]	10,000
Canada[c]	6,500
France[d]	300,000
Germany (West)[d]	30,000
Hungary[b]	5,000
Italy[b]	15,000
Luxemburg[b]	400
Netherlands[c]	1,000
New Zealand[c]	150
Poland[c]	600,000
Portugal[c]	80,000
South Africa[b]	15,000
Spain[b]	30,000
Switzerland[c]	5,000
UK[d]	16,000
USA[b]	60,000
USSR[b]	250,000
Total	1,590,050
Developing countries	
Argentina[b]	10,000
Brazil[b]	30,000
Chile	5,000
China[b]	25,000
India[c]	500
Mexico[b]	8,000
Tanzania[c]	400
Tunisia[c]	25,000
Total	103,900
Grand total	**1,693,950**

Source: Based on Varughese et al. (1986).

[a] Small area also planted to triticale in Greece, Kenya, and Madagascar.
[b] Estimate.
[c] CIMMYT survey.
[d] Suijs (1986).

The Development of Triticale Cultivation in Erongarícuaro Municipio, Michoacán

CIMMYT was some years from the Armadillo discovery when a few farmers in Erongarícuaro began experimenting with the handfuls of seed they received through the extension agent. Even though in 1966 triticale still exhibited high infertility and shriveled seed, two local farmers found the rudimentary crop sufficiently promising to expand production to 2 ha the following year. Their interest in triticale derived from the same objective behind local experimentation with rye: a search for a quality forage crop for their animals.[3] From the first year's planting these farmers began their own agronomic trials--with female family members selecting the most promising seed for replanting,[4] observing the nutritional results from feeding the grain to their animals, and contrasting triticale's performance with other forage/feed crops.[5]

By 1969 when Armadillo seed became available, the number of growers in Erongarícuaro increased to half a dozen. Local experimentation with the crop took a significant step that year when the mother of one of the cultivators attempted to make bread by mixing triticale and bread wheat flours. Once more assuming the *ad hoc* role of intermediary between CIMMYT researchers and local farmers, the extension agent mentioned the woman's experience to Borlaug. This spontaneous experiment, occurring when donor interest in triticale's potential was growing, proved decisive in orienting research to triticale that could be grown for food in marginal production areas.

In 1972, CIMMYT triticale breeders began regular visits to Erongarícuaro, bringing advanced lines selected for their grain yield and milling characteristics. As triticale was still in a formative phase, very few agronomic recommendations were provided. In fact, much of the information that later formed the guidelines for triticale cultivation emerged from the experience of Erongarícuaro's farmers with seed rates, fertilizer use, planting dates, and cultivation in diverse microenvironments. Their "on-farm" research had thus become a complementary and integral part of CIMMYT's triticale breeding program.

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[3] This desire for a quality forage crop was related to processes of agropastoral intensification which were well in evidence by the 1960s (see Chapter 3).

[4] Although women's role in field farming in this region of Mexico is customarily limited to weeding and harvesting, traditionally they select seed for the following year's planting.

[5] Forage/feed crops were few. The 1950 agropastoral census does not even mention oats, the major fodder crop in the area today. Only barley and alfalfa were planted for animals but in insignificant amounts (less than 6 ha). Until the 1960s animals were either fed maize stover or grazed on natural pasture.

Research on experimental varieties increased in 1974 when four of the best-yielding lines from Obregón were brought to Michoacán for testing. In the following years anywhere from six to 20 varieties would be tested in a given season by Erongarícuaro's farmers. Towards the end of the 1970s, Bacum, a substitute triticale, had emerged as the local favorite both for its yield and bread-making quality (SARH 1986). Goqui, a tall awnless variety, also found favor as a forage crop, but it was eventually dropped from the breeding program since its lower grain yield and shriveled kernels were undesirable for making bread (Kohli, pers. com.).

Continued on-farm and experiment station testing culminated in 1978 with the development of Juanillo, a complete triticale and the highest yielding variety up to that time. Juanillo appeared at a time of mounting interest by Erongarícuaro's farmers in triticale production: in just one year, from 1978 to 1979, the number of cultivators had increased from 36 to 63 (Tapia 1979; Hansen 1981a). Lack of seed soon emerged as a major constraint to expanded cultivation, and in 1980 a "seed bank" was established with one of the farmers who had initiated triticale cultivation more than 10 years earlier. One hundred kilograms of triticale seed (nearly enough to plant 1 ha at the recommended 120 kg/ha seed rate) would be made available to any interested farmer on credit with the proviso that the same amount be returned at the end of the season. Subsequent modification of Juanillo and testing by Erongarícuaro's farmers led to the creation in 1983 of its plump-grained, high-yielding progeny, Eronga, named on behalf of the cultivators who had contributed so much to its development. In that same year, when state government funds helped found a cooperative bakery in the town of Erongarícuaro, triticale utilization within the local farming community appeared clearly defined. The development of Eronga as a substitute for wheat in tropical highlands brought to completion the partnership between CIMMYT triticale researchers and Erongarícuaro's farmers.

The shifts in triticale breeding priorities over the past 20 years, briefly summarized here, proved to have significant repercussions for how Mexican smallholders utilized triticale. While farmers had been equal partners in developing triticale into a high-yielding food grain, by the 1980s broader social and economic processes began to affect varietal needs. These processes, reviewed in the next chapter, provide the background for understanding farmers' changing triticale utilization patterns, discussed in Chapter 4.

3

The Study Area

The municipio of Erongarícuaro is located in the state of Michoacán, 450 km west of Mexico City at 19° N latitude (Map 1). It encompasses 281 km^2 of highland terrain (2,040-3,000 masl), formed by the volcanic physiographic region which crosses central Mexico at the 19th parallel. About 12,500 people live in the municipio's 15 communities, at a density of 57 persons/km^2, and average family size is nine persons (Taylor 1987). Household incomes vary between (1982) US$ 200 and $350, augmented considerably by migrant remittances (Adelman et al. 1987); nearly every family has at least one member working in the US. Twenty-five percent of the population speaks Purepecha, the language of the Tarascans, who have inhabited the region for the past 6,000 years (Barrera Bassols 1986).

Three geographic zones give the municipio its distinctive landscape: 1) the lacustrine plains which surround the closed basin formed by Lake Pátzcuaro (2,040 masl); 2) intramontane valleys (2,040-2,400 masl) nestled between volcanos that reach 3,000 masl; and 3) the sierra or volcano zone, with slopes of between 10 and 25°(2,400-3,000 masl). Erongarícuaro is typical of many tropical highland regions in that farming extends along an altitudinal gradient that spreads from the lakeshore at 2,040 masl up the volcanic slopes to 2,700 masl.

The vast majority of households in the study area produce subsistence as well as cash crops. Three land races of maize are the basis of subsistence production; about one-fourth of the maize area is intercropped with beans. Wheat was the principal cash crop into the 1970s, when production of oats and lentils diversified agricultural incomes. Field crops, however, form but one part of a more diversified economic strategy which includes: rearing cattle and small animals; horticulture; exploiting forest and aquatic resources (lumbering and collecting pine resin and aquatic reeds [*Cyperus* spp.] for making mats and baskets); fishing in Lake Pátzcuaro; producing crafts (chiefly in the municipio's seven indigenous communities); and, since the 1940s, migrating to jobs in the US.

Ninety percent of the municipio's land is *ejido* land, distributed under the agrarian reform of the 1930s; the remainder is owned privately or by indigenous communities. In the upper communities all holdings are ejido land and average 6-7 ha per family. Below 2,400 masl, farm holdings are ejido land, or owned by indigenous communities, or held by private individuals, and average 2-4 ha (Appendix A). Each holding, moreover, tends to be divided into two or three parcels distributed through the highly differentiated environmental zones. Of the 12,500 ha classified as the municipio's productive land, 40% is cultivated, 25% is pasture, 6% is fallow, and the remainder is forested (mainly in two ejido communities located above 2,400 masl). Land area in cultivation within the municipio is about the same presently as it was in the 1950s.[6]

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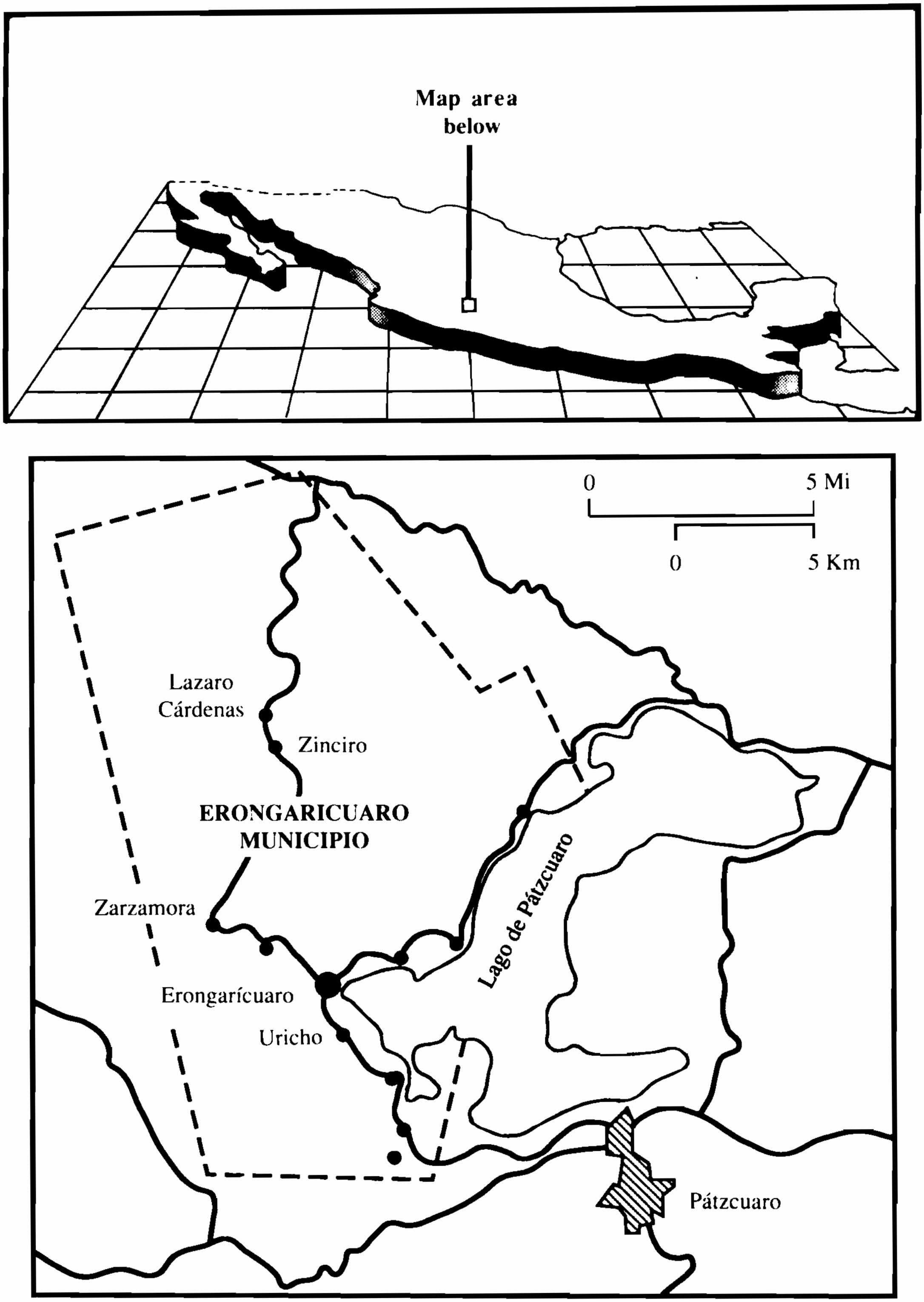
[6] Cropped land in 1950 was 3,350 ha; in 1987, 3,146 ha (1950 Agrarian Census; 1988 SARH figures).



Map 1. Erongarícuaro Municipio, Michoacán, Mexico.

Agroclimatic Features

The climate of Erongarícuaro is classified as subhumid temperate, with a mean annual temperature of 16°C and variation from an average minimum of 2°C in January to an average maximum in April-May of 30°C (Figure 1). In the zone above 2,400 masl, temperatures are much lower, the annual mean averaging between 12 and 14°C. Precipitation occurs principally from June to October and averages 900-1,000 mm annually (Figure 2), increasing to 1,300 mm in the upper reaches. During the dry season from November to February, rain falls occasionally, but aggregate totals seldom exceed 100 mm. Frosts also occur during this period on the average of 27 days, increasing to 30-50 days in the upper areas of the municipio. Within these general patterns there is considerable microclimatic variation.

Soils in Erongarícuaro derive primarily from volcanic episodes that occurred between 30 and two million years ago. Three types of soils are dominant. About 85% of the municipio's soils are andosols, formed by the weathering of volcanic ash. In the lower altitudes are also found: luvisols, a clay soil derived from recent volcanism; special types of luvisols that are enriched by colluvial-alluvial deposition; and gleysols, exposed by the retreating waters of Lake Pátzcuaro (Barrera Bassols 1986). Farmers have grown triticale with success in all of these soil types. The municipio's soils in general show moderate pH values, averaging 6.1 (Table 2).

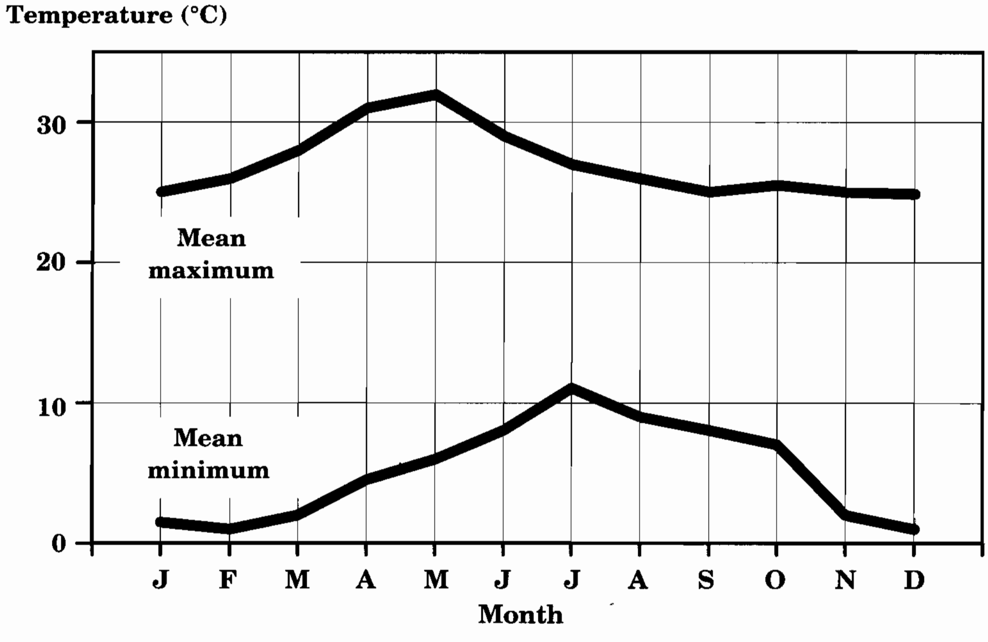


Figure 1. Mean monthly maximum and minimum temperatures, Pátzcuaro, 1973-86.

Source: SARH.

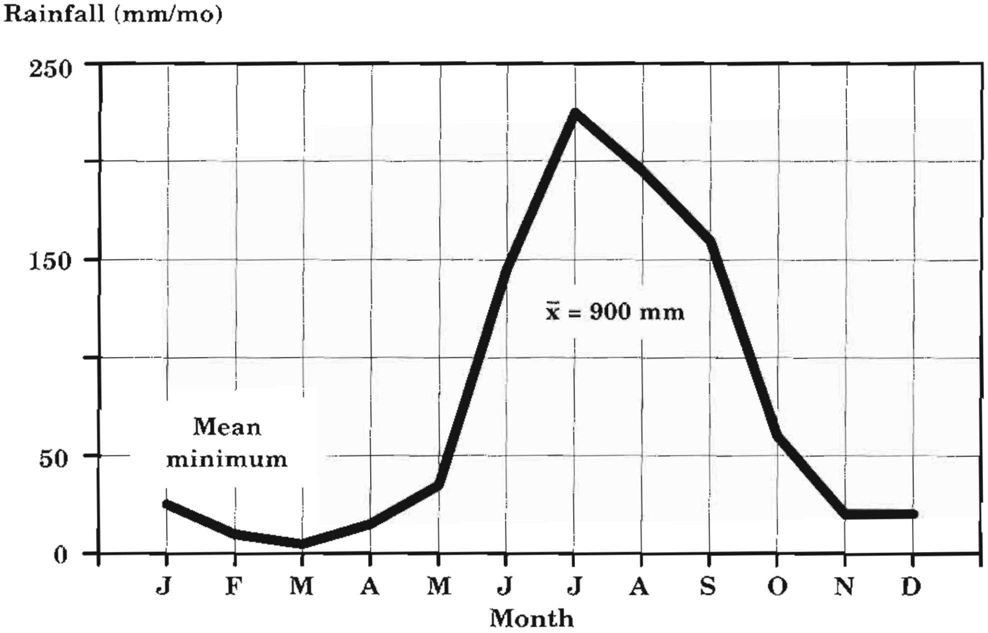


Figure 2. Mean monthly precipitation, Pátzcuaro, 1973-86.
Source: SARH.

Table 2. Soil properties, Erongarícuaro Municipio

Ecological zone and land use	pH	Organic matter (%)	Cation exchange capacity (meg/100g)	N (%)	P (ppm)	K (ppm)	Al (ppm)	Fe (ppm)	Zn (ppm)
Highlands									
Mountains	6.2	4.8	10.7	0.2	1.0	327	1.3	24	0.1
Slopes	6.2	3.7	12.7	0.7	0.3	421	1.1	21	0.2
Plains	5.9	7.6	10.3	0.3	0.3	480	2.9	20	0.3
Lake area									
Slopes	5.9	2.6	15.4	0.2	0.3	482	2.5	22	0.2
Invierno	6.4	2.6	18.0	0.1	16.8	500	0.6	40	0.9
Plains	5.6	3.5	16.0	0.2	0.2	432	3.4	25	2.0
Lacustrine	6.5	3.6	20.6	0.2	29.0	848	0.5	61	0.6

Source: Soil sample results 1988 (Carney, unpublished data) and 1989 (Bell and Carney, unpublished data).

Note: N = 30 soil sample results.

Agroecological Zones and Farming Microenvironments

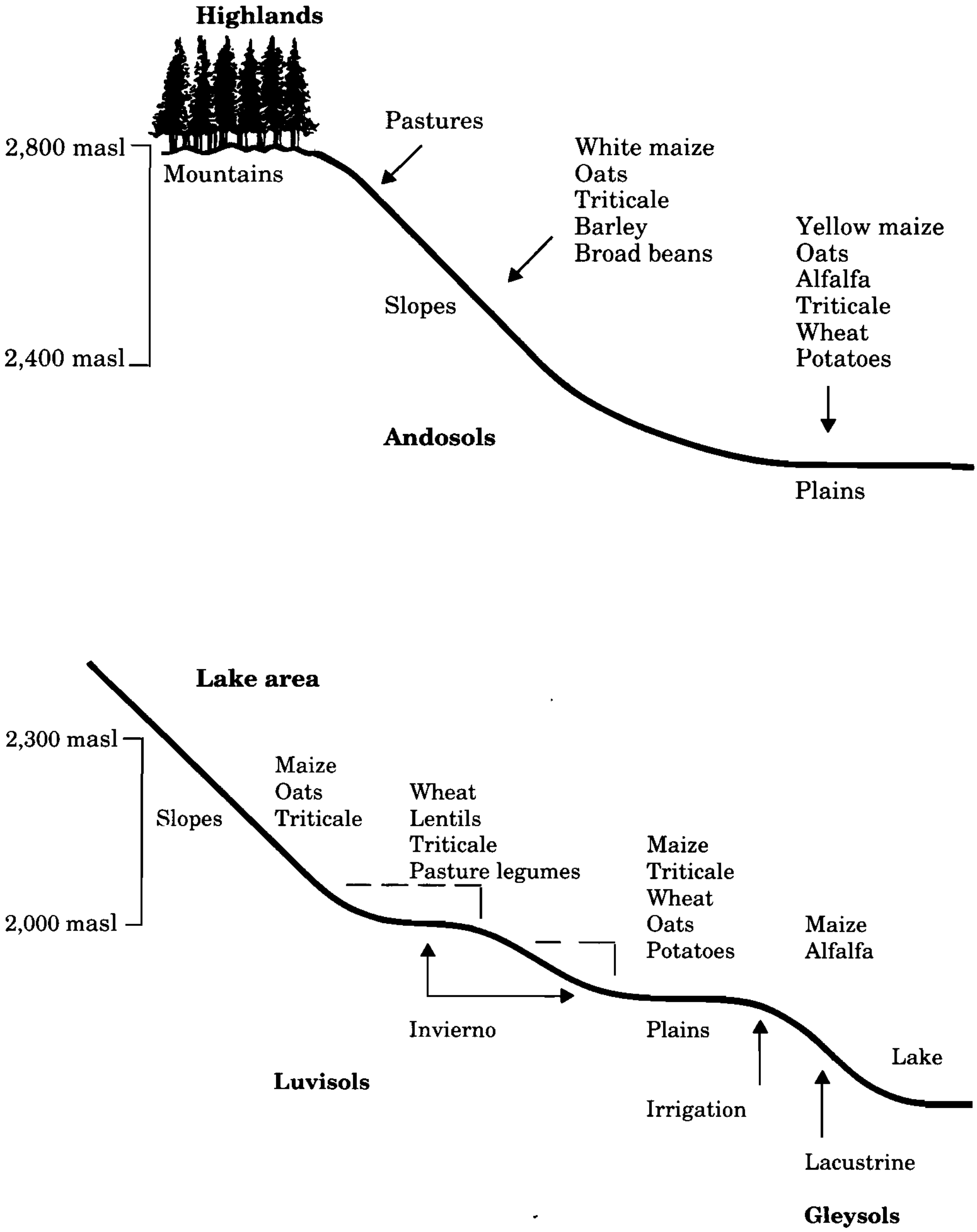
The altitudinal gradient and related differences in temperature and rainfall create two major agroecological zones in Erongarícuaro Municipio: the upper highland region, where land is farmed from 2,400 to 2,700 masl, and the lake area below 2,400 masl. The zones are presented schematically in relationship to topography, soil type, and crop selection in Figure 3.

The most significant environmental factor regulating land use in Erongarícuaro is soil class (Toledo et al. 1980; Gorenstein and Pollard 1983; Barrera Bassols 1988). Each type of agriculture--rainfed (*temporal*), irrigated (*riego*), and the utilization of soil moisture reserves (*humedad*)--refers to distinct management practices under differing moisture regimes. Three-quarters of agricultural production is strictly rainfed and occurs with the onset of summer rains. Irrigation, which has been practiced since before the Conquest in the early 16th century (Gorenstein and Pollard 1983), permits cultivation in the dry season along 140 ha of the lakeshore.

Humedad cultivation refers to the management of soil moisture reserves in the dry winter season (*invierno*). During the dry season the lake recedes to expose a ribbon of land with high moisture-holding capacity (*ataimu*), which sustains cultivation from November to May. A second type of dry season farming occurs at the base of volcanic slopes, on luvisols enriched by colluvial-alluvial deposits (*charandosa*). These moisture-retentive clay soils permit cultivation in the dry season when less than 100 mm of rain falls (see Figure 3 for location).

Another form of humedad cultivation occurs in two soil types (*t'upuri*) in the upper communities. The humic allophanes can be distinguished by their brown tones and finer texture from the other soil's yellow earth color. Whereas the humic allophanes are deficient in phosphorus, both soil types retain moisture. In the dry season these soils form a surface cap which prevents the evaporation of moisture from the soil beneath (West 1948). At the end of the dry season (March-May), the soil is moist below 7 cm from the surface. By sowing maize deeply to take advantage of these moisture reserves, farmers can advance maize cultivation two months before the rains and decrease the risk of frost damage before harvest. The cultivation of humid soils is an indigenous form of agricultural intensification (West 1948; Wilken 1988) that extends farming beyond the limits of a single rainy season. In addition to providing flexibility in options for cultivation, the use of humid soils enables farmers to stagger agricultural labor demands through a longer cropping period.

Figure 3. Agroecological zones and land use patterns, Pátzcuaro region.



Land Use Areas

Agropastoral activities are central to the mixed farming system still prevailing in the municipio, known as *año y vez*, which was introduced by Spanish land grantees and Franciscan missionaries following Nuño de Guzman's bloody defeat of the Tarascan empire in 1529. The pre-existing maize-bean-squash complex, based on hillslope cultivation with a digging stick, was broadened by the Spanish, who brought wheat, barley, broad beans, lentils, and the plow, extending cultivation to basin plains (Beals 1946; West 1948; Brand 1951). Año y vez, a three-field agricultural system in which pasture for cattle and sheep was rotated with grain and legume crops, was the basis of the hacienda system, which occupied the plains stretching along the margins of Lake Pátzcuaro and the intramontane valleys of the municipio. With the dismantling of the haciendas from 1918 through the 1930s, the land reverted to the system's laborers (*peones*) through the creation of ejidos or by sale.

The transfer of land to the peones initiated an intensification of agricultural production. Cattle ownership was crucial to the emerging land use system.[7] Cattle provided draft traction for preparing fields and, even more critically, the manure that enhanced agricultural productivity before chemical fertilizers were available. The use of manure encouraged the widespread planting of barley, which supplemented maize stover as animal feed but additionally provided a valuable rotation crop, since barley produced well in a field's second or third year of cropping before the field was returned to animal pasture for enrichment with manure (West 1948). In this first phase of agricultural intensification maize was planted to meet subsistence needs while wheat was sown as the principal cash crop.[8]

With the wide availability of chemical fertilizers during the 1970s, the crop components of the system changed. A second phase of agricultural intensification was ushered in, which contributed to a doubling of maize yields per hectare by the 1980s (Appendix B) and sales of surpluses. Field preparation remained dependent on draft animals, but barley declined in importance with the diffusion of forage and food legumes (alfalfa, lentils, and broad beans), which had the additional benefit of enhancing soil fertility. Farm incomes were diversified by marketing surplus maize and food legumes. By the 1980s yet another change was underway, this time related to a growing reliance on pastoral rather than agricultural activities for generating income. While labor

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[7] Significantly, during the 1940s and 1950s the *bracero* program of labor migration to the US (originally intended to overcome farm labor shortages during the Second World War) provided the income with which many smallholders obtained draft animals (Carney, fieldwork interviews).

[8] West (1948) commented on the importance of wheat as a cash crop, noting that in Erongarícuaro Municipio twice as much land was planted to wheat as to maize.

Table 3. Contemporary cropping systems of Lake Pátzcuaro region

	Soil	Moisture regime	Cycle	Crops	Land use system[a]	Technology
Highlands						
Mountains	Tupuri (Andosol)	Residual soil moisture, then rainfall	--	--	Pasture	--
Slopes	Tupuri (Andosol)	Residual soil moisture, then rainfall	Mar-Nov/Dec	Maize, oats, triticale	Año y vez	Animal traction
Plains	Tupuri (Andosol)	Rainfall	Jun-Dec	Maize, triticale, broad beans, oats, potatoes, alfalfa, pasture legumes	Año y vez or año con año	Animal traction or tractor
Lake area						
Slopes	Charanda (Luvisol)	Rainfall	June-Dec	Maize, oats, triticale	Año y vez or año con año	Animal traction
Plains	Charanda (Luvisol)	Rainfall	Jun-Dec	Maize, oats, triticale, potatoes, beans, wheat	Año con año	Animal traction or tractor
Colluvial deposits (Invierno)	Charanda (Luvisol)	Rainfall	Oct/Nov-Mar/Apr	Wheat, lentils, triticale, pasture legumes	Double cropping 15 of 24 months (See Figure 4)	Animal traction or tractor
			Jun-Dec	Maize		
			Dec-Jun/Oct	Pasture		
Lacustrine	Ataimu (Gleysol)	Rainfall	Jun-Dec	Maize, alfalfa, triticale	Double cropping, WS Año con año	Animal traction or tractor
		Residual lake moisture	Oct/Nov-Dec/Jan	Forage legumes	DS Año con año	Animal traction or tractor
Irrigation	Charanda (Luvisol)	Pumped water	Nov/Dec-Apr/May	Maize, wheat, vegetables	Double cropping, WS rainfed, DS irrigated	Animal traction or tractor

Source: Fieldwork data.

[a] Land use systems: Año y vez = crop one year; pasture second year; repeat. Año con año = cropped annually. WS = Wet season. DS = Dry season.

migration and migrant remittances support the growing use of tractors over draft animals for field preparation, cattle ownership is nonetheless increasing. Farmers are de-emphasizing food crop cultivation as a source of farm income in favor of cash-earning strategies that are oriented towards sales of animals and their by-products, and the related demand for animal feed.

Contemporary Cropping Patterns

The año y vez system is currently practiced on sloped land as a two-field rotation, in which a field is grazed by cattle for one year and planted to crops in the next. The more fertile plains are generally sown continuously (known locally as *año con año*) (Table 3). In the lower communities where the luvisols enriched by colluvial deposits are located, a form of double cropping occurs, with the soil covered by crops 15 out of 24 months.[9] Figure 4, a diagram of cropping calendars by altitude, is a guide for understanding this double cropping system.

From September to November, wheat, lentils, or pasture legumes are sown. Until harvest from March through May, these crops are sustained by residual soil moisture from the main rainy season and by occasional winter rains (*cabañuelas*). After harvest, the field is planted to maize, which is cut from November to December. Cattle are then pastured on the plot until June or October, depending on whether the farm household decides to plant maize or wheat in the following cycle.

The variation in the crop and cattle components of this land use system over the past 40 years is a response to changing economic opportunities. The invierno production zone has long served as an area where farmers who are short of land have experimented with different forms of crop production. This is the droughty environment where the Tarascans adapted Spanish wheats to pay tribute to royal land grantees (*encomenderos*) (West 1948). With the demise of the hacienda system in the early twentieth century, wheat grown in the dry season (known locally as *trigo aventurero*) emerged as the major cash crop. Production of wheat during the dry season in humid soils has declined in importance only during the past three decades, and this decline is related to two important responses to technological and socioeconomic change. First, the availability from the 1950s of rust-resistant wheats enabled farmers to obtain higher yields of wheat planted in the wet season; second, in the past decade, farmers shifted to production of forage legumes in the dry season as the expanding cattle sector encouraged the development of markets for animal feed. Consequently, the two-year rotation of maize-cattle pasture-wheat is shifting to maize-cattle pasture-legume/animal feed (during the dry season).

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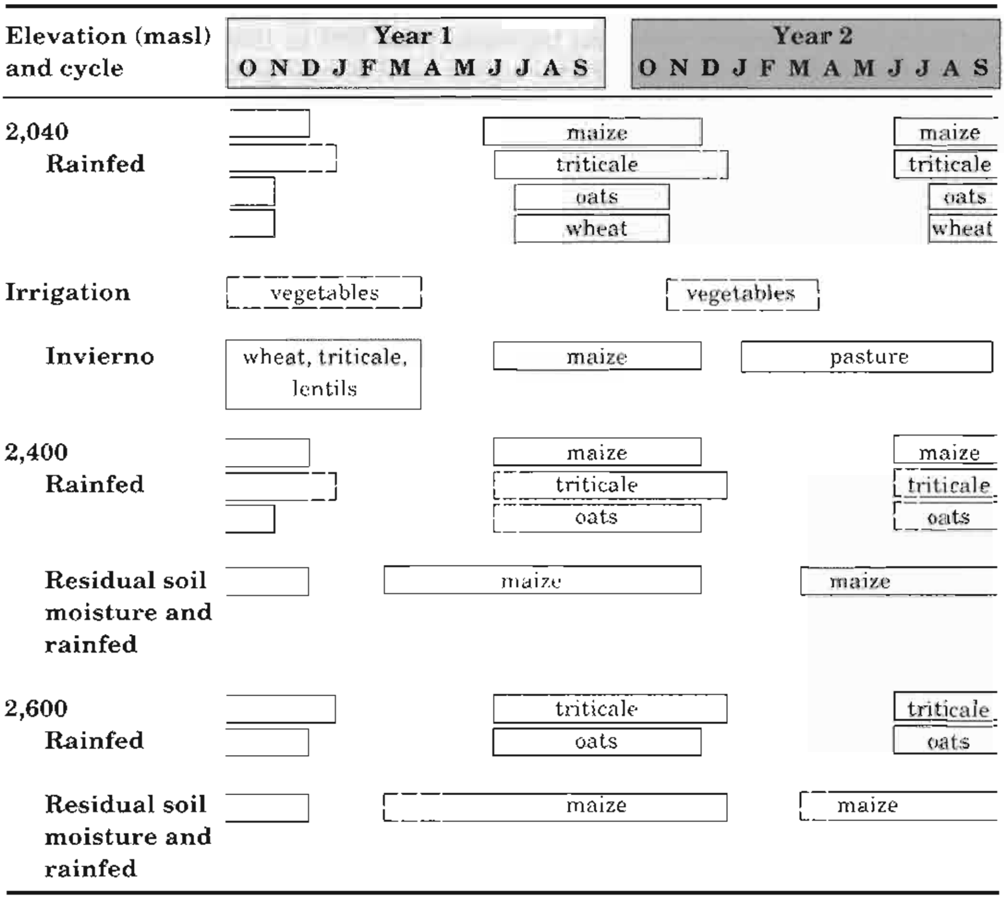
[9] This practice is found on perhaps about 15% of the municipio's land, particularly in indigenous communities.

In the upper farming zone, the shorter duration, rainfed (yellow) maize is planted in June, three months after the longer cycle (white) maize is sown into humid soils. Both types of maize are harvested in December. Depending on topography and edaphic factors, triticale and oats are sown between June and July and harvested from December to January. In the lower farming zone, maize is sown in June for a December harvest while wet season wheat, triticale, and oats are planted in July to mid-August and harvested in December-January.

Figure 4. Cropping calendar, Erongarícuaro Municipio.



Technological Change

Inorganic fertilizers were first available in the municipio in the late 1950s but were not widely used until the 1970s, when credit was provided for their use in maize cultivation and their price relative to a kilogram of maize decreased (Appendix C). While farmers do not receive credit for fertilizer used on wheat and triticale, 67% of the municipio's triticale farmers purchase fertilizer to use on those crops, chiefly ammonium sulphate and simple super phosphate.

The use of tractors has increased steadily since the 1970 agrarian census, when fewer than 3% of the municipio's farmers plowed their land with a tractor. By 1979, 30% were doing so (Tapia 1979), and in 1989, 50% of the municipio's farmers used tractors for field preparation. Among farmers growing triticale, the percentage of tractor users has increased from 50% in 1980 (Hansen 1981b) to 75% currently. The surge in tractor use by both farmer groups is related to high rates of migration to the US, which has had three important effects at the level of the household: labor scarcity, which makes tractor plowing cheaper than paying day laborers to prepare fields with ox-drawn plows;[10] remittances, which provide cash for households to hire tractor services; and an increasing "feminization" of agriculture, as female family members assume a greater role in farm management and decision making. Despite the trend towards greater tractor use, draft animals remain important for cultivating the stony hillslopes often planted to maize.

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[10] For households without labor for field preparation, tractor hire is cheaper. In 1989 it cost MN 80,000 to tractor plow 1 ha. On the other hand, to complete 1 ha with a team of an oxen required about five days at a labor/draft animal rental cost of MN 25,000-30,000 per day, or MN 100,000-150,000.

4

Smallholder Uses of Triticale

Triticale production patterns in Erongarícuaro over the past 20 years are examined in this chapter. The intent is to identify the ways in which triticale is utilized by smallholders, describe how these uses have shifted over time, and illuminate the factors influencing changing patterns of cultivation. On a broader level, the discussion draws attention to dynamics in smallholder farming systems which need to be better understood for the design and transfer of appropriate, sustainable technology.

Adopters: Current Utilization Patterns

The area sown to triticale peaked at the end of the 1970s when Tapia (1979) and Hansen (1981a) examined the crop's diffusion in Erongarícuaro, but its continued cultivation 10 years later suggests that triticale has secured a firm place within the farming system (Figure 5). The total number of triticale cultivators is about the same as a decade earlier, although area per cultivator has declined from 2.7 to 1.1 ha.[11] The contraction of area has resulted from the meagre and unprofitable opportunities for selling triticale grain locally and farmers' consequent adjustment of triticale area to meet their needs on the farm. The 78 ha planted to *triticale* represents about half of the area currently sown to wheat in the municipio (SARH 1988).

Even though the Eronga variety currently planted throughout the municipio was developed as a food grain, farmers presently use it only as a feed grain (Table 4), primarily for milch cows, chickens, and pigs. Few growers sell triticale grain, but in 1988 one farmer sowed 35 ha--nearly half the total area planted to triticale in the municipio--for sale as animal feed through regional feed markets. The primary value of triticale for most of the municipio's smallholders, however, is to improve household production through better animal nutrition and the marketing of animals or their by-products, milk and eggs.

Table 5, which provides a more detailed breakdown in triticale utilization patterns on farms, illustrates another important aspect of triticale production: triticale straw is also valued as a cattle feed and frequently mixed with maize stover. Demand for straw in the municipio is constant because of the high rates of animal ownership,[12] and straw is also occasionally marketed.

In addition to using triticale grain and straw for feed, Erongarícuaro's farmers also utilize the crop as forage. Six cultivators grazed animals on their triticale

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[11] Figures of area planted per cultivator in 1988 have been adjusted to drop the one farmer who sowed 35 ha.

[12] Between the 1950 and 1970 agrarian censuses, animal ownership in the municipio nearly doubled from 1,338 to 2,717 head. Most of the increase was in cattle. SARH extension agents do not have current figures but agree that numbers are increasing, an opinion corroborated in village group interviews.

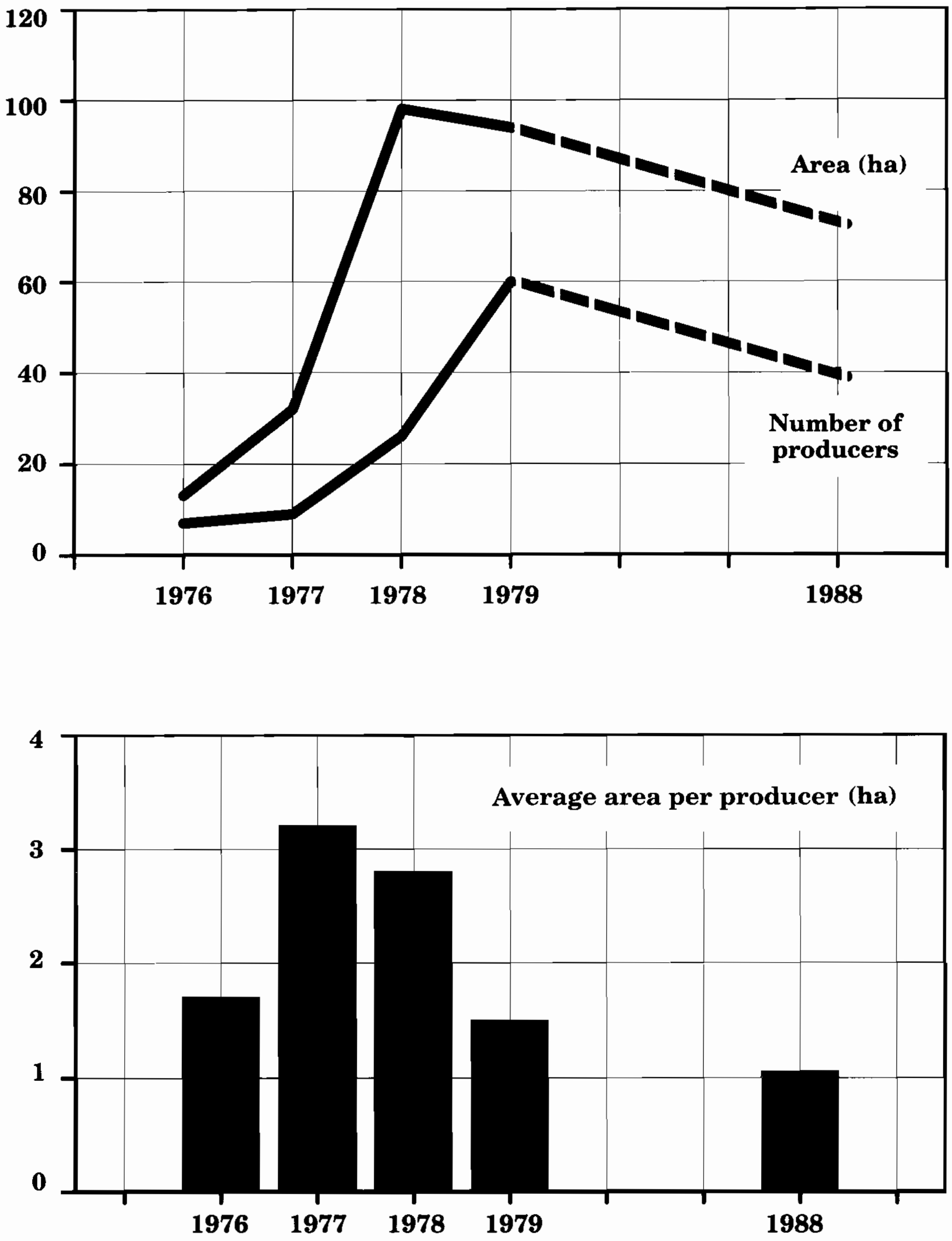

Figure 5. Area, number of producers, and average area per producer for triticale, Erongarícuaro Municipio.

Sources: Data for 1976 and 1977 from growers list kept by M. Campos, Erongarícuaro; 1978 and 1979 data from Hansen (1981a); 1979 farmer number from Tapia (1979); 1988 data from Carney fieldwork (excludes grower who planted 35 ha).

parcels in 1988, but only two farmers planted triticale explicitly for this purpose. Both had fenced parcels which prevented the intrusion of free-ranging animals. The other four cultivators turned their triticale plots into pasture when the crop was damaged by an early September frost. Converting an agricultural plot to a grazed field in the wake of early frost is a common practice in the area and one that has led farmers to appreciate triticale's grazing quality and to inquire frequently about the availability of forage triticale. Interest in forage varieties appears to be growing as more farmers tend to "store" assets in cattle and orient marketing strategies towards animal sales.

Table 4. Farmers' main purpose for cultivating triticale, Erongarícuaro Municipio, 1988

Purpose	**Number of farmers**
Food grain	0
Feed grain on farm	28
Feed grain for sale	2
Straw for forage	3
Straw for sale	0
Seed for sale	1
Total farmers	34

Source: Fieldwork data.

Table 5. Growers' use of triticale in 1988: proportion of crop by use category, Erongarícuaro Municipio

	Percent farmers (n = 34) use triticale for:					
Proportion of total crop	**Food grain**	**Feed grain**	**Use straw for feed**	**Sell straw**	**Seed**	**Sell grain**
None	97	6	12	85	0	7
< 10%	3	0	0	3	91	0
11-75%	0	3	0	0	6	9
> 75%	0	91	88	12	3	21

Source: Fieldwork data.

Adopters: Past Utilization Patterns

When Tapia (1979) and Hansen (1981a) researched triticale diffusion patterns, researchers' and farmers' perceptions of triticale were shifting from its potential as a feed crop to a food crop. Increasingly, farmers were cultivating substitute triticale, primarily Bacum and Armadillo, as a food crop (Tapia 1979). While Goqui, a forage variety, continued to find favor, more interest was placed on the first two varieties, which showed promise as wheat flour replacements. These varieties were more easily milled (Varughese and Kohli, pers. com.) than the complete varieties, Juanillo and Eronga, diffused in the following years.

Tapia's study captured the burgeoning enthusiasm for triticale's potential as a food crop, which framed the way that his data were interpreted. Despite the fact that 50% of triticale farmers were cultivating the grain for animal consumption,[13] Tapia (1979) focused on the 5% who used the crop on the farm for food and the 23% who sold it.[14] He noted that in area cultivated triticale was rapidly replacing wheat, which he attributed to triticale's higher yields and to producers' growing interest in the grain as a substitute for wheat. Tapia argued that the major factor limiting production was millers' unfamiliarity with triticale and the lack of a commercial price. Once triticale became "known" in the marketplace, the drop in triticale area from 1978 to 1979 would rebound. He also believed that triticale area had declined between these two years because of overplanting by enthusiastic pioneers who had prematurely confronted the market with a new crop.

Tapia viewed triticale as a multipurpose cash crop--the grain for milling into flour, the straw for animal consumption. He compared the socioeconomic characteristics of triticale producers with nonproducers to show that the former group had more animals per cultivator, were less likely to leave land fallow, and consequently were more commercially oriented. Triticale cultivation thus represented a form of agricultural intensification among more market-oriented smallholders.

In 1980 another agricultural economist, Hansen, examined triticale diffusion in Erongarícuaro. He was interested in technology transfer, specifically the way in which varietal development could be made more useful for smallholders. Whereas Tapia concentrated on the use of the crop as a wheat flour substitute, Hansen examined the utilization of triticale for animal consumption. Hansen regarded triticale cultivators as representative of the municipio's smallholders, whom he viewed as "traditional" farmers. For him the critical difference

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[13] Of the grain used for animal feed, 70% was fed to milch cows and 30% to pigs. Very little was fed to chickens and draft animals (Tapia 1979). By 1989, farmers had learned that triticale also provided a high quality chicken feed.

[14] Tapia argued triticale was sold as a wheat-flour substitute.

between traditional and commercial cultivators was the importance of draft animal traction to the former and the crucial fact that the livestock had to be fed. Hansen's results show that the production of triticale for use on the farm had grown to 25% from the 5% reported by Tapia two years earlier (Table 6). He suggested that the increased on-farm use of triticale was due to its importance for animal, rather than human, consumption.

Whereas Tapia had focused on declining wheat production in the rainy season and on the role of triticale in replacing wheat, Hansen's attention was drawn to the role of dry season wheat production in the farming system. Although farmers milled the wheat grain for flour, wheat also provided straw in the spring when draft animal feed demands soar and fodder supplies dwindle. He carried this insight to his analysis of triticale adoption patterns among smallholders, arguing that straw quality was important in producers' acceptance of the crop.

Hansen's emphasis on the importance of straw in smallholders' acceptance of the crop caused him to assign less attention to the role of triticale grain in animal consumption. But his research did reveal the importance of agro-pastoral activities in Mexican smallholder farming systems. He showed that farmers were utilizing triticale for their animals, in direct continuity from their initial experiments 15 years earlier with rye and unimproved triticale for forage. Hansen also sought to further researchers' understanding of ways to make technology design appropriate for smallholders by arguing for a shift from single- to dual-valued approaches--in effect, favoring a breeding strategy that would also support research on triticale for animal needs (1981a). His study thus drew attention to the fact that the improvement of milling quality

Table 6. Growers' use of triticale in 1980: proportion of crop by use category, Erongaricuaro Municipio

	Percent farmers use triticale for:			
Proportion of total crop	**Home consumption (n=84)**	**Animal feed (n=79)**	**Seed and other uses (n=79)**	**Sale[a] (n=80)**
None	74	19	52	46
< 10%	21	3	29	8
11-75%	4	26	16	28
> 75%	0	52	3	19

Source: Hansen (1981a).

a Not clear if sale of grain and/or straw.

and test weight (important characteristics in triticale intended for human consumption) was unimportant in triticale destined for animal rations (CIMMYT 1986) and that additional research was required on this significant aspect of smallholder varietal development needs.

Nonadopters, Disadopters, and Recent Adopters

Farmers who have never tried triticale cultivation typically are short of land, own few or no animals requiring feed, and consider the crop costly to produce. All but the first factor are strongly correlated with the demographic cycle of the household, namely aged parents or those with children in higher educational institutions, in migration to the US, or to urban areas of Mexico. Such households experience a shortage of family labor to assist in the harvest (predominantly performed with a sickle).

Patterns of disadoption in 1988 and 1978 are presented in Tables 7 and 8. Of the farmers interviewed during 1988/89 who had stopped growing triticale, all but two had done so within the previous 10 years. More than half had ceased cultivation because they sought a cash crop. Triticale failed to meet that expectation because farmers were unable to find a market for the grain or found oats a more profitable substitute. This second, more frequently cited, response is significant because oats are used as fodder in the municipio and find a ready market.[15]

Table 7. Reasons for disadoption of triticale, Erongarícuaro Municipio, 1988/89

Reason for disadoption	Number of farmers
High harvest costs	13
Oats cheaper to produce, better market price	10
No market	8
Unsatisfactory wheat flour substitute	4
Crop lost to frosts	3

Source: Fieldwork data.
Note: N = 38.

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[15] One important facet of production is that area sown to oats is fairly evenly divided between rainfed production and dry season production on humid soils, which suggests that oats have year-round value for animal feed.

Households' income-seeking strategies also figured in reasons for disadoption in 1978 (Table 8). While only three respondents directly referred to the lack of a market as a reason for disadoption, two other responses, preference for another crop and land unavailability, are related to this reason. During the period of Hansen's research, triticale was cultivated only in the wet season, the principal cropping period. Households with a limited resource base make decisions on crop selection in the context of which crops can best meet their subsistence and cash needs. In Erongarícuaro maize meets the former need and, traditionally, wheat the latter. The failure of a market to develop for triticale as a replacement for wheat flour diminished triticale's value as a cash crop and favored other crops on the few hectares typically available for planting in the wet season.

In 1988/89 losses to frost figured as three informants' reason for disadoption, but when the data are disaggregated and ranked for multiple responses, more than half the interviewees had problems determining appropriate sowing dates to minimize the risk from early autumn frost. This problem was particularly apparent in the *charanda* soil areas in the lower altitudes (Figure 3) where farmers depend on the rains to begin planting triticale. Loss of grain to frost figured as the most common factor precipitating the decision to abandon triticale cultivation.

Table 8. Reasons for declines in and disadoption of triticale production, Erongarícuaro Municipio, 1978/79

Reason for decline/disadoption	**Number of farmers**
Land unavailable	14
Seed problems: unavailability, impurity, cost	11
Prefer other crop	9
Migration or ageing household labor force	6
Lack of fencing	5
Lack of market	3

Source: Adapted from Hansen (1981a).
Note: N = 48.

The most frequently cited response for disadoption in 1988/89 was high labor costs, especially for harvest. During the period covered in the 1978 and 1988 disadoption surveys, the cost of labor rose in response to increased migration to the US for work (Hansen 1981b).[16] Labor costs, however, become significant for triticale disadoption only when combined with the charges for postharvest threshing and dehulling, which make triticale a more expensive animal feed than oats. Although outmigration has undoubtedly reduced family labor availability and raised agricultural wage rates above the national average of MN 10,000/day (Table 9), the costs of cutting and binding a plot's production are about the same for triticale as oats. But unlike oats, an awned triticale variety such as Eronga must be threshed and dehulled so cattle can digest it.[17] The additional costs, presented in Tables 10 and 11, give oats a comparative advantage as a livestock feed even though oat yields seldom exceed 700 kg/ha.

Table 9. Daily agricultural wage rates in selected communities, Erongarícuaro Municipio, 1989

Community	Average wage (Pesos/day)	Equivalent in kg maize/day[a]
Napizaro	12,500	33
Zinciro	12,500	33
Lazaro Cárdenas	11,000	30
Erongarícuaro	11,000	30
Uricho	11,000	30

a Hibon (1990) reports wage rates equivalent to 25 kg maize/day in another region of Mexico, where farmers are also predominantly smallholders but where migration rates are lower.

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[16] Legal migration to the US from the municipio began in the 1940s when the US initiated the bracero program and continued until the mid-1960s. When labor migration became illegal, young men who left Michoacán returned less frequently to help with farming during the agricultural season. Villagers point out that during the 1980s migration to the US soared and shifted to longer term patterns. One migration study of a community in the municipio reveals the significance of 1980s migration patterns for agricultural labor: 70% of the households in the village had family members in the US, and these households had an average of 2.8 migrants each (Taylor 1986).

[17] Farmers claim that, if the grain is not milled, livestock choke on its awns. Awnless varieties of triticale are unavailable in Mexico, but smallholders still recall one (Goqui) that was released by CIMMYT researchers for local experimentation during the 1970s.

The significance of threshing and dehulling costs on household decisions to cultivate triticale changes, however, with the type of technology available to smallholders. Table 10, which compares costs of harvesting by hand and with a combine, shows the considerable savings possible with the latter, which cuts and threshes the grain; but there are no small-scale or intermediate combines

Table 10. Average harvesting and threshing costs for triticale per hectare, Erongarícuaro Municipio, 1989

Technology and year	Operation and cost (Pesos/ha)		Total cost (Pesos/ha)
	Cut and bind	Thresh[a]	
Manual harvesting and thresher			
1987/88	134,000	160,000	294,000
1988/89	218,000	200,000	418,000
	Combine		
Combine harvesting			
1987/88	60,000		60,000
1988/89	133,000		133,000

Source: Fieldwork data.

a Based on yield of 2 t/ha.

Table 11. Post-harvest dehulling costs per hectare for triticale, Erongarícuaro Municipio, 1989

Year	Cost per hour (Pesos)	Average triticale dehulling rate[a] (kg/h)	Average yield (kg/ha)	Cost (Pesos/ha)
1989	25,000	500	2,000	100,000

Source: Fieldwork data.

a Dehulling done with mill.

available in the municipio. A large combine harvester is available, but only to growers who plant triticale on the plains in the lower reaches of the municipio. The combine owner is reluctant to spend hours to reach plots of a few hectares scattered on the slopes and in the intramontane valleys in the upper reaches.

Farmers who have just begun to grow triticale do so for quite specific purposes, all associated with animal husbandry. Another significant change from the 1978/79 study and previous patterns of adoption is that triticale is beginning to be adopted by farmers who are short of land but increasing livestock ownership. Many recent adopters have 4 ha of land or less and grow triticale because they lack pasture. Triticale straw is of relatively minor importance compared to the grain, which is recognized as a superior feed for dairy cattle. Triticale is also cultivated by some of the municipio's farmers who specialize in poultry production for the market. Recent triticale adopters tend to apply both fertilizer and herbicide to boost production of what they consider a high-quality feed grain that hastens animal fattening.

Triticale Adoption Patterns and Smallholder Cash-Generating Strategies

The earliest growers experimented with triticale for forage, though by the 1970s Tapia was able to link the crop's rapid diffusion to its potential as a wheat replacement. But in the two years spanning Tapia's and Hansen's fieldwork, the number of farmers growing triticale for sale increased from 23% to 54%, representing a shift to its sale for animal consumption (Hansen 1981a). By 1988/89, sales of triticale had diminished to 30%, but its use as a feed for animals on the farm had expanded.

An historical framework elucidates why Erongarícuaro's farmers participated so enthusiastically with CIMMYT breeders in developing a high-yielding food type triticale. During the 1970s when wheat remained the primary cash crop, triticale delivered much higher yields than local wheats. Interest in the crop as a wheat flour substitute was growing at the local, regional, and state levels. Farmers' wives experimented with it for bread, as did millers throughout the region. The national agricultural research organization in conjunction with CIMMYT gave the regional extension service seed to multiply for distribution, while the state government provided financial backing for the cooperative bakery to produce bread made partly with triticale flour. CIMMYT personnel interested in helping smallholders realize triticale's potential regularly visited Erongarícuaro. A market appeared to be developing, and smallholders encouraged the research orientation underway, which led breeders to select for grain yield and food qualities. But by the mid-1980s the market for triticale as a wheat replacement had failed to materialize.

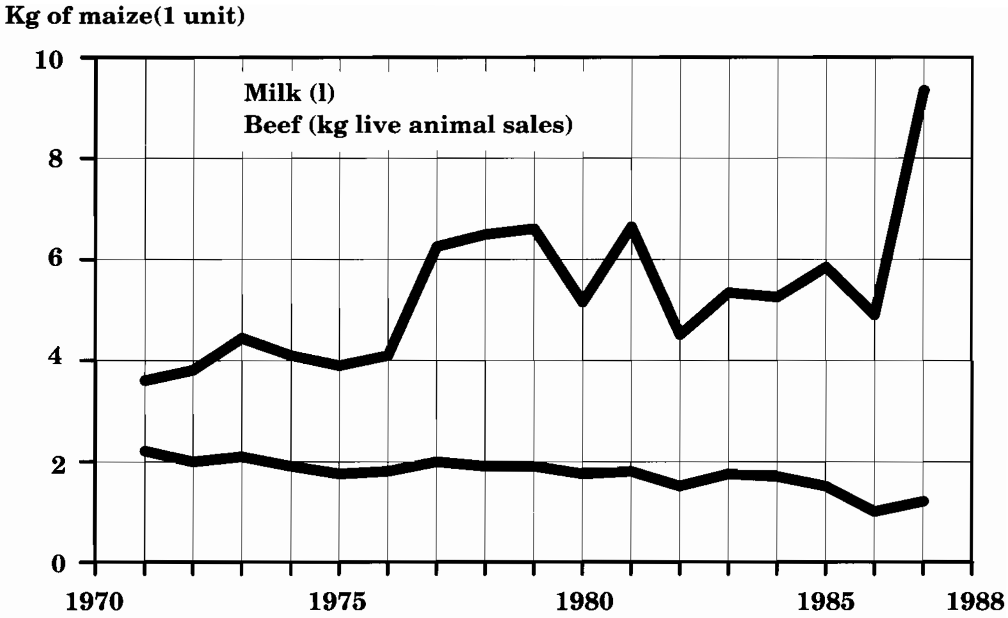

Figure 6. Prices of meat and milk relative to maize, Mexico, 1970-88.
Source: Adapted from Hibon (1990).

Although markets failed to develop, farmers had accrued considerable experience with triticale as an animal feed. Initially it was sold for that purpose, but in the 1980s when labor migration made oats cheaper to produce, adoption patterns shifted and triticale was used on the farm, as a quality feed for specific farm animals. The current emphasis of smallholders on livestock and animal products for cash generation is brought into relief in Figure 6, a graph of Mexican milk and meat prices relative to maize for 1970-88. The steadily declining relative price of milk in evidence during the past few years has forced farmers to look at cost savings in dairy production. Triticale, which enables an increase in daily milk output,[18] is a high-quality animal feed. The increasing relative price of beef, on the other hand, has made it more profitable for smallholders to emphasize cattle over food crop production.

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[18] Farmers say: "With triticale cows give more milk, hens lay more eggs, and pigs fatten rapidly."

A recent study on outmigration in two of the municipio's villages illuminates the importance of livestock in village production linkages. The two villages, representative of communities found throughout the municipio, were net importers of feed grain (accounting for 17% of household income transfers), but they were "exporters" of animals and animal products, which amounted to 38% of gross output (Adelman et al. 1987). Conversely, sales of crop products contributed only 11% to total family income. Besides demonstrating that the villages are open rather than "traditional" economies, the data illuminate how important sales of animals and their products are to household economic activities in the 1980s.

In conclusion, the reorientation in triticale use during the past decade from 25% to 3% as a food crop, with nearly all the rest used as animal feed, and overall changes in the commercial orientation of triticale from 54% to 30% for sale, represent important shifts in utilization patterns. By the early 1980s, when the market for triticale as a wheat flour substitute floundered and labor markets changed, farmers had accumulated considerable experience with the crop. They had learned to adjust the food crop variety to some of their farm animals' needs, and they had incorporated triticale into a diverse range of microenvironments.

5

Smallholder Experimentation with Triticale

This chapter examines the experience and innovation of Erongarícuaro's farmers with triticale. The intent is to demonstrate how pre-existing agroecological principles are applied to a new cultivar or crop and to illustrate how that knowledge can promote adoption in periods of social and economic change. Rhoades and Bebbington (1988), who identify three types of farmer experiments, provide a useful framework for organizing the material included in this chapter. Adaptation experiments are conducted by farmers who test a new technology within a known agroecosystem. Problem-solving experiments take place when farmers seek solutions to old and new problems, whereas curiosity experiments are those which farmers, much like agricultural scientists, set up to test an idea that comes to mind.

Adaptation Experiments with Triticale

This type of experimentation occurs when farmers test a new technology, such as a triticale variety, within a known environment. Experimentation involves growing the variety in a range of land use areas as well as monitoring and assessing crop growth and performance. In the case of triticale in Erongarícuaro, the objectives of this experimentation were to test where triticale grew best; to determine where periodic risks could be minimized; and/or to adjust a crop's cultivation to a farm family's limited resource base. These types of experiments bring into relief the significance of farmers' knowledge of specific microenvironments and soil moisture reserves for their ability to adopt triticale.

Although the upper and lower farming systems in Erongarícuaro are climatically distinct, they share three major land use areas: the slopes, plains, and special microenvironments where soil moisture-holding capacity extends the cropping calendar. Farmers have experimented with triticale cultivation in each topographic area as well as under each type of moisture regime. This experimentation has increased their ability to adjust triticale cultivation to changing household circumstances and needs.

When triticale was emerging as a potential cash crop to replace wheat, cultivation focused on the wet season. The earliest adaptation experiments aimed to establish ideal seeding rates and sowing dates once the rains commenced. Initially triticale was grown with a seeding rate of 80 kg/ha, but farmers found this too low for desired plant populations and subsequently adjusted seeding density to 150 kg/ha, which is now the average rate. The determination of ideal planting dates has been more problematic for triticale farmers. Planting dates vary considerably from one community to another because of the municipio's steep terrain and microclimatic differences. Erongarícuaro's farmers have consequently learned by trial and error when to plant a variety with a longer cycle than the native wheats.

Two villages at the same altitude (2,080 masl) in the lower reaches of the municipio plant rainfed triticale at quite disparate periods: one from the second to the third week of July; the other from the fourth week of July through the first week of August. These differences reflect microenvironmental variance. The major crop risk is the occasional frost during flowering. Triticale flowers earlier than wheat and requires a longer period for the grain to ripen. It generally flowers about 65-70 days after planting and is vulnerable to frost until 110-120 days of growth, or from approximately weeks 10-17 of the cultivation cycle. A mid-July to early August planting thus places the crop at risk from the last two weeks of November to the first 15 days of December, about the time triticale is ready for harvest. While there was an unusually rare frost in September 1988, the 15-year average risk for nearby Pátzcuaro (at nearly the same latitude) was just two days towards the end of November and four in December (Figure 7).

In the upper municipio's communities (2,400 masl) for which no meteorological data are available, frost represents an even greater hazard. The planting of rainfed triticale is generally underway by the third week of July, and the crop is harvested in late November or December. Farmers have experimented by planting triticale on both the plains and higher volcanic slopes. They say that, although triticale grows taller in the flat valleys, it experiences greater frost

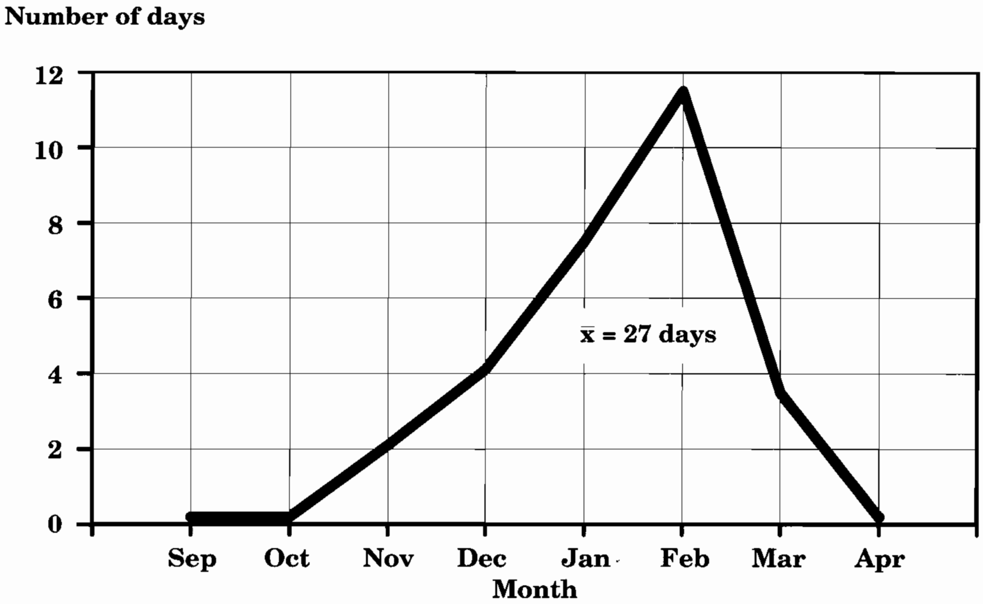

Figure 7. Mean monthly days of frosts, Pátzcuaro, 1971-85.
Source: SARH.

risk; consequently, many farmers plant it on the volcanic slopes. One farmer in 1988 experimented with sowing triticale during the second week of August at 2,600 masl on the slopes. His crop was not damaged by the early September frost that affected plots on the plains, and his experiment proved successful. He obtained the community's highest triticale yield: 2.5 t/ha.

As triticale use has shifted towards animal feed during the past decade, farmers increasingly have tended to sow the crop in humid soils, a practice that permits early autumn or spring harvests and makes fodder available when supplies are lowest. Two microenvironments favor dry season cultivation: the soils exposed by the seasonal retreat of the lake, and the luvisols enriched by colluvial deposits, located in the municipio's lower area. In the municipio's upper area, an early autumn harvest is possible by planting triticale in the humid t'upuri soils. By sowing triticale in these soils at the end of May or early June, prior to the onset of the rains, farmers seek to reduce the crop's risk from autumnal freezes and provide their animals fodder before the maize harvest. Each type of adaptation to humid soils provides farmers flexibility in meeting the year-round fodder needs of their animals.

Adaptation of triticale to dry season cultivation in the winter on humid colluvial soils has involved considerable experimentation. Sowing dates must be adjusted to avoid two types of stress, drought and frost. The crop relies on occasional rains, which average only 81 mm, and the flowering cycle must be attuned to months when frost risks are minimized. Seeding dates for dry season cultivation vary considerably, with planting occurring from late October to December and harvests in the months of April through May. Because dry season farming is risky, smallholders seldom apply fertilizer, and this has led to a reduction in fertilizer use among triticale cultivators in the past decade, from 80% reported by Tapia (1979) to 67%.

Although Erongarícuaro's smallholders have the accumulated experience to know the microenvironments where triticale grows best and risk is minimized, many triticale farmers have to adjust cultivation to their limited resource base. One-third of Erongarícuaro's triticale farmers have less than 5 ha available for cultivation. This group of farmers is most likely to plant triticale during the dry season. Though they know the yields will be lower than during the rains, they also know that dry season production is a form of agricultural intensification that enables farmers with little land to obtain a feed crop for their animals during the spring.

Problem-Solving Experiments

Problem-solving experiments, in particular, illuminate the role of perception and household decision making on triticale utilization. These experiments also reveal how smallholders' incorporation into wider economic circuits has implications for their decisions on how to use triticale. Problem-solving experiments by triticale farmers have taken place in the two distinct epochs of cash-generation strategies affecting triticale utilization: 1) the 1970s, when the crop was viewed as a wheat flour substitute; and 2) the 1980s, when it is utilized for animal feed.

The woman who experimented with making bread from triticale flour portended not only subsequent research on the grain for food but also smallholders' interest in growing a highly productive wheat substitute for *sale*. In the 1970s when triticale diffused rapidly throughout Erongarícuaro, none of the available wheat varieties could rival triticale in yield. Wheat was the region's principal cash crop.[19]

During this period, much local experimentation was underway with mixing triticale and wheat flour. Eventually a mixture of 20-30% of triticale flour with wheat flour was found to give the best results, reducing the bread's "gummy" quality. Several families who have experimented with triticale flour milled from the Eronga variety point out that they achieved better baking results with the older substitute triticales, Alamos and Mapache. One man who was involved with the triticale bakery in Erongarícuaro explained why Mapache was considered the best bread-making triticale: it had desirable taste qualities and was soft grained. Smallholders also experimented with some success in using triticale for pastries and tortillas. Tortilla dough made from triticale is easier to flatten than wheat tortilla dough, but people prefer maize tortillas made from grain of local land races. Local experiments substituting triticale flour for wheat flour have now generally ceased because wheat flour is relatively inexpensive.

As discussed earlier, Erongarícuaro's farmers have experimented with triticale as an animal feed since its introduction. The major problem in converting Eronga from human to animal uses is the grain's awns, which make cattle choke. Farmers have solved this problem by dehulling the grain or milling it with the straw, a process that removes or breaks up the spiked awns but increases the costs of using triticale to feed dairy cattle.

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[19] Tapia (1979) reported 88% of sampled farmers growing wheat for sale.

Curiosity Experiments

The first of four curiosity experiments was farmers' experimentation with triticale as animal forage. Their results were positive enough that they continued to sow triticale, which caused other smallholders to experiment. Those farmers who planted triticale in the earliest period of its diffusion throughout the municipio still speak well of Goqui, a tall, awnless variety that performed well. However, they lost the seed and have not been able to locate it elsewhere.

A second, and related, curiosity experiment currently underway is to see how triticale performs mixed with other grain crops as animal forage. At least two farmers in 1988 planted it with barley and wheat during the rainy season to determine if it improved their animals' diets. They claim, however, that Eronga does not regenerate well after grazing.

Building upon the experience of dry season cultivation, a third curiosity experiment involves one farmer who has experimented with rotating triticale with potatoes. He hypothesized that the fertilizer applied to potatoes might have a residual benefit for triticale, which he plants in humid charandosa soils as a dry season crop immediately after harvesting the potato crop in late October. Despite the fluctuations in winter precipitation from year to year, his method yields a better harvest than is obtained by other dry season farmers. His triticale plot regularly yields between 1.5 and 2 t/ha.

The wife of the farmer who tried mixing triticale flour with wheat for bread in 1969 also conducted a curiosity experiment. She and her family viewed triticale as a more productive type of wheat than the aventurero varieties then available. Her experience with various substitute triticales resulted in a slightly leavened bread with acceptable taste qualities. Her experiment was communicated with much enthusiasm to CIMMYT plant breeders and provided support for the directions that were emerging in triticale research.

All the experiments examined in this chapter point out how farmer experimentation and individual innovation interact to bring about crop adoption. But they also draw attention to the socioeconomic, environmental, and historical contexts in which adoption occurs. Over the past 10 years, the shift toward feed crops and animals and their by-products as sources of farm income has effected concomitant changes in the ways smallholders have managed the microenvironments available for their livelihood. Their knowledge of the specific agronomic potential of each microenvironment has proved crucial in maintaining and diffusing triticale cultivation as income opportunities have changed.

Conclusions

A corollary of the growing emphasis on developing production technologies appropriate for the rural poor is that they be sustainable. Crop research for the stressed environments where smallholders frequently farm requires special attention to the development of production technologies that are environmentally sound, enhance the long-term productivity of resources, and ensure the stability of ecosystems (CIMMYT 1989b). This research approach in essence calls for the development of crops that promote resilience, resistance, and flexibility (Clark and Munn 1986).

As this review of triticale utilization in Erongarícuaro over the past 20 years points out, triticale is one such crop. It has enhanced smallholders' flexibility in responding to social, economic, and environmental variability and promoted the resilience of the agropastoral farming system, critical to rural livelihood and welfare. Triticale has emerged as a sustainable crop among this group of smallholders because it has provided farmers flexibility in adjusting their crop-livestock system to social and economic change. But as this study has also shown, farmers' cumulative experiences with growing triticale during the past decades proved crucial in recognizing the crop's potential. It was farmers' knowledge of the uses of triticale, rather than the specific type of variety developed by researchers, that made triticale sustainable in the farming system.

One conclusion reached by this study is that interest in the rural poor does not necessarily lead to work on crops for home use or food. Smallholders in Erongarícuaro, like large land holders elsewhere, are actively engaged in the market. But their limited resources require them to integrate cash-generating strategies with subsistence needs. Researchers need to recognize that appropriate crop development for the rural poor should not solely focus on food crops.

Another conclusion that can be drawn from the experience of Erongarícuaro's smallholders with triticale is the significance of crop-livestock interactions for the sustainability of smallholder systems and rural livelihoods. Even though we do not yet have utilization studies for triticale in other smallholder production areas like Madagascar, China, and Tanzania, agropastoral activities figure as a fundamental component of many smallholder farming systems in Latin America (Mayer 1979), sub-Saharan Africa (McDowell 1988), and southwestern Asia (Husain 1990). Farmers in Michoacán, Mexico, much like those in Poland, Tunisia, the US, Australia, and many European countries, plant triticale for animal feed. It now appears time to adjust crop development research to this fact.

There is need for research on the two types of uses to which smallholders have directed many of their adaptation experiments: forage and feed grain. As we have seen, interest in triticale by Erongarícuaro's smallholders originally derived from experiments with the crop as animal forage, and only briefly shifted to its food potential when markets appeared to be developing. Early recognition of the potential of this "wheat for animals" (as it is known locally), however, led to continuous experimentation with the crop as an animal feed. It was this accumulated experience that enabled smallholders to adjust the available food crop variety to the needs of specific farm animals. While this adjustment maintained triticale within the farming system, the cost of dehulling the grain has limited the crop's diffusion to those involved in dairy and egg production. But the crop could play an even more important role as a generalized animal feed, and also benefit more resource-poor farmers, by providing a cash crop for sale to livestock owners. Development of an awnless variety or one that does not require dehulling would give triticale a comparative advantage to oats, since triticale yields better, even without the application of fertilizer; fares well under drought stress, as witnessed by yields in dry season cultivation; compares favorably in forage production and protein content (Skovmand et al. 1984); accumulates more phosphorus in its straw, important for the nutrition of certain types of farm animals (Skovmand 1984); has a higher biomass production (CIMMYT 1986); is more resistant to the foliar diseases prevalent in oats (Tuleen et al. 1985); and yields better in phosphorus-deficient soils, like those in Erongarícuaro's upper reaches.

Forage triticales also merit research. Significant advances on forage triticales have already occurred in Argentina (Kohli pers. com.). These varieties should be tested and modified for Mexico's conditions, and trials set up to analyze regeneration under grazing pressure. They also should be tested for how well they produce without inorganic fertilizer, a scarce resource for many of the Third World's smallholders, which makes them reluctant to apply fertilizer on a crop destined for their animals.

A research program on forage and feed triticales may also necessitate a reconsideration of the current emphasis on complete triticale types. Soil analyses in the municipio's microenvironments show a mean pH of 6.1, and suggest that the volcanic soils are far less acidic than believed by extension agents. A more significant problem of some of the county's soils is phosphorus deficiency; the respective merits of substitute and complete triticales should be evaluated on phosphorus-deficient soils.

Research already underway at CIMMYT on shorter duration triticales holds considerable promise for smallholders, since earlier maturity would reduce the risk from frost. Triticale needs about 135-140 days to mature, but primary triticales have been produced that take only 128 days to mature (Varughese 1987). Cutting one or two weeks off of the crop's maturation period would substantially diminish the early autumn frost hazard frequently experienced with planting triticale in the municipio's upper reaches.

The diversity of microenvironments sown to triticale, and the decades-long experience of Erongarícuaro's smallholders in growing the crop, continue to make the municipio a valuable testing area for research on forage and feed triticales. It presents a microcosm of several agroclimatic and highly differentiated microenvironments, a diversity which is characteristic of many tropical highland areas. The range of edaphic environments offers researchers many opportunities for conducting on-farm trials on triticale's drought tolerance, frost risk, phosphorus extraction, and regeneration under grazing pressure. The region moreover benefits from an extension service (SARH) that has actively worked to service its clients' needs. This institutional framework, which at an earlier period was the vehicle for the conjunction of the complementary expertise of smallholders and CIMMYT researchers, can be so again.

In addition to identifying traits that smallholders would like to see in triticale varieties, this study offers another important insight for research. The farmer-scientist collaboration is significant for the development of agricultural technologies appropriate for the resource-poor farmers who frequently cultivate small, fragmented parcels in marginal environments. Erongarícuaro's farmers played a crucial role in initial experimentation with triticale, and their interaction with biological and social scientists was, and remains, important for triticale's development. In smallholder farming systems, social and economic factors such as the size of land holdings, international labor migration, and changing food policies can disrupt an agricultural system as decisively as environmental factors such as drought, temperature extremes, pest problems, or soil nutrient loss (Hecht 1987). Farmer-scientist collaboration thus facilitates the conjunction of complementary types of agronomic knowledge that is so critical to addressing the needs of farmers (Bebbington 1988).

Finally, and of relevance to the broader concern with developing sustainable technologies for smallholders, this study argues that the challenge posed will require an innovative and integrated framework--one that builds on the perspectives of scientists working from differing research disciplines. This study was strengthened by the work of agricultural economists, anthropologists, geographers, soil scientists, plant breeders, agronomists, and human ecologists who have conducted research in the Tarascan area of Mexico over the past 50 years. Building on the best of traditional and modern scientific practices may prove just the foundation needed to meet the challenge of developing sustainable technologies for smallholders.

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Appendix A

Land ownership and population by community, Erongarícuaro Municipio, Mexico

Community and type of land ownership	Population, 1980	Area (ha)	Number of households	Area per household (ha)
Zinciro				
Ejido	838	457	75	6
Nocutzepo				
Ejido		484	101	5
Private		34	13	3
Total	661	518	114	5
Jaracuaro				
Communal	1,452	84	60	1
Uricho				
Ejido		247	89	3
Private		108	65	2
Total	1,453	355	154	2
Erongarícuaro				
Ejido		628	86	7
Private		246	31	8
Total	261	874	117	8
Napizaro				
Ejido	679	773	84	9
Lazaro Cárdenas				
Ejido	683	476	66	7
Yotatiro				
Private	315	228	33	7
La Zarzamora				
Ejido		53	26	2
Private		160	na	na
Total	379	213	26	2
Colonia Revolución				
Ejido		47	29	2
Private		13	12	1
Total	na	60	41	2
Arocutin				
Ejido		150	51	1
Private		51	57	3
Total	386	201	108	2
Puacuaro				
Ejido		144	70	2
Private		12	15	1
Total	1,452	156	85	2
Oponguio				
Private	310	64	23	3
Tocuaro				
Private	361	71	44	2
Grand total	**11,270**	**4,530**	**1,030**	**4**

Source: SARH, 1980 Population Census. na = not available.

Appendix B

Maize production in Erongarícuaro Municipio, selected years

Year	Area (ha)	Yield (kg/ha)	Production (t)
1950	1,949	927	1,806
1970	1,117	704	786
1982	2,736	1,160	2,536
1983	1,824	2,066	3,769
1984	1,817	1,780	3,241
1985	2,299	1,766	4,061
1986	2,106	1,529	3,221
1987	2,087	1,254	2,618
1988	1,436	1,799	2,584

Sources: Data for 1950, 1970 from Agrarian Censuses; data for 1980s from SARH.

Appendix C

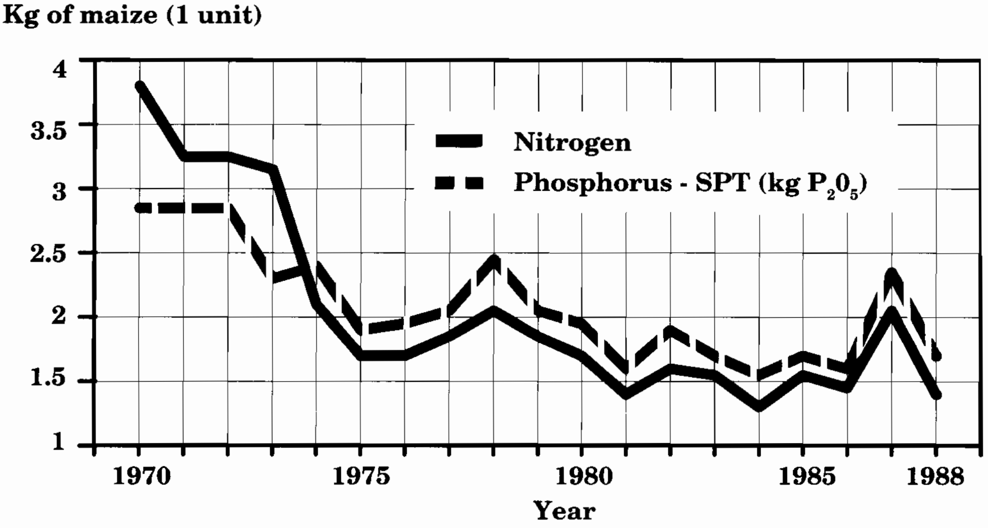

Figure C1. Price of nitrogen and phosphorus relative to maize, Mexico, 1970-88.

Source: Adapted from Hibon (1990).

Appendix D

Individuals Contacted for This Study

Erongarícuaro

Mateo Campos Gutiérrez
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M.C. José del Rosario Esparga Soto
Salvador Alvarez
Jorge Hernández García
Arturo García
León Rodríguez Deluya
José Olivas Simental
Mario de Jesús Pahua

Others

Gonzalo Chapela y Nuria Costa Leonardo (Chapingo study)
Pedro Alvarez Icaza
Dr. Ricardo Raniagua Guzmán (INI)
Dr. Vicente Arredondo Ramírez (CREFAL)
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Salvador Alvarez (Asociación Rural de Agricultores)

State of Mexico

Dr. Javier Trujillo (Entomologist-Ecologist, Colegio de Posgraduados, Chapingo)
Dr. Víctor Toledo (Human Ecology Unit, UNAM, Mexico City)
Cap. Silvino Aguilar Anguiano (Director General, Meteorología Nacional)

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