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POLICY REFORMS AND MEXICAN AGRICULTURE:

Views from the Yaqui Valley

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Abstract: The overall effects of policy reforms enacted during the 1990s in Mexico on financial and economic profitability of Yaqui Valley agriculture are assessed in this study, which describes the reforms, examines how exogenous shocks affected the reform process, and documents how rural people and institutions adjusted to the changed circumstances. Virtually all of the reforms affected Yaqui Valley farmers because of the commercial character of their agriculture (relatively large, irrigated wheat farms), their close proximity to the US, and the new "openness" of Mexico's economy. By almost any standard, the reforms were both wide-ranging and successful, at least as measured in efficiency terms, yet the Yaqui Valley's rural communities face significant challenges at the start of the 21st century. The ejido communities have lost cohesiveness, and even larger-scale farmers in the private sector face serious income problems. More generally, farmers have yet to find profitable new production systems, including the associated marketing institutions, which are consistent with greater reliance on world agricultural prices and diminished dependence on explicit and implicit subsidies from the government.

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Preface

The research findings in this document are the product of a joint effort that began in 1994 among researchers from CIMMYT (the International Maize and Wheat Improvement Center), INIFAP (Mexico's National Institute for Forestry, Agriculture, and Livestock Research), and CESP (the Center for Environmental Science and Policy) at Stanford University. This collaborative initiative has focused on the Yaqui Valley of Sonora and has involved biology, technology, and policy specialists from the outset. The "Yaqui Group" has been able to build on more than 20 years of farm surveys in the Valley by CIMMYT economists and on the world-class agricultural experiment stations of CIMMYT and CIRNO (Regional Research Center for the Northwest, formerly known as CIANO) located near Cuidad Obregón. All of the research has also been enhanced by an extraordinary group of Yaqui Valley farmers.

This report on agricultural policy reforms in Mexico was written by three economists: Rosamond L. Naylor, Senior Fellow at Stanford University; Walter P. Falcon, Professor at Stanford University and Chairman of CIMMYT's Board of Trustees; and Arturo Puente-González, Senior Economist and Technical Secretary to the Chief Director of INIFAP, who also spent 30 months at Stanford as a Research Scholar working on this and other reports. They are particularly indebted to Ivan Ortiz-Monasterio and Dagoberto Flores-Velásquez of CIMMYT, who supervised a series of field experiments and interviews in the Yaqui Valley designed specifically for this study. They are grateful as well for the comments of an interdisciplinary team of scholars from Mexico, Stanford, and other universities in the US who are involved with related aspects of Yaqui Valley research.

The authors express their appreciation for the substantive and personal support provided by Timothy Reeves, CIMMYT Director General, Prabu Pingali, CIMMYT Economics Program Director, and Jorge Kondo-López, Chief Director of INIFAP. Without their help, this monograph would and could not have been written.

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R.L.N.
W.P.F.
A.P.G.

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Acronyms and Abbreviations

ASERCA	Apoyo y Servicio a la Comercialización Agropecuaria (Support Services for Agricultural Marketing, Mexico)
BANRURAL	Banco Nacional de Credito Rural (National Rural Credit Bank, Mexico)
BANCOMEXT	Banco Nacional de Comercio Exterior (National Bank for Foreign Trade, Mexico)
CECARENA	Centro de Conservación y Aprovechamiento de los Recursos Naturales (Center for Conservation and Use of Natural Resources, Mexico, at the Instituto Technologico Estudios Superiores de Monterrey)
CESP	Center for Environmental Science and Policy, Stanford University, USA
CIMMYT	Centro Internacional de Mejoramiento de Maíz y Trigo (International Maize and Wheat Improvement Center)
CIRNO	Centro de Investigación Regional del Noroeste (Regional Research Center for the Northwest, Mexico); formerly CIANO (Centro de Investigación Agrícola del Noroeste)
CONACYT	Consejo Nacional de Ciencia y Tecnología (National Science Foundation, Mexico)
CONASUPO	Compania Nacional de Subsistencias Populares (National Basic Commodities Company, Mexico)
CNA	Comisión Nacional del Agua (National Water Commission, Mexico)
CSE	Consumer subsidy equivalent
FERTIMEX	Fertilizantes Mexicanos (Fertilizer Company, Mexico)
FIRA	Fideicomisos Instituidos en Relación con la Agricultura en el Banco de México (Trust Fund for Agriculture, Mexico)
FIRCO	Fideicomisos de Riesgo Compartido (Trust Fund for Shared Risk, operated by the Ministry of Agriculture, Mexico)
FONAES	Fondo Nacional de Apoyo para las Empresas de Solidaridad (National Fund for Social Enterprises, operated by the Ministry of Social Development, Mexico)
GATT	General Agreement on Tariffs and Trade
INIFAP	Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias (National Institute for Forestry, Agriculture, and Livestock Research, Mexico)
NAFTA	North American Free Trade Agreement
NASA	National Aeronautical and Space Administration, USA
OECD	Organization for Economic Co-operation and Development
PEMEX	Petróleos Mexicanos (National Oil Company, Mexico)
PROCAMPO	Programa de Apoyos Directos al Campo (Direct Aid to the Farmer Program, Mexico)
PSE	Producer subsidy equivalent
SAGAR	Secretaría de Agricultura, Ganadería y Desarrollo Rural (Ministry of Agriculture, Livestock, and Rural Development, Mexico)
SRL	Sociedad de Responsibilidad Limitada (Limited Responsibility Society, for irrigation management, Mexico)
WTO	World Trade Organization

Policy Reforms and Mexican Agriculture: Views from the Yaqui Valley

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Introduction

Scope of the Study

"Globalization, privatization, and liberalization" were rallying cries of the 1990s. Yet despite many policy reforms, few case studies have been completed on how these changes affected agricultural communities in low- and middle-income countries. This study assesses the effects of policy reforms in Mexico on the farmers of the Yaqui Valley—a region of northern Mexico characterized by relatively large, irrigated wheat farms. It addresses four central questions: What reforms have been enacted? How have exogenous shocks affected the reforms and the reform process? How have rural people and institutions adjusted to the changed circumstances? What have been the overall effects of the reforms on financial and economic profitability of Yaqui Valley agriculture?

No single study can provide universal answers to questions of this type. However, early case studies can help to frame critical issues and to suggest methods of analysis. We hope that the regional approach used here will be replicated elsewhere in Mexico and also in other countries to provide the basis for more general comparative assessments of reform processes and their effects on agriculture.

The Yaqui Valley

The Yaqui Valley of Sonora, Mexico is a region characterized by rapid economic and ecological change. Population growth, urbanization, agricultural intensification, and changes in land use are only some of the major developments underway in the area. These forces accentuate the longer-run development of the Valley, whose history is itself a small saga (see Annex A). The introduction of irrigation in the 1890s, the often bloody takeover of considerable portions of Valley land from the Yaqui Indian tribes, and the establishment in the 1930s (and thereafter) of a substantial number of *ejido* (collective) farming units make for unusually diverse groups and interests within the region (Lewis 1999).

The Yaqui Valley is composed of 235,000 hectares (ha) of irrigated land lying between the Sierra Madre and the Gulf of California (Figure 1). Farms are irrigated from reservoirs on the Yaqui and Mayo Rivers and from some 700 public and private irrigation wells. Water is the lifeblood of the Valley, and regional economic development has brought with it increased difficulties from water shortages, potential competition between urban and rural uses of water, and various forms of water pollution.

The Yaqui Valley is also the home of the Green Revolution for wheat. The principal wheat experiment station of the International Maize and Wheat Improvement Center (CIMMYT) is adjacent to Mexico's Regional Research Center for the Northwest (CIRNO). Farmers of the Valley

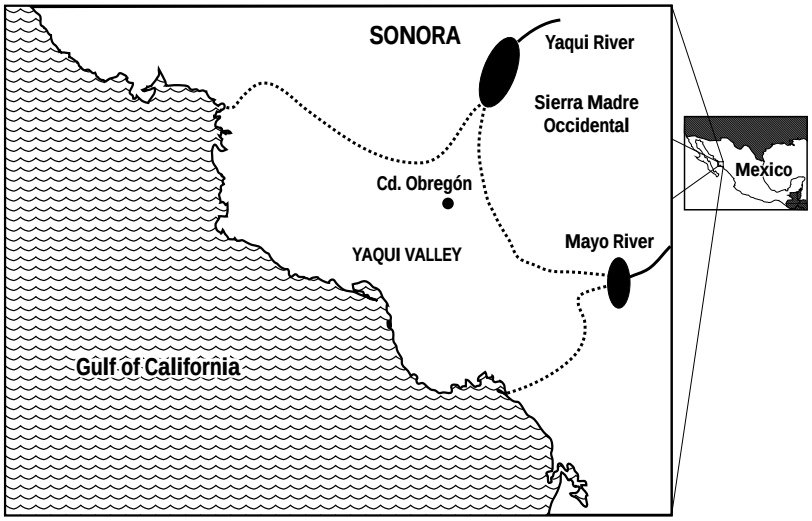

Figure 1. Location of the Yaqui Valley, Sonora, Mexico.

Source: Adapted from Licon-González et al. (2000).

(through a cooperative called the Patronato) produced much of the seed used in the direct transfer of semidwarf wheat technology to South Asia in the late 1960s. The agro-ecosystem of the Yaqui Valley is typical of about 40% of all wheat areas in developing countries (Pingali and Rajaram 1999), although its technology and 6 ton per hectare (t/ha) yields are considerably more advanced than those in most other wheat producing areas of the developing world. The Yaqui Valley is one important indicator, therefore, of where progressive, wheat-based farming systems may be headed in the next 25 years.

The size of a typical ownership unit in the Yaqui Valley in 1990 was about 25 ha for privately owned farms and about 10 ha for ejido-owned land (Puente-González 1999).[1] Ejido holdings cover about half of the Yaqui Valley area, but rental arrangements in this portion of northern Mexico are widespread. Operational units greater than 50 ha are common, and farms in the region thus resemble the irrigated agriculture of the southwestern United States (US) much more than they do the subsistence-oriented wheat and maize systems of central and southern Mexico.

During the 1990s, farmers in the Yaqui Valley were integral participants in Mexico's policy transformation. The commercial character of farms in the region, their close proximity to the US, and the new "openness" of Mexico's economy meant that farmers in the Valley were affected by virtually all of the Mexican reforms. These policy changes altered both the absolute levels of factor and product prices within Mexican agriculture and also the relative agricultural prices between Mexico and the US. The Yaqui Basin is thus an interesting vantage point from which to examine the reforms' consequences with respect both to agricultural trade and development.

The Yaqui Valley is, in short, an extraordinary laboratory for policy analysis. That said, there are still important scale problems associated with regional studies. Many of the legal, institutional, and policy changes affecting the Yaqui Valley were designed as national programs and not as programs finely tuned for one extraordinary valley in an agriculturally diverse country. We attempt to make clear when conclusions drawn from the Yaqui Valley study are likely to be relevant for other regions of Mexico, but we are well aware of the difficulties in drawing inferences about the effects of national policies based on data from a single region.

Planned Reforms

The 1980s saw increasing government involvement in almost all phases of the Mexican food system. Significant price supports for agricultural products, large input subsidies on water, credit, and fertilizer, and major consumption subsidies on basic food products were justified primarily as poverty-alleviation policies. By 1990, government expenditures on agriculture were so complicated in Mexico that neither food consumers nor food producers (nor probably the government) had any real understanding of the net effect the policies were having on efficiency, equity, or the environment. What was clear, however, was that the expenditures were large in absolute terms—the equivalent of US$ 6 billion[2] or about 13% of the Mexican federal budget in 1990 (OECD 1997). The policies also distorted relative prices within agriculture to a significant degree. Overall, the producer subsidy equivalent (PSE)[3] for agriculture in 1990 was about 30% of the value of agricultural production and the consumer subsidy equivalent (CSE) for food products was about minus 5%—the negative estimate implying that food consumption was being subsidized on a net basis relative to a world price standard (OECD 1997).

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1 Many of the Yaqui Valley-specific data used in this monograph were compiled by Arturo Puente-González into a data volume (Puente-González 1999). Dozens of references, mostly in Spanish, were used in building regional data sets from a host of federal, state, and district publications.

2 M$ refers to Mexican pesos and US$ to United States dollars. Unless otherwise noted, translations between M$ and US$ are made with respect to the average exchange rate for the period being cited. In 1991, for example, the nominal M$/US$ rate was 3.0; in 1996, the rate was 7.6; and in December 1999, the rate was 9.3.

3 The producer subsidy equivalent is defined as the value of the subsidy needed to make domestic production of a commodity competitive in world markets. Producer subsidy equivalents are often given as a percentage of a commodity's value and reflect the share of farm earnings attributable to subsidies.

The reforms of the 1990s replaced most of the policies that prevailed in the previous decade. Both the scope and the scale of the reforms were very impressive. The five key components included:

(1) Development of a 15-year program of direct income payments to farmers (PROCAMPO), which was linked to the abolition or reduction of a wide array of input subsidies and price supports;
(2) Installation of new international trading arrangements for agriculture, mainly via the North American Free Trade Agreement (NAFTA), which reduced trade barriers, motivated large changes in prices of many agricultural inputs and outputs, and thus dramatically altered relative prices to producers;
(3) Reduction of the government's institutional involvement in agriculture, such as downsizing the National Basic Commodities Company (CONASUPO), privatizing the Mexican Fertilizer Company (FERTIMEX), and removing or reducing government credit subsidies (BANRURAL);
(4) Decentralization of operating authority and funding responsibilities for irrigation systems to local water-user groups via the Water Laws of 1992 and 1994; and
(5) Amendment of Article 27 of the Constitution of Mexico, which made possible the (legal) sale and rental of ejido land.

The overall effect of these reforms shifted responsibility for agriculture from government to the private and ejido sectors, from federal authority to regional responsibility, and from government-determined pricing rules to the marketplace. Several of these reforms had antecedents in earlier periods, but what is remarkable about this set of policies is that they all came into existence largely within the three-year period from 1992 to 1994. Not surprisingly, many rural communities were ill prepared for the rapid changes that followed. They found themselves in rather desperate searches for new sources of income and new farming methods that could reduce costs and increase revenues. (A common joke told by Valley farmers was that they switched from a wheat-soybean cropping system to a wheat-California rotation.)

Not surprisingly, most members of rural communities (and indeed most analysts) could not disentangle the specific effects from each of the foregoing reforms from other major shocks discussed in the next section. In a series of field surveys,[4] farmers mainly responded to questions about the effects of different reforms by citing a single event, like NAFTA or Article 27. Although technically incorrect, those responses underscored an important analytical point: multiple changes happened so rapidly in rural Mexico that disentangling the effects of each policy was and is impossible.[5] We therefore give brief explanations of the major changes; describe the salient farm-level responses to these changes; and then use comparisons of financial and economic profitability prior to and after the policy transition to summarize the totality of what occurred.

Toward Decoupled Policies

Policies adopted in the 1990s were aimed at increasing the efficiency of the agricultural sector by opening it to international competition and by reducing the extent of government intervention in marketing. Perhaps the most important policy change was the movement away from direct price supports for grains, beans, and oilseeds—administered through CONASUPO—to direct income payments to producers through the PROCAMPO program. The shift toward decoupled support of the agricultural sector coincided with Mexico's entrance into NAFTA in 1994. It also preceded a broader global mandate to eliminate distortions caused by agricultural price policies undertaken as part of the Uruguay Round of the General Agreement on Tariffs and Trade (GATT) in 1995.

Before 1990, CONASUPO provided price supports to domestic producers of staple grains, beans, and oilseeds (Yuñez-Naude 1998). Like many state trading enterprises

[4] Three field surveys have been completed thus far under the auspices of Stanford University. All of the surveys dealt with general agricultural conditions, but each had a particular focus: nitrogen fertilizer (1994-96); farm management practices (1996); and land ownership and rental arrangements (1999). For a description of methods used in each survey, see (respectively) Matson et al. (1998), Avalos-Sartorio (1997), and Lewis (1999). Hereafter, these field inquiries are referred to as the Stanford University surveys. References are also made to farm surveys on production technology and practices by CIMMYT's Economics Program, reported in Pingali and Flores (1998) and Meisner et al. (1992).

[5] Several attempts to credit or debit everything that happened in Mexico to NAFTA also suffer from this problem. A very readable summary of these analyses, all wrongly ascribed to NAFTA, can be found in Krugman (1993).

in developing countries, CONASUPO bought commodities at prices above world prices and then subsidized sales to consumers, thereby insulating Mexico from international competition. In addition, CONASUPO maintained control over imports and exports and had subsidiaries involved in storage, processing, marketing, and distribution. Parallel marketing institutions also existed for other crops, such as cotton, coffee, and sugar.[6] In the case of wheat, the most important crop in the Yaqui Valley, CONASUPO sold domestic purchases and imports to millers at a price equivalent to or below the purchase price. Farmers in the high-yield, price-supported environment of the Valley were thus able to secure relatively large and stable incomes on a systematic basis.

The restructuring of CONASUPO began at the turn of the decade, and by 1991, a new agency, ASERCA (Support Services for Agricultural Marketing) had been formed within the Ministry of Agriculture to oversee marketing of all staple crops, apart from maize and beans. The purchase and storage of agricultural commodities were placed in the hands of the private sector. The main responsibilities of ASERCA were to facilitate market development for wheat, sorghum, rice, soybeans and other oilseeds and to promote the export of cotton, fruits, and vegetables. Unlike CONASUPO, the new agency did not purchase agricultural commodities from producers, but instead provided market information and helped to establish regional and international distribution channels.[7]

A 15-year program of direct income payments was introduced through ASERCA in 1994. Payments were based on the historical area of farmland devoted to wheat, maize, beans, cotton, rice, soybeans, safflower, sorghum, and barley; they were not related to the level of current output (hence, "decoupled"). The idea was to provide a greater role for markets in determining production decisions based on available inputs for each region. In practice, larger-scale farmers continued to receive the greatest share of support. However, PROCAMPO also benefited some subsistence farmers who previously did not receive price supports, and to a lesser extent it helped farmers on small, low-yielding plots where price supports were minimal.

The transition to decoupled policies had implications for the national agricultural budget, as well as for the incomes of farmers in the Yaqui Valley. In 1990, 15% of the agricultural budget was spent on price supports and subsidies; in 1995, only 7% of the agricultural budget was spent on these programs, and almost 30% was spent on direct income payments (OECD 1997). Moreover, the real value of the agricultural budget in 1995 was only about half of its value in 1991.

Farmers in highly productive areas like the Yaqui Valley were the biggest losers (in absolute M$) from the policy shift. Although farmers benefited relatively from income payments on large land holdings, PROCAMPO payments represented only a small share of their total revenues—typically about 5%. The PROCAMPO payments thus provided only meager compensation for the removal of the price supports that had prevailed earlier.

Toward Decentralized Factor Markets

Since 1992, there has been a shift toward privatization and a reduction in federal control of the fertilizer industry, as well as of the credit, land, and water markets. This shift affected input prices, competitiveness, and farm practices in ways that pushed farmers toward cropping systems that adhere more closely to Mexico's international comparative advantage—particularly in export-oriented regions like the Yaqui Valley.

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6 By 1988, production subsidies through CONASUPO totaled more than US$ 500 million. In that same year, CONASUPO consumer subsidies also added nearly US$ 1 billion in budgetary costs (OECD 1997).

7 Throughout the first half of the decade, CONASUPO maintained producer price supports for maize and beans, plus consumer subsidies for maize tortillas (which were removed in 1998). Early on, ASERCA provided payments to wheat millers based on the volume of domestic purchases and sales; these payments ended in 1995 after consumer price ceilings for wheat flour and bread had been removed (OECD 1997). CONASUPO was formally closed in May 1999 by presidential decree (OECD 2000).

Fertilizer

During the 1980s, domestic fertilizer prices were held below international prices through a series of budget transfers to the state-owned fertilizer company, FERTIMEX. The transfers, which increased from roughly US$ 100 million to US$ 400 million between 1979 and 1988, supported production, storage, transportation, and marketing outlets for fertilizer (OECD 1997). In addition, energy inputs and ammonia used to produce fertilizers were subsidized through the Mexican National Oil Company, PEMEX.

Direct subsidies on fertilizer were eliminated with the privatization of FERTIMEX in 1992, when it withdrew from retail distribution. At the same time, indirect subsidies through PEMEX were reduced, although some preferential pricing for ammonia to private companies persisted. The direct subsidy on urea (comparing domestic and international prices) fell from 24% in 1989-91 to 0% in 1993-96. In 1996, real urea and triple super phosphate prices were 85% and 53% higher, respectively, than 1988 prices for the average Mexican farmer (Puente-González 1999).

Credit

Mexico's financial system also went through a major reform in the late 1980s, which led to a reprivatization of commercial banks in 1992 (OECD 1997). Farmers in Mexico have traditionally been credit-constrained. Relatively high risks associated with agricultural conditions (especially in rainfed areas), high and volatile interest rates associated with rapid rates of inflation and changes in macroeconomic policies, and lack of collateral (particularly for *ejidatarios*[8]) have created the largest barriers to lending. To compensate for these difficulties, the Mexican government had earlier supported agricultural lending through the promotion of public-sector development banks. In 1988, roughly 80% of total agricultural lending in Mexico was done through these development banks, and interest rate concessions accounted for over one-third of total agricultural expenditures (Puente-González 1999; OECD 1997).[9] Loans were made to producers at subsidized (and sometimes zero) rates without collateral, and the government covered the operating deficit of the development institutions. Moreover, loan repayments by many farmers—even at the subsidized rates—tended to lag by months and even years.

The restructuring of banking that began in 1989 occurred mainly within BANRURAL (the National Rural Credit Bank), the primary bank servicing the ejidos. By 1996, the area covered by BANRURAL loans dropped from 7 million to less than 2 million hectares, and the number of producers receiving credit dropped from 1 million to 500,000 (Puente-González 1999). As a result, interest rate concessions in 1995 were valued at only 10% of those in 1988 in real terms, and they accounted for only 5% of total agricultural expenditures. As the role of BANRURAL declined, other institutions assumed some lending responsibilities.[10] Nevertheless, total expenditures on subsidized interest fell by over 75%, making it much more difficult for small private farmers and edijatarios to secure loans.

Land

The change in credit conditions occurred simultaneously with an important change in land policy within Mexico. The amendment to Article 27 of the 1917 Mexican Constitution (the Agrarian Law of 1992) altered over 70 years of land policy with respect to ejido land ownership (Lewis 1999). The stated goal of the policy was to modernize the agricultural sector, thereby appeasing critics of the ejido system within the Salinas administration who believed that inefficiencies associated with collective land tenure and small plot sizes impeded agricultural growth (Gates 1993). The reform of Article 27 set up a flexible

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8 Members of ejido communities; more specifically, people who farm ejido land.

9 The main institutions operating in this capacity included BANRURAL (National Rural Credit Bank), FIRA (Trust Fund for Agriculture, a secondary bank that discounts loans to commercial banks), FIRCO (Trust Fund for Shared Risk, operating through the Ministry of Agriculture), and FONAES (National Fund for Social Enterprises, operating through the Ministry of Social Development). The latter two promoted credit at zero interest (Puente-González 1999).

10 In 1991, FONAES began operation and has since become a principal lender of credit (Puente-González 1999).

land-tenure regime inside ejidos by allowing communal and individual property holders to rent, sell, and mortgage land legally for the first time. New institutions were established to facilitate this process and to certify official land titles. Joint ventures between the ejido sector and the private sector were also encouraged. A legal market for ejido land was thus established, replacing the illegal market that was widely acknowledged to exist.

The amendment had important implications for agriculture in Mexico, and especially for farmers in the Yaqui Valley. When the policy was implemented, ejidos accounted for just over 50% of the total cultivated area, 50% of the total irrigated area, and 70% of all farmers in Mexico. In the Yaqui Valley, 56% of total agricultural area and 72% of producers belonged to ejidos (Puente-González 1999; CNA 1998). When coupled with changes in government credit and water policies, the reform of Article 27 accelerated increases in private ownership and in the operational size of farms within the Valley.

Water

Rural areas were also significantly affected by the decentralization of control over irrigation water. The transfer from the federal government to local user groups had many of its origins in Mexico's 1982 financial crisis. Irrigation subsidies at that time totaled nearly US$ 500 million, and the budget squeeze in subsequent years drastically curtailed funds for investments in, and maintenance of, irrigation networks (OECD 1997). By the end of the 1980s, the deterioration of Mexico's irrigation infrastructure had begun seriously to affect the productivity of Mexico's irrigated land (World Bank 1995; Kloezen 1998). The government concluded that the best—perhaps the only—way to sustain irrigated agricultural production was to transfer control of water to local groups of farmers and to make them responsible for raising most of the revenue for maintaining the irrigation systems. The underlying assumptions were that local groups would best understand local conditions, and that they would be willing to pay most of the maintenance costs if the resulting benefits were clearly visible.

A National Water Commission (CNA) was created in 1989 to help oversee the transfer (World Bank 1995). The Commission retained the right to specify the amount of fresh water that can be used for industrial, urban, and agricultural purposes. Control over the use of the water within agriculture, however, was given to farmer groups. The Water Law of 1992, plus the supplemental water regulations of 1994, laid the legal basis for this decentralization. Most larger irrigation districts were subdivided into modules of about 10,000 ha, and water concessions of from 5 to 50 years were then transferred to these units. Modules were not given rights to a specified volume of water, but instead were granted a percentage of the water determined to be available by the CNA on a season-by-season basis.

By 1998, irrigation management for about 95% of Mexico's publicly irrigated land had been transferred. (Management for more than 2.5 million hectares of privately irrigated land was largely unaffected.) Local user costs covered about 90% of the upkeep of these systems, which also meant that the irrigation systems were now largely insulated from the vagaries of the federal budget (Johnson 1997). In 1995, for example, irrigation modules were little affected by the macroeconomic crisis that had a devastating effect on many line items in the federal budget.

The transfer of control also had the effect of streamlining operations. Farmer groups proved themselves much more demanding of irrigation personnel, and during the first five years of the transfer program, local irrigation staffs were cut an average of about 50% (Johnson 1997). Federal subsidies on maintenance dropped to zero by 1993, yet maintenance of the systems had greatly improved.

As one of the early test cases, the Yaqui Valley was very much a leader in the decentralization of water management. Its service area of 233,000 ha was initially divided into 51 modules to provide operational supervision of the secondary canals (Distrito de Riego del Río Yaqui 1996).[11] The modules were later federated into a Limited Responsibility Society (SLR) with responsibility for maintaining the primary canals and drains.

[11] These modules turned out to be rather small, however, and are now being re-grouped into about 40 units to realize economies of scale in administration and operation.

After receiving the concessions, Yaqui Valley units raised user charges to farmers. For the period 1988 to 1994, the real cost of water to farmers rose by about 70%, although real charges declined somewhat after 1995. Fortunately for Valley farmers, the water flows of the irrigation system were fairly uniform through the mid-1990s at about 2 billion cubic meters of water annually. Farmer concerns about being given concessions for only the percentage of the water flow deemed appropriate by the CNA, therefore, did not create great operating difficulties in the first half of the decade. As discussed in a subsequent section, however, the drought of 1996-2000 caused serious problems for Valley farmers.

Finally, farmer-to-farmer sales of water within modules, which were permitted under the decentralized management, also facilitated the movement of water toward higher valued crops and larger operational units in the Valley (Rosegrant and Schleyer 1996; Lewis 1999). The capacity to move water among farmers and seasons also proved beneficial in dealing with the pest problems associated with the summer soybean crop.

Toward Freer Trade

The transition from coupled price supports to decoupled income supports, along with the liberalization of factor markets, enabled Mexico to move toward a regime of freer trade for the agricultural sector. NAFTA, launched in January 1994, was the first trade agreement between advanced industrial countries and a developing country in which most agricultural trade was included (OECD 1997). Although NAFTA encompassed trade in all sectors of the Mexican economy, it had particular relevance for agriculture. In 1993-94, almost 90% of the country's farm exports were shipped to the US and Canada, and over three-quarters of its agricultural imports came from these two countries. The signing of NAFTA thus represented a major step in Mexico's ongoing program of trade liberalization, which began with its accession to the GATT (now the World Trade Organization) in 1986.

The NAFTA agreement included provisions on market access, domestic agricultural support, export subsidies, and sanitary and phytosanitary measures. With respect to market access, NAFTA partners agreed to convert all nontariff barriers, including import permits (which had begun to be eliminated in 1986), into tariffs and tariff-rate quotas.[12] According to the agreement, the tariff measures will be phased out by 2008. Unlike the Uruguay Round of the GATT, which was signed one year later, the initial terms of NAFTA encouraged the removal of—but did not firmly restrict—export subsidies and domestic price-support policies (OECD 1997).

Before NAFTA was signed, import licenses affected roughly one-third of Mexico's agricultural imports from the US. Still, some liberalization had already taken place, and the number of agricultural products with import licenses had been reduced from 320 in 1985 to 57 in 1990 (OECD 1997). With the introduction of NAFTA and the phasing out of price supports, CONASUPO's share of total imports for wheat, beans, and rice fell from 68%, 62%, and 95% (respectively) in 1983-88 to 0% in 1994-96, and its share of maize imports fell from 83% to 16% over the same period. The signing of the Uruguay Round accords in January 1995 restricted export subsidies but had little additional impact on domestic protection. A consolidated tariff ceiling was set at 25% for most agricultural products, although tariffs applied in practice have remained at the lower rate set earlier by NAFTA (about 15% on average by the end of the decade).[13]

The trade liberalization measures associated broadly with NAFTA had important consequences for both the level and stability of farm incomes in Mexico. Prior to the 1990s, effective import monopolies for many commodities shielded the agricultural sector from substantial overvaluation of the peso and from the fluctuations of international market prices. With freer trade, agricultural producers—particularly in commercial regions like the Yaqui Valley—became more vulnerable to macroeconomic policy swings and global market volatility. At the same

[12] Some commodities were excluded from the Mexico-Canada subtreaty, including sugar, dairy products, poultry, and eggs (OECD 1997).

[13] Sensitive commodities with tariff rate quotas—such as maize, dry beans, powdered milk, barley, poultry, and eggs—maintained tariffs of 50% (OECD 1997; Yuñez-Naude 1998). A maximum tariff of 50% was also set for wheat flour, although the NAFTA rate of 15% has continued to apply for both wheat and wheat flour.

time, Yaqui Valley farmers benefited from the devaluation of the peso during 1995-96 and the consequent gain in international competitiveness for their crops. In short, farmers no longer operated in a protected, semi-closed economy, and their private profits at the turn of the century were subject to both the benefits and hazards of international markets.

The links among trade, macroeconomic, and agricultural price policies during the past decade underscore how the interaction of multiple reforms affected farmers in the Yaqui Valley. While NAFTA was often blamed or applauded for changes in efficiency and equity within the agricultural sector, it represented only one of many reforms in the Mexican economy. Moreover, a series of external economic, biological, and weather shocks also altered the economics of farm production. Despite these shocks, the directions of change in the agricultural sector—and in the rest of the Mexican economy—would have been entirely different during the 1990s without Mexico's vigorous move toward freer trade.

Unexpected Shocks During and After the Reforms

The foregoing review of agricultural reforms in the Mexican economy indicates that policies designed for a nation often affect particular regions, such as the Yaqui Valley, in quite specific ways. They are thus largely exogenous to the agricultural region in question. Other exogenous forces—most notably national macroeconomic policies that alter exchange rates and interest rates—can have large and differential effects at the regional level. This phenomenon was never clearer to Yaqui Valley farmers than during the peso crisis in the fourth quarter of 1994. In addition, Valley farmers were battered by exogenous swings in international commodity prices, by two unexpected biological shocks that seriously curtailed their cropping systems, and by a regional drought.

Macroeconomic Shocks

The peso crisis in December 1994 originated seven years earlier when the Salinas government launched a stabilization program to reduce inflation (then running at an annual rate of 160%). The program centered on strict exchange rate controls,[14] tight fiscal and monetary policies, and liberalization of financial markets to attract foreign investment. By the end of 1993, just before NAFTA went into effect, the annual inflow of foreign capital exceeded US$ 29 billion, and consumer inflation fell to an annual rate of 8% (Ramírez 1996). At the same time, however, real annual interest rates on peso-denominated short-term bonds (*cetes*) were in the 12-16% range; real GDP growth remained low (only 2.7% on average between 1988 and 1993); and the current account deficit rose to over 6% of GDP (Ramírez 1996; Savastano et al. 1995). Those trends, which occurred in the context of strict exchange rate controls, led to an effective appreciation of the peso by more than 60% between 1987 and 1992 and to a further appreciation of 32% in 1993 (Savastano et al. 1995; Puente-González 1999).

The causes for the specific timing of the peso collapse remain a contentious issue. There can be little doubt, however, that in 1994 the exchange rate was overvalued, the economy was stagnating, and the growing current account deficit was not sustainable. High interest rates and a strong peso were creating difficulties for domestic industry. Moreover, a series of destabilizing political events in 1994 created substantial investor uncertainty (Ramírez 1996). Portfolio investors, who had invested almost nothing as late as the first quarter of 1991, increased their quarterly financial flows to almost US$ 8 billion by the fourth quarter of 1994. In December 1994, however, they withdrew massive sums in the course of only a few days (Figure 2).[15]

[14] The Mexican peso was fixed to the US dollar for most of 1988, then allowed to depreciate the following three years at a preannounced rate. In November 1991, a publicly announced intervention band for the peso was established, with a constant floor and a ceiling that depreciated at a predetermined rate. The band was initially set at 1.5% and rose to 9% by the end of 1993 (Savastano et al. 1995).

[15] As foreign investors grew wary of the administration during the course of 1994, they switched almost entirely out of *cetes* and into *tesobonos*—the newly issued, dollar-denominated, short-term bonds created to hold investor interest. During the course of 1994, the value of *tesobonos* jumped from US$ 1.4 billion to US$ 30.4 billion, while the value of *cetes* fell from US$ 22.7 billion to US$ 5.4 billion. This shift greatly increased the level of dollar-indexed government debt (Ramírez 1996).

A major panic at this time was set off by the administration's move to widen the exchange-rate band and then to allow the exchange rate to float. The failure of the Mexican authorities to consult adequately with the international financial community prior to the float almost surely aggravated the peso panic.[16]

The result was the collapse of the peso. The M$/US$ rate, which stood at M$ 3.4/US$ 1 on 1 December 1994, fell to M$ 6.0/US$ 1 on 31 January 1995. The crisis was both good news and bad news for the farmers in the Yaqui Valley. They were affected negatively by the associated high real rates of interest and higher prices on imported farm inputs, but they benefited from the increased competitiveness of their export crops.

World-Price Shocks

The ramifications of the 1994-95 peso crisis were widespread in the Yaqui Valley, but perhaps no more so than the sharp rise and the even sharper decline in commodity-price movements that characterized the 1990s. Mexico's new agricultural openness meant that Yaqui Valley farmers, other things equal, benefited when world prices rose for their commodities. A significant improvement in world prices was precisely what happened from 1992 to 1996—the increase beginning fortuitously just at the time when the reforms were being implemented. World prices (in nominal US$) for wheat, maize, soybeans, and cotton *rose* between 1991 and 1996 by 37%, 55%, 11%, and 5%, respectively (Table 1). Farmers reported difficulties in sorting out reform effects within Mexico from global price movements, but rising world prices for agricultural commodities helped greatly to offset the reductions in specific-crop subsidies within Mexico.

As farmers throughout the world know, however, prices that go up can also go down (Figure 3). Between 1996 and 1999, world prices *fell* by 37%, 46%, 27%, and 34% for

Table 1. Nominal world prices (US$/t) for major crops, 1991, 1996, and 1999

Commodity	1991	1996	1999
Wheat	129	177	112
Maize	107	166	90
Soybeans	240	267	195
Cotton	1,680	1,770	1,170

Source: World Bank, *Global Commodity Markets* (various issues).

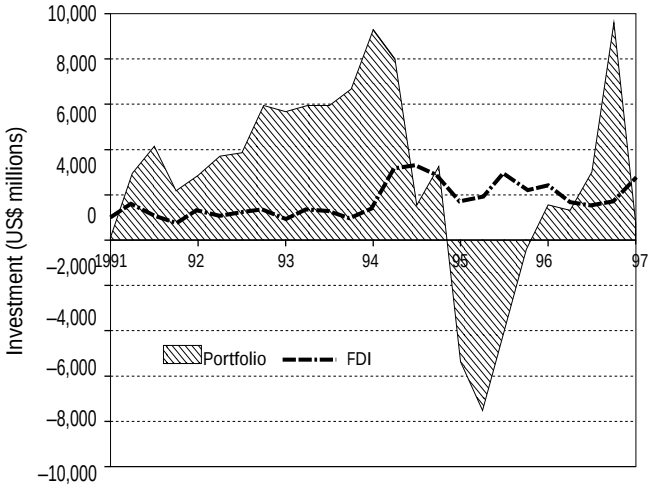

Figure 2. Foreign-direct investment and foreign-portfolio investment, Mexico, quarterly, 1991-97.

Source: IMF (various issues).

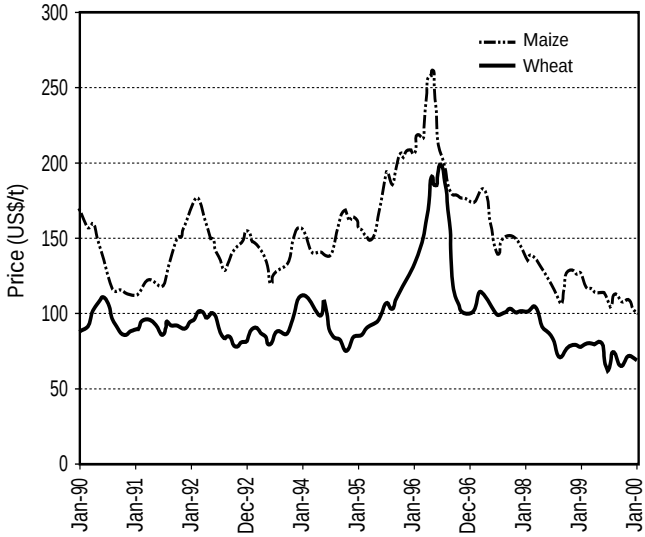

Figure 3. Nominal world wheat and maize prices, 1990-99.

[16] Investor panic began shortly after President Zedillo was sworn in on 1 December. By 20 December, international reserves had fallen to US$ 10.5 billion and the exchange rate band was widened from 9% to 15%. Two days later, reserves fell by another US$ 4 billion and the peso was allowed to float (Savastano et al. 1995).

wheat, maize, soybeans, and cotton, respectively. Differential inflation rates in Mexico relative to world inflation and the continuing depreciation of the Mexican peso relative to the US dollar (from M$ 7.8/US$ 1 in January 1997 to M$ 9.5/US$ 1 in December 1999) complicate comparative peso profit calculations through time.[17] Even So, there can be no doubt that globalization added to price instability for Yaqui Valley farmers and that, in the last half of the 1990s, falling commodity prices were significant factors in putting farmers into a difficult cost-price squeeze.

Biological Shocks

Export sales of relatively high-valued wheat seed and also of bread wheat had historically been important sources of income to farmers in the Yaqui Valley. Exports of both commodities were seriously curtailed in the l990s by the spread of Karnal bunt (KB), a fungal disease caused by a pathogen (*Tilletia indica*) that particularly affects bread wheat.[18] This pathogen is thought to have entered the Valley via seed exchanges with India, and since the early 1990s it has grown into a major problem for Mexico. Production of certified wheat seed is precluded in areas affected by KB (unless the seed has been specially treated with methyl bromide), and federal laws in Mexico also ban the production of bread wheat in areas where incidence of the fungus on grain is greater than 2%.

Internationally traded wheat originating from KB-endemic areas is severely regulated, and many countries, including the US, no longer permit the import of bread wheat from Mexico as a consequence of KB. Wheat varieties that show resistance to KB do exist, but once a region is infected with *T. indica* spores, it is extremely difficult to restore and recertify a region as "clean." Not surprisingly, KB caused major changes in the autumn portion of the Valley cropping system.

A second biological shock was caused by the silverleaf whitefly (*Bemisia argentifolii*), which invaded the Valley in 1994-95.[19] The whitefly population literally exploded during the course of 18 months, and the infestation had disastrous consequences for the soybean crop. Soybeans came into the Yaqui Valley as recently as 1960, but by 1994, they occupied about 80% of the summer-planted area (Puente-González 1999). Unfortunately, whiteflies have a fatal attraction for soybeans, destroying yields by extracting the sap from soybean plants and by covering them with honeydew. In only three years, from 1994 to 1997, soybean area went from 120,000 ha to 20 ha (Pacheco 1998). The consequences for farm planning were particularly severe, since this important legume had a May-October growing season and was one of the few crops that meshed perfectly with the November-April growing season for bread and durum wheats. Hurried searches were undertaken to find alternatives for the winter and summer cropping seasons.

Weather Shocks

Extreme weather events, which affected much of the world during the 1990s, were also very evident in the Yaqui Valley. Indeed, the severe 1996-2000 drought in northern Mexico put agriculture on the brink of an economic disaster.

Rainfall in the catchment above the three Valley dams was relatively stable between 1984 and 1993. Despite small year-to-year variations, reservoir volumes in October (the beginning of the autumn cropping season) averaged about 6 billion cubic meters of water (Distrito de Riego del Río Yaqui 2000).[20] Beginning in 1994, however, reservoir levels began an almost steady downward trend (Figure 4).

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[17] These calculations are described in much more detail later in this monograph; see "Changing Profitability of Farming in the Yaqui Valley," page 17.

[18] When present on more than about 3% of wheat kernels, KB causes wheat flour to have weakened gluten and to taste bitter. Other observers say that KB also causes flour to smell and taste "fishy." Further technical information about KB can be found in Wilcoxson and Saari (1996). Durum wheat varieties, used for making pasta, typically show much greater resistance to KB than do bread wheat varieties.

[19] The means by which this infestation of flies entered the Valley—thought locally to have entered within shipments of baled hay—is not well documented (Pacheco 1998).

[20] Total reservoir capacity is about 7.2 billion cubic meters.

Irrigation water had become sufficiently constrained that by the 1998/99 crop year, almost no water was discharged for the summer season. For the succeeding 1999/00 autumn season, the number of irrigation applications for wheat was cut from five to four. Even with these cutbacks, the situation was grim. Reservoir levels in March 2000 were less than 20% of reservoir capacity, and by May 2000, levels (1.25 billion cubic meters) had slipped almost to the minimum pool heights of the reservoirs—the point at which remaining water supplies are accessible only by pumping.

Much discussion among farmer groups in the Valley during the summer of 2000 focused on curtailing autumn crop area, cutting irrigation applications from four to three for wheat, switching to alternative crops such as sunflower and safflower, and planting more drought-resistant wheat varieties that could use water more efficiently.[21] Late summer and autumn rains in 2000 replenished water volumes by a significant amount, but in mid-November 2000, reservoir levels still had increased to only 2.6 billion cubic meters, and the mood in the Valley continued to be tense.

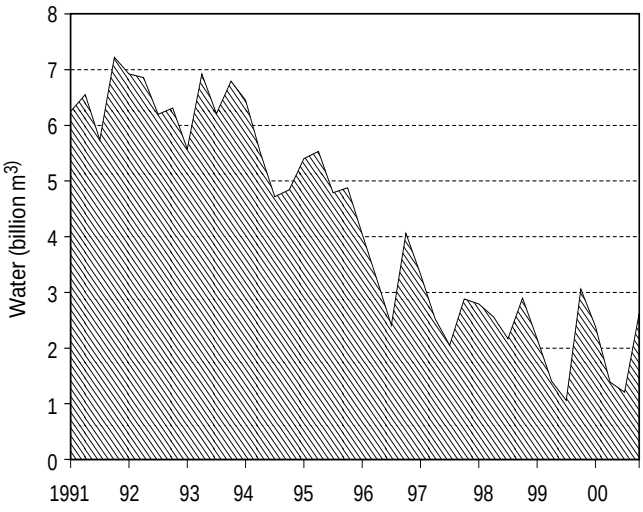

Figure 4. Yaqui Valley reservoirs, volume of water, January, April, July, and Octuber, 1991-2000.

Source: Distrito de Riego del Río Yaqui (2000).

The decline in water availability, especially when added to the decline in world commodity prices during 1996-99, reminded farmers just how vulnerable they had become to both global climate change and global markets. One effect of this vulnerability was serious reconsideration of the future of Yaqui Valley agriculture, especially with regard to increasing the economic efficiency with which irrigation water was used.

Farmers' Responses to Changed Circumstances

As indicated, farmers in the Yaqui Valley faced great uncertainty during the 1990s. Domestic agricultural policies were changing, the M$/US$ exchange rate was uncertain, world commodity prices were volatile, a drought in northern Mexico depleted reservoirs, and new pests and diseases wreaked havoc on several key crops. In each of the Stanford University surveys in the Valley, farmers spoke repeatedly about how multiple sources of uncertainty plagued their efforts to plan for the future. The multiple effects of the changing agricultural circumstances in the Valley also meant that, as a practical matter, our evaluation of the reforms must take the form of a before-after assessment, rather than a with-without analysis for specific policy changes.

The primary focus of this assessment is thus on how farmers reacted between 1991 and 1996 with respect to production patterns, farm management practices, marketing and credit arrangements, and size of operations. A secondary focus is the period from 1996 to 1999, when the immediate effects of the reforms had been absorbed but price and weather effects led to continued turbulence in the Yaqui Valley.

Altered Production Patterns

Changed cropping patterns were farmers' most obvious response to the new circumstances of the 1990s. Each year of the decade had its own special story, but the most significant trends were in the areas planted to bread wheat

[21] One manifestation of the new concerns was a national seminar, "Reconversion of the Yaqui Valley," held in Cd. Obregón in April 2000. For a report on that seminar, see Falcon and Naylor (2000).

and soybeans. As indicated in Table 2, virtually all of the wheat grown in the Yaqui Valley during 1991 was bread wheat. By contrast, more than 80% of the wheat grown in 1996 was durum wheat. This switch was driven primarily by KB and not by prices (Table 3). Similarly, soybeans went from being the dominant summer crop in 1991 to occupying nearly zero area in 1996 because of the whitefly invasion. Interestingly, although the switch to durum wheat caused few adjustment problems for farmers, the loss of soybeans from the cropping rotation had far-reaching consequences.

With adequate irrigation water, the climate of the Valley permits cropping throughout the year. As shown in Figure 5, however, a number of key crops such as cotton and autumn-planted maize do not "pair" annually with a winter-planted bread or durum wheat crop because of seasonal overlaps. Moreover, relatively little research had been done on summer-planted maize and sorghum, and partly as a consequence, yields for these crops were less than when they were planted in the fall. Finally, farmers lost the biological advantages of pairing a nitrogen-fixing legume (soybeans) with a nitrogen-using grass (wheat). From a farm planning perspective, the loss of soybeans was one of the most serious problems of the 1990s.[22]

Three other changes in output patterns are also worthy of note. First, a combination of Mexico's new economic openness, the increased urbanization of the Yaqui Valley, and rising per capita incomes had a positive, although marginal, effect on the production of higher-valued crops. The Valley had long been known as a producer of bulk commodities. On several earlier occasions, farmers produced melons, only to suffer disastrous consequences when increased supplies caused domestic melon prices to plummet and induced US authorities to impose import restrictions at the border. During interviews, many farmers continued to express skepticism about the potential of demand-driven products—a skepticism that was reflected in the very limited area in 1991 devoted to such products. The aggregate area in vegetables was still not large in 1996,

Table 2. Harvested area (000 ha) by season and crop, Yaqui Valley, Mexico, 1991 and 1996

	1991	1996
Fall/winter		
Maize	71	80
Bread wheat	125	14
Durum wheat	0	76
Safflower	4	21
Vegetables	6	8
Other	7	5
Spring/summer		
Cotton	31	40
Soybeans	69	0
Maize	6	42
Sorghum	5	28
Vegetables	1	2
Other	12	4
Perennial		
Alfalfa	2	3
Citrus	0	1
Total	338	322

Source: SAGAR (1998).

Table 3. Nominal and real farm-level prices (M$/t) by season and crop, Yaqui Valley, Mexico, 1991 and 1996

	1991		1996	
	Nominal	Real	Nominal	Real[a]
Fall/winter				
Maize	636	636	1,680	655
Bread wheat	650	650	1,895	739
Durum wheat	_	_	2,100	819
Safflower	700	700	2,200	858
Spring/summer				
Cotton (seed)	1,700	1,700	4,000	1,560
Soybeans	840	840	2,150	838
Maize	636	636	1,680	655
Sorghum	400	400	1400	546

Source: Comisión Nacional del Agua (1998).

[a] Real prices of farm products in 1996 (relative to 1991) were obtained by setting the Mexican National Consumer Price Index (MNCPI) equal to 100 for 1991, then deflating 1996 product prices by the MNCPI for 1996.

[22] Mexico is currently cooperating with the International Center for Tropical Agriculture (CIAT, the Centro Internacional de Agricultura Tropical) on a major research effort designed to bring the whitefly under control. There is great optimism about this project, and perhaps within five years soybeans will again be grown in the Yaqui Valley.

but by 1998, area under vegetables had doubled relative to 1991 (SAGAR 1998). Citrus groves also doubled during the 1990s.

It is too early to predict the future with any confidence, but there are a few hints that fruit and vegetable systems geared more to demand in the US (and Mexico City) will become an increasingly important part of Valley *incomes*. Even with the reforms, however, it is unlikely that a significant part of Valley's *area* will soon be shifted out of the production of bulk commodities. Until better marketing arrangements are in place, the negative price consequences of (say) 100,000 additional hectares in vegetables are likely to be disastrous for growers' incomes.

A second economic and agricultural force in the Yaqui Valley was growth of the livestock sector. Livestock numbers grew quite rapidly between 1991 and 1996, and by the latter year, production of pigs and poultry was about 350,000 head and 6 million birds, respectively (SAGAR 1998). This shift into livestock also had consequences for regional feedgrain markets. Wheat, for example, became increasingly important as a local livestock feed; up to half of the Valley's wheat output was used for feed by the end of the 1990s.

The competitiveness of the livestock sector clearly improved as a result of the changed subsidy policies on grains associated with PROCAMPO and NAFTA. New price relationships, in turn, induced a restructuring of the Valley pork industry into much larger units (Southard 1999). At times, feed demand in the Valley was sufficiently strong to cause a switching of regional grain prices from an FOB-export to a CIF-import basis. The livestock industry was thus a primary beneficiary of the agricultural reforms in Mexico, although its future growth could well be limited by the pollution problems associated with large-scale livestock producing units.[23]

A third effect of the reforms was the emergence of aquaculture as a significant economic activity. Shrimp farming became increasingly visible in the Yaqui Valley during the last half of the decade, although the 1992-94 reforms were responsible only indirectly for its emergence.[24] The expansion of aquaculture in the Valley was rather more a part of a global, demand-led phenomenon that was made more promising in the face of widespread disease shocks in shrimp-producing countries of Asia and the Americas (Naylor et al. 1998, 2000).

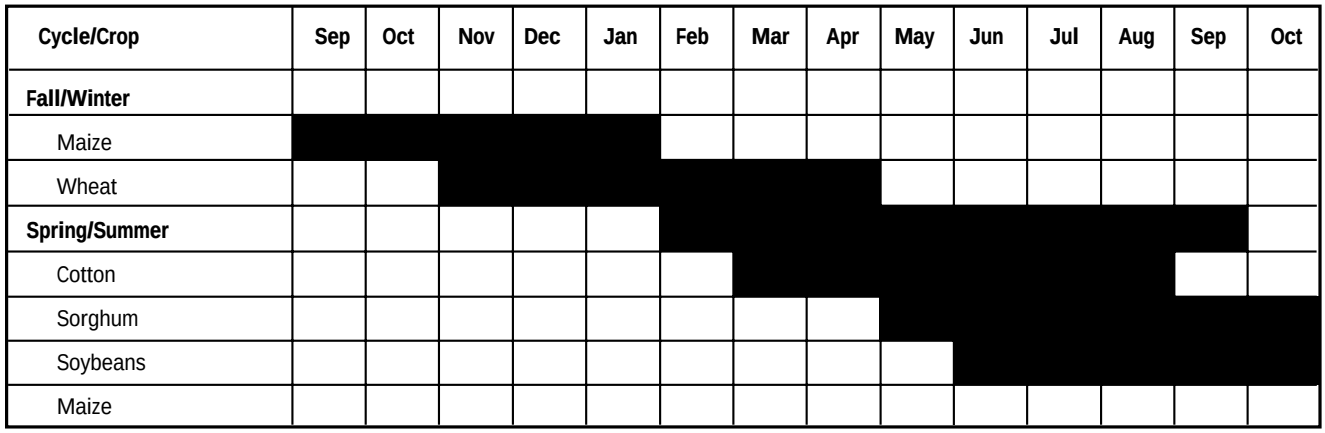

Figure 5. Agricultural calendar, major crops, Yaqui Valley, Mexico.
Source: Adapted from Meisner et al. (1992).

[23] Predicting future developments in the Valley's pork industry is complicated further by the very large price movements for pork in the US. Between August 1996 and March 1999, for example, average pork prices to US farmers went from US$ 0.60 per pound to US$ 0.28 per pound (USDA 1999).

[24] A good summary of aquaculture development in Sonora is given in Villa Ibarra (1998).

The southern Sonora coastal zone, of which the Yaqui Valley is a part, was a relative latecomer to shrimp farming, but by 1999 more than 4,000 ha had been converted to ponds (Licon-González 2000). Given the favorable resource base for farming shrimp near the coastline, it was not surprising that a subset of large private agriculturists focused on aquaculture. More surprising, however, were the shrimp-farming interests displayed by several ejido communities. The source of this interest grew from two roots. The first was the search for a high-value product that could be grown with limited land. The second derived from historical actions that placed many ejido settlements on comparatively poor agricultural land adjoining the sea. Ironically, this land suddenly became very valuable for shrimp farming. Limited data from the 1998-99 Stanford University survey indicated that coastal land had quadrupled in value between 1995 and 1999. Whether the ejido communities will keep the units in agriculture, sell or rent this land (now legally possible because of the change in Article 27) for development, or invest in shrimp ponds themselves is unclear, but whatever choice is made is likely to depend on the types and forms of investment capital that are available. Clearly, however, the "opening up" of the Yaqui Valley by the reforms affected product markets, factor markets, and the welfare of various groups in ways that were not easily predicted in 1991.

Changed Farming Practices

Policy reforms and macroeconomic shocks during the 1990s had major impacts not only on cropping patterns but also on farm practices. The cost structure of farming in the Yaqui Valley changed dramatically between 1991 and 1996 (Table 4). Fertilizers became more costly with the elimination of subsidies, machinery costs increased with the decline in energy subsidies and the rise in import costs, and expenditures on interest escalated with changes in macro policy. As a result, many farmers adjusted the quantity, quality, or method of application of their inputs.

Adjustments in farming practices occurred within the context of an already intensive production system. Fertilizer applications in the Yaqui Valley are among the highest in the world; for example, farmers applied roughly 250 kg of nitrogen per hectare to wheat over a 6-month production cycle (Table 5). Although high rates of nitrogen use were attributed in the past to subsidized prices, most farmers did not respond quickly to recent price increases by lowering their fertilizer applications significantly. With the elimination of subsidies on fertilizers, the real price of urea almost doubled between 1988 and 1996, and the ratio of wheat to urea prices fell by 30% in that same period. The somewhat surprising lack of response reflected farmers' general perception that the value of yield losses from applying less fertilizer would be greater than the resulting cost savings.[25]

This perception by farmers was probably not accurate, at least as judged by field experiments in 1997/98. In those experiments, nitrogen applications ranging from 0 to 350 kg/ha were applied to large plots in farmers' fields. At planting time, farmers consistently underestimated the yields of durum wheat that they *expected* from nitrogen applications of less than 250 kg/ha, relative to the *actual* yields at harvest of the durum wheat that came from those same plots. There was also anecdotal evidence in the

Table 4. Changes in average farm-cost structure, Yaqui Valley, Mexico, 1991 and 1996

	Percent of average production costs[a]	
Input	**1991**	**1996**
Land	23.2	11.8
Machinery	16.3	22.0
Wages	10.4	6.7
Fertilizers	9.2	11.3
Interest	8.8	16.2
Water	4.0	3.1
Other[b]	28.1	28.9

Source: Puente-Gonzáles (1999).

a Averaged over costs of producing maize, wheat, safflower, cotton, sorghum, and soybeans in the Yaqui Valley.

b Other costs include additional chemicals, insurance, technical assistance, production organization fees, taxes, interest charges, and other administrative fees.

[25] These perceptions may have been heightened by the replacement of soybeans, a nitrogen-fixing crop, with corn or sorghum in the summer season.

1997-98 survey to indicate that farmers had started to reduce fertilizer quantities in response to lower grain prices. They had also begun to adjust the timing of their fertilizer applications so as to reduce losses of nitrogen into groundwater and the atmosphere and to improve the protein content of their durum wheat.

Rising costs induced farmers to adjust other practices besides fertilizer applications. Land preparation in the Yaqui Valley typically involved a series of machinery passes (for example, 6-7 for wheat). Recent survey results showed that a large number of farmers eliminated at least one pass per cycle during the 1990s in response to rising fuel prices and farm machinery costs. Notably, this change was linked to the shift from planting wheat on flat ground (the traditional method) to planting on beds (Table 5).[26] The advantages of bed planting included a reduction in land preparation costs, a reduction in weeding costs (with a switch from application of herbicides to tractor cultivation of weeds), a reduction in seeding rates, and more efficient water utilization. The beds also greatly facilitated the switch to conservation (low) tillage systems for handling crop residues (Harris 1996).

Altered Credit and Marketing Arrangements

Institutions governing credit for, and sales of, exportable products also changed in response to macroeconomic conditions in the mid- to late-1990s. During the 1994/95 cropping season, farmers were faced with interest rates that soared to 80% in nominal terms (30% in real terms) and an exchange rate that had lost half of its value. While the latter was beneficial for exports, interest payments became one of the largest variable costs in farmers' budgets (Table 4). Many small-scale farmers simply could not pay the interest charges and lost their ability to obtain loans for future seasons (Lewis 1999).

By the 1995/96 winter cropping season, however, new lines of credit became available to farmers growing durum wheat, cotton, and other exportable crops. The new credit, which was arranged through producer organizations in the Yaqui Valley,[27] enabled farmers to obtain credit in dollars in exchange for contracts to sell most of their output in dollars (with specified quality standards). Contracts specified, for example, that producers sell 4 t/ha of durum

Table 5. Farming practices for wheat, Yaqui Valley, 1980/81 to 1997/98 seasons

	1980/81	1988/89	1994/95	1997/98
Fertilizer use (kg/ha)				
Nitrogen	177	231	251	244
Phosphorus	50	47	52	53
Nitrogen fertilizer (% of farmers who use each)				
Gas (NH_3)	20	48	84	76
Urea	46	69	42	58
Aqua ammonia	54	49	33	18
Phosphorous (% of farmers who use)	59	78	67	88
Land preparation (number of machine passes)	6.8	7.1	6.5	6.3
Method of planting and irrigation (% of farmers)				
Traditional	60	36	20	12
Beds	6	33	55	64
Corrugations	34	32	25	24

Source: Surveys conducted by Stanford University and the CIMMYT Economics Program.

[26] A third form of planting, known as corrugations (*corrugaciones*) was also used. With this method, farmers drill or broadcast seed on flat land, and after planting, form beds. This method results in a more random seed distribution through the bottoms and tops of beds and precludes mechanical weeding.

[27] Initially the producer organizations went through a chain of bureaucratic institutions to secure credit for their members, starting with FIRA. In the 1997/98 season, the bureaucratic line was reduced and credit was made available to some organizations directly from FIRA through BANCOMEXT (the National Bank for Foreign Trade).

wheat at a forward-contracted international price. In some cases—especially for cotton—farmers contracted to sell all of their output in dollars. Dollar-based loans were made to farmers at rates that were significantly more favorable than for peso-based loans. Stanford University surveys between 1995 and 1997 showed that annual interest on dollar-based loans was in the 13-18% range, while interest on peso-denominated loans was 25-30%. The 1995-96 Stanford University survey showed that almost half of the farmers interviewed received credit in dollars, and the average interest cost on credit was M$ 353/ha for dollar-denominated loans and M$ 902/ha for peso-denominated loans. Farmers who secured credit in dollars were thus able to lower costs and eliminate much of the exchange rate and interest rate risks associated with fluctuating macroeconomic conditions.

Although the new arrangements had major benefits for the farming community as a whole in the Yaqui Valley, they also had some drawbacks. For example, price differentials between durum wheat sold in international markets and bread wheat sold to domestic distributors created both problems and opportunities for producers. In the 1995/96 season, most larger-scale farmers planted durum wheat for export, which had the effect of reducing bread wheat supplies in Mexico and hence increasing the bread wheat price. Survey data from that season showed that the average price of wheat (much of it for feed) was M$ 1,513/t for durum wheat and M$ 2,172/t for bread wheat (FOB farm-gate, including discounts and premiums). As a result, many farmers opted against forward dollar-based contracts in 1996/97 for their durum wheat, planted bread wheat instead, and obtained their credit in pesos. Uncertainty about changes in relative crop prices, changing end uses, further depreciation of the peso, and fluctuating interest rates continue to weigh heavily on farmers' minds each season as they decide which currency to use and which crops to grow.

Ejiditarios and other small-scale farmers faced different problems, in large part because they were excluded from dollar-based contracts. Some subsidized credit remained available for these groups, but it was reduced significantly, and many small-scale farmers were unable to secure credit at either subsidized or unsubsidized rates (Lewis 1999). The emergence of new credit and marketing institutions thus had important implications in determining who was doing the actual farming in the Yaqui Valley.

Expanded Operational Holdings

One major outcome of constrained credit for ejiditarios was an increase in the amount of ejido land rented out to private landholders. In the survey on land rental markets in 1998-99, 70% of the ejiditarios interviewed were renting out their land, and 96% of these rentals were to the private sector (Lewis 1999). Almost all of the ejiditarios renting out their land reported that limited access to credit was a primary motivation. Other reasons for renting out their land included high input prices, high water prices, insufficient water supplies, low crop prices (especially the elimination of crop price supports on key crops), and a shortage of affordable machinery. The survey results indicated further that the growing trend in rentals by ejiditarios had already eroded the strength of ejido communities in the Yaqui Valley (Lewis 1999).

The expanding rental market also led to an increase in operational holdings for farmers in the Valley and a consolidation of farming activities. In 1991/92, about 55% of the wheat area was farmed by ejidos,[28] 37% of the wheat area was on land owned and farmed by the private sector, and 8% was produced on land rented in by the private sector. By 1997/98, the respective numbers were 29%, 46%, and 25%. This rental trajectory has not yet stabilized. However, it appears that the various changes in policies, especially in Article 27, increased the scale of operational units in the Valley and hastened the demise of numerous ejido communities as agricultural producers.

[28] Of the 55% farmed by ejidos, 19% was farmed by collective ejidos and 36% by individual ejidos, in which commonly owned land had been parceled out to individual ejidatarios.

Changing Profitability of Farming in the Yaqui Valley

Aggregating the effects of 1991-96 policy changes is difficult; allocating the effects by specific policy is virtually impossible. It is possible, however, to assess financial (private) profitability for typical Yaqui Valley farming systems in 1991 and in 1996.[29] These calculations can then be compared to economic (social) profitability to derive broad conclusions about the efficiency impacts of the reforms in public policy. The assessment begins with a look at per-hectare profits for each of the major crops and then proceeds to per-farm calculations.[30]

Tables 6 and 7 show per-hectare costs and returns for the major crops of the Yaqui Valley in 1991 and 1996, respectively. The derivations are "synthetic" estimates based on CIMMYT surveys, Stanford surveys, and a substantial number of federal, state, and district reports (Puente-González 1999). Cost and revenue data are reported in financial prices (what farmers actually paid and received) and in economic prices. The latter prices value tradable products and tradable factors at world prices, and non-tradable factors, such as labor, in terms of their domestic opportunity costs. These tables also include the rental cost of land in total costs and the marginal cost of irrigation water, that is, the cost per hectare of operating and maintaining the irrigation system. Lastly, the economic calculations use a shadow exchange rate to correct for overvaluation of the peso.[31]

Farm profitability in 1991 depended heavily on the degree of protection given the grain sector by government policy. As shown in Table 6, bread wheat and fall-planted maize were financially very profitable—M$ 747/ha (US$ 248) and M$ 404/ha (US$ 134), respectively. From an efficiency point of view, however, this profitability was largely illusory. If farmers had been forced to compete with international prices, they would have sustained very large losses—M$ 273/ha (US$ 90)and M$ 700/ha, (US$ 232), respectively. Not all grains were given this protection, and the financial and economic losses indicated for sorghum show why that crop was seldom grown in the Valley. Of the shorter summer crops, only soybeans were financially profitable. Interestingly, government policy discriminated against cotton with respect to its own price, yet cotton was subsidized sufficiently heavily with respect to its costs to give farmers a net subsidy of M$ 386 (US$ 128). The problems with cotton were its awkward timing in the rotation (Figure 5) and its uncertain price. For farmers in 1991, the key issue was whether to grow bread wheat *and* summer-planted soybeans, *or* autumn-planted maize, *or* spring-planted cotton. With grain prices generally guaranteed, most farmers opted for the wheat/soybean combination, even though the after-the-fact calculations in Table 6 show cotton to have been a slightly better alternative.

Second, the divergences between financial and economic prices in 1991 were also revealing. There was great variation among commodities, but by far the largest distortion arose from the trade and marketing protection given to bread wheat and winter maize—M$ 1,063/ha (US$ 352) and M$ 940/ha (US$ 311), respectively. On the cost side, the divergences came about primarily from fertilizer and interest rate subsidies, which were fairly consistent per hectare across all crops except cotton, for which input subsidies were higher.

Just five years later, the rural economic situation had changed dramatically. As shown in Table 7, yields for most crops were up substantially in 1996 as a consequence of better seed, improved water management, and additional inputs as farmers responded to higher prices. By 1996, durum wheat had largely replaced bread wheat, and soybeans had dropped from the rotation. Even with high world prices, farmers in the Valley had few profitable

29 "Financial and economic" are analytic terms used by the World Bank. They are identical in concept to "private and social," which are used in other parts of the cost/benefit literature. In this paper, the divergences between financial and economic profitability are limited to those created by policy distortions and market failures. They do not take into account externalities such as pollution, some of which involve substantial costs.

30 Because of survey data limitations, comparisons are restricted to the crop sector only.

31 Many additional assumptions were needed in the construction of Tables 6 and 7, and these are described in Puente-González (1999).

Table 6. Financial and economic profitability of major crops, Yaqui Valley, Mexico, 1991

	Bread wheat		Fall maize		Summer maize		Sorghum		Soybeans		Cotton	
	Financial	Economic	Financial	Economic	Financial	Economic	Financial	Economic	Financial	Economic	Financial	Economic
Yield (t/ha)	4.6	4.6	3.7	3.7	3.0	3.0	4.6	4.6	2.3	2.3	2.4	2.4
Price (M$/t)	650	419	636	382	636	388	400	367	840	819	1,700	1,786
Tradable inputs (e.g., fertilizer, pesticides) (M$/ha)	714	719	453	601	517	711	455	478	425	472	780	972
Domestic factors (e.g., labor, irrigation water) (M$/ha)[a]	978	935	955	915	999	985	977	889	997	964	1,227	1,374
Indirectly tradable inputs (e.g., own machinery) (M$/ha)	397	385	330	340	283	371	371	505	261	339	430	566
Services (e.g., insurance) (M$/ha)	154	161	211	257	218	284	231	300	174	203	494	611
Revenue (M$/ha)	2,990	1,927	2,353	1,413	1,908	1,164	1,840	1,688	1,932	1,884	4,080	4,286
Costs (M$/ha)[b]	2,243	2,200	1,949	2,113	2,017	2,351	2,034	2,172	1,857	1,978	2,931	3,523
Profits (M$/ha)	**747**	**-273**	**404**	**-700**	**-109**	**-1,187**	**-194**	**-484**	**75**	**-94**	**1,149**	**763**
Revenue divergence (M$/ha)	_	1,063	_	940	_	744	_	152	_	48	_	–206
Cost divergence (M$/ha)	_	43	_	–164	_	–335	_	–138	_	–120	_	–592
Net divergence (M$/ha)	_	1,020	_	1,104	_	1,078	_	290	_	169	_	386
Producer subsidy equivalent (%)	_	34	_	47	_	56	_	16	_	9	_	9
PROFITS (US$/ha)[c]	**249**	**–79**	**135**	**–203**	**–36**	**–344**	**–65**	**–140**	**25**	**–27**	**383**	**221**

Source: Adapted from Puente-González (1999).

a Includes rental price of land, and water charged at market cost (M$ 14/thousand m^3).

b Real cost of capital assumed to be 6.5% per year.

c Nominal exchange rate equals M$ 3.02/US$ 1, whereas the equilibrium rate assumed equal to M$ 3.45/US$ 1 for conversion of international to domestic prices.

Table 7. Financial and economic profitability of major crops, Yaqui Valley, Mexico, 1996

	Durum wheat		Fall maize		Summer maize		Sorghum		Cotton	
	Financial	**Economic**	**Financial**	**Economic**	**Financial**	**Economic**	**Financial**	**Economic**	**Financial**	**Economic**
Yield (t/ha)	5.3	5.3	4.8	4.8	4.0	4.0	4.4	4.4	3.0	3.0
Price (M$/t)	2,100	1,569	1,680	1,457	1,680	1,457	1,400	1,172	4,000	4,265
Tradable inputs (M$/ha)	2,033	1,933	1,320	1,368	1,909	2,205	1,572	1,697	3,016	3,389
Domestic factors (M$/ha)[a]	2,348	2,246	2,328	2,228	2,334	2,563	2,150	2,362	3,434	3,827
Indirectly tradable inputs (M$/ha)	1,330	1,105	1,360	1,127	1,093	1,338	1,559	1,882	2,043	2,577
Services (M$/ha)	549	596	647	726	728	872	770	921	1,382	1,674
Revenue (M$/ha)	11,130	8,316	8,064	6,994	6,720	5,828	6,160	5,157	12,000	12,795
Costs (M$/ha)[b]	6,260	5,880	5,655	5,449	6,064	6,978	6,051	6,863	9,875	11,467
Profits (M$/ha)	**4,870**	**2,436**	**2,409**	**1,545**	**656**	**-1,150**	**109**	**-1,706**	**2,125**	**1,328**
Revenue divergence (M$/ha)	_	2,814	_	1,070	_	892	_	1,003	_	–795
Cost divergence (M$/ha)	_	380	_	206	_	–914	_	–812	_	–1,592
Net divergence (M$/ha)	_	2,434	_	864	_	1,806	_	1,815	_	797
Producer subsidy equivalents (%)	_	22	_	11	_	27	_	29	_	7
Profits (US$/ha)[c]	**641**	**312**	**317**	**198**	**86**	**–147**	**14**	**–219**	**280**	**170**
REAL PROFITS (US$/ha)[d]	**573**	**279**	**284**	**177**	**77**	**–132**	**13**	**–196**	**251**	**152**

Source: Adapted from Puente-González (1999).

a Includes rental price of land, and water charged at market cost (M$ 29/thousand m^3).

b Real cost of capital assumed to be 6.5%/year.

c Nominal exchange rate equals M$ 7.60/US$ 1, whereas the equilibrium rate assumed equal to M$ 7.81/US$ 1 for conversion of international to domestic prices.

d Deflated by the US GDP deflator, which amounted to 11.7 % between 1991 and 1996.

alternatives (at *ex post* prices) among the summer crops. With few opportunities for double cropping, the basic choice faced by farmers was a fall-planted grain crop or a spring-planted cotton crop. Grains tended to dominate that profit comparison (M$ 4,870/ha (US$ 641) for durum wheat, for example, versus M$ 2,125/ha (US$ 280) for cotton). More generally, farmers realized that the greatest profit potential was in the autumn season. Surveys also indicated that farmers became increasingly aggressive in trading summer claims on irrigation water for assurances of enough water to sow 100% of their land during the fall season.

In addition, Table 7 reflects the greatly lowered levels of subsidies to the agricultural sector. In 1996 PSEs were substantially lower for most crops than in 1991. The principal distortion within tradable inputs was an implicit fertilizer subsidy arising from PEMEX's subsidized sale of gas to the fertilizer industry.

The reduced distortion of 1996 relative to 1991 occurred in part because of the reforms. More significant, however, was the sharp increase in international grain prices. As shown in Figure 3, the upward spike in world grain prices probably gave farmers a false sense of security, as the post-1996 era was soon to demonstrate.

Data from Tables 6 and 7 were incorporated into Table 8 to show net income per farm for three representative cropping patterns. Although stylized, each year's pattern is based broadly on farm surveys of typical farmer plantings and production techniques. Three patterns for each year provide some indication of how crop selection affected the incomes of typical farmers.

Table 8 displays a representative private farm of 25 ha in 1991, which was assumed to grow to 30 ha in 1996—a growth that simulated the greater size of operating units that arose from new rental arrangements. Double cropping during a single year was aggregated into the line in Table 8 indicated as "cropped area," whereas the physical size of the representative farm was listed under "cultivated area." For ease of comparison, all income data are shown in constant 1991 dollars.

Four aspects of Table 8 are significant. First, cropping systems varied substantially among farmers, as did incomes from those systems. Some farmers made better choices than others, in part because planting decisions were made on the basis of expected or *ex ante* prices and returns, whereas the calculations of Table 8 use actual or *ex post* prices. Second, farm incomes clearly increased, roughly doubling between 1991 and 1996. The total-income comparison can be seen at the bottom of Table 8, whereas

Table 8. Farm incomes (in real 1991 US$) from typical cropping patterns, Yaqui Valley, Mexico, 1991 and 1996

	1991						1996[a]					
	System A		System B		System C		System D		System E		System F	
	Area	Income	Area	Income	Area	Income	Area	Income	Area	Income	Area	Income
Bread wheat	20	4,980	25	6,225	5	1,245	_	_	_	_	_	_
Durum wheat	_	_	_	_	_	_	30	17,190	_	_	15	8,595
Fall maize	5	675	_	_	_	_	_	_	20	5,680	_	_
Soybeans	20	500	25	625	5	125	_	_	_	_	_	_
Cotton	_	_	_	_	20	7,660	_	_	10	2,510	15	3,765
Cultivated area	25	_	25	_	25	_	30	_	30	_	30	_
Cropped area	45	_	50	_	30	_	30	_	30	_	30	_
Total income (real 1991 US$)	_	**6,155**	_	**6,850**	_	**9,030**	_	**17,190**	_	**8,190**	_	**12,360**

Source: Tables 5 and 6. Typical cropping patterns from Stanford University and CIMMYT Economics Program surveys.
[a] Assumes the operating unit grew from 25 to 30 ha between 1991 and 1996.

the per-hectare comparisons by crop can be seen by comparing the bottom lines of Tables 6 and 7. Despite summer-crop difficulties, Valley farmers did well during the reform implementation period as they adjusted cropping patterns, increased yields, and enjoyed commodity prices that were generally higher than in 1991.

Third, the profits per farm shown in Table 8 are sensitive to yield and price assumptions. For this reason, variations in incomes across cropping systems may not be as great as the table suggests. For example, certain farmers may be particularly good at growing certain crops, which would reduce income variations across systems. More importantly, and as noted earlier, the generally healthy farming profits of 1996 came near the peak of recent world prices for many commodities. Attaching 1998 commodity prices to the 1996 cost data resulted in a calculated net loss for all commodities.[32]

Finally, Table 8 includes only a limited number of crops and does not include livestock, specialty crops, or aquaculture. Numerous farmers, often those regarded as most progressive, saw these alternate sources of income as the way forward for the Yaqui Valley.

In short, the economic efficiency of Yaqui Valley agriculture, and the incomes it generated, increased during and immediately after the reforms. These conclusions must be tempered by three important caveats, however. First, Yaqui farmers received great cyclical help from rising world commodity prices during this period. To be sure, the reforms permitted farmers to partake of these gains, just as the reforms made farmers more vulnerable to falling world prices in 1996-99. Second, it is unclear what happened to the distribution of income in rural areas. The reforms clearly had the effect of eliminating crop-production options for many ejidatarios. For some ejidatarios, perhaps many, this loss worsened their incomes absolutely and also relative to others in the Valley. For others, however, the right to rent out their land legally for cash undoubtedly raised their incomes relative to being producers themselves, especially if they were then able to supplement their land rental fees with wage income. The longer-run policy hope was that efficiency gains in the Yaqui Valley (and elsewhere in Mexico) would create streams of incomes and jobs that could more than offset the reduction in subsidies to the ejido sector. Definitive answers on whether this hope is being realized need considerably more research.

Third, the direct environmental consequences of the reforms are unclear and remain largely unanalyzed in this study. Nonetheless, pollution in the Valley is a rapidly growing problem. Disease and estuary problems related to shrimp aquaculture (Naylor et al. 1998, 2000); groundwater pollution from concentrated livestock production (Rice 1995); continuing insecticide problems from areas under cotton; and the very large losses of nitrogen (from fertilizer) via various pathways have all become important issues (Matson et al. 1998; Panek et al. 2000). Finding ways to internalize (into financial costs and returns) these negative externalities will take great policy ingenuity—as well as great policy determination—in the Yaqui Valley and throughout Mexico. It seems clear, however, that the economic profits shown in Tables 6 and 7 would be reduced if quantitative estimates of these environmental damages could be calculated and then transferred into the budgets of farmers in the Valley.[33]

Conclusions

There is widespread belief that the launching of NAFTA in January 1994 singularly altered the nature of Mexico's agriculture. As shown by the schematic summary in Figure 6, this conclusion is only partially correct. The trade agreement may indeed have forced some of the reforms, but for farmers of the Yaqui Valley, the cumulative effects of decoupled income-support policies and of decontrolled factor markets were at least as far-reaching. Mexican history did not design a tidy statistical experiment for allocating total impacts among this broader set of policy changes, but debiting or crediting NAFTA with all that happened to Valley agriculture in the 1990s would be a flagrant misreading of Mexico's reform and market processes.

[32] Cost data in Tables 6 and 7 represent average costs. In the short run, many farmers were covering marginal costs.

[33] Measuring environmental damage from various Yaqui Valley sources is a principal focus for Stanford University's ongoing research.

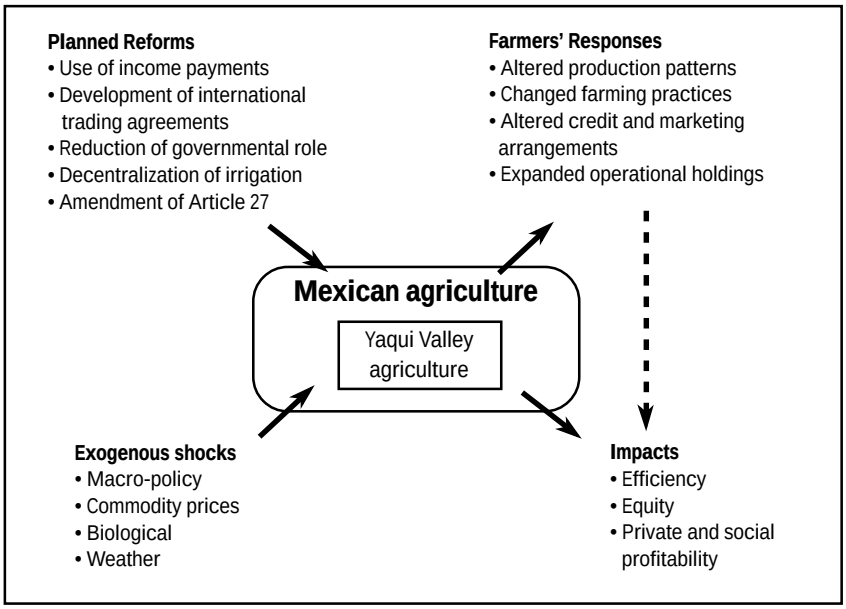

Figure 6. Schematic summary of reforms and shocks, Yaqui Valley, Mexico, 1990s.

At the beginning of the 21st century, Mexico's agriculture is more efficient and more competitive internationally than it was just ten years earlier. Especially in the Yaqui Valley, product and factor prices were significantly realigned during the 1990s, and institutions serving agriculture became more market oriented. Between 1991 and 1996, wheat yields increased considerably, and average real farm income grew substantially.

If conclusions about the economic efficiency gains are clear, they are much less definite with respect to the reforms' income effects on private farmers and ejidatarios in the Yaqui Valley. In a globally oriented agriculture, export activities obviously fare poorly in periods of low world prices. Mexican agriculture may be more efficient now than prior to the reforms, but it may also lack some of the income safety nets that were available earlier. How much would have been spent by the government on those safety nets, in the absence of the reforms shown in Figure 6, is a key, yet unanswerable, analytic question. The effect of the reforms on longer-run migration of farmers out of Valley agriculture is a similarly important question.

One of the most significant, and perhaps most surprising, findings of the Stanford University surveys concerns the combined effects of credit and land reforms. The elimination of preferential credit subsidies to the ejido communities, combined with the legalization of land rentals and sales by ejidos, has had important consequences in the Yaqui Valley. More and more ejido land is rented out to private farmers, enlarging the average scale of the latter and hastening the agricultural demise of the ejidatarios. Whether, on balance, ejidatarios are better off renting their land and seeking additional wage income is a long-run question deserving much more analysis.

As broad, and perhaps as compelling, as the efficiency changes have been for the Yaqui Valley, the 1990s also showed the key role of exogenous shocks to the agricultural sector. Macro-level policy in Mexico, volatile world commodity prices, and agricultural pests and diseases had at least as much to do with Yaqui Valley farm incomes as did the policy changes. Implementation of the reforms in Mexico was also clearly assisted by the rise in world agricultural prices during 1992-96. (There is more to implementing reforms than luck with timing, but the latter surely helps!)

At the beginning of the 21st century, however, three problems loom very large. First, the widespread and deep decline in global commodity prices during 1996-99 poses severe income problems for Yaqui Valley farmers in the newly open environment in which they live. This price-income problem is tightly coupled with technology problems for the summer season. With the loss of many subsidies because of the policy reforms, plus the loss of soybeans in the cropping system because of whitefly infestations, farmers are searching for new production alternatives. Mexico's new openness to trade may provide more production alternatives by way of demand-driven, high-valued products. However, much of the marketing and information infrastructure needed for such systems is not yet in place.

Second, livestock, fruits, vegetables, and aquaculture may provide profitable options for the future, but even if the infrastructure and information systems can be put in

place, there remain serious environmental dilemmas associated with each of these activities. Such dilemmas are likely to require joint actions and basin-wide planning efforts in a region that is well known for its highly successful yet highly individualistic farmers.

Third, unavailability of irrigation water poses a new and major threat to the region. No-one knows whether the drawdown of reservoirs between 1995 and 2000 was a random event or a harbinger of high-probability events of the future. But new thought is urgently needed on water-conserving crops that are not currently grown in the Valley; on optimal strategies for using irrigation water more efficiently on crops that are grown—such as two versus four supplemental irrigations for wheat; and on whether it makes sense to produce any crops during the summer in the face of very high evapotranspiration rates during that season. New varieties of wheat and maize more adapted to water stress offer important research challenges for the next decade.

By almost any standard, the Mexican reforms of the 1990s were both wide-ranging and successful, at least as measured in efficiency terms. Yet at the turn of the century, all is not well with the Yaqui Valley's rural communities. The ejido communities appear to have lost cohesiveness, and even the larger-scale farmers in the private sector currently face serious income problems. More generally, farmers have yet to find profitable new production systems, including the associated marketing institutions, which are consistent with greater reliance on world agricultural prices and diminished dependence on explicit and implicit subsidies from the government.

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Annex A
Profile of the Yaqui Valley, 1890-2000

1890	The Ministry of Development grants to Carlos Conant the right to open irrigation channels on the margins of the Yaqui, Mayo, and Fuerte Rivers and to launch their colonization.
1891	Conant and US investors establish the Sonora and Sinaloa Irrigation Company to execute the contract for irrigation and colonization.
1900	The Sonora and Sinaloa Irrigation Company completes 39 km of channels from the Yaqui River.
1901	The Sonora and Sinaloa Company goes bankrupt.
1902	The Sonora and Sinaloa Irrigation Company and its shareholders reach an agreement on payments. The Company pays its debt with land.
1903	Conant receives a new concession from the Ministry of Development to irrigate and colonize the Yaqui Valley.
1904	Conant begins the Compania de Irrigación del Valle de Yaqui to accomplish development work in the Valley.
1904	The Sonora and Sinaloa Irrigation Company sells its rights to the Richardson Construction Company, a California-based land development company.
1907	Conant dies at the age of 63.
1907	The railroad reaches the point known as Esperanza Station, which years later gives rise to Cd. Obregón.
1909	Richardson Construction Company forms the Compania Constructora Richardson and negotiates a new contract with the Ministry of Development regarding construction and colonization.
1909	David Richardson begins a new company, the Yaqui Land and Water Company, with an initial capitalization of US$ 15 million.
1909	Esperanza Station grows to a population of 450.
1911	Compania Constructora Richardson establishes an agricultural experiment station and publishes a crop calendar, including recommendations for 73 crops.
1913	Civil war extends into Sonora.
1913	Farmers in the Yaqui Valley plant 11,000 hectares.
1914-17	Development in the Yaqui Valley is delayed because of the war.
1920	The government and the Yaqui people sign a peace agreement, concluding 50 years of intense warfare.
1925	Irrigated area increases from 15,000 to 37,000 ha.
1926	The government cancels the concession to the Compania Constructura Richardson and buys its shares of the Yaqui Land and Water Company, paying US$ 6 million. The company turns all of its shares over to the government development bank.
1927	The State of Sonora declares the creation of Cajeme County.
1927	Agricultural producers organize a research station.
1928	The National Bank of Agricultural Credit takes over the irrigation system and land.
1930	Cajeme County (including Cd. Obregón) grows to a population of 12,000.

1936	The National Bank of Agricultural Credit assumes control of development but later transfers control to the National Irrigation Commission.
1937	The government applies the Land Tenure Law and expropriates private land to distribute among new ejidatarios. Altogether 17,000 ha are distributed to ejidatarios, with 27,000 ha remaining in the private sector. An additional 34,000 ha of new land is also allocated to ejidatarios.
1937	The government launches the construction of the Angostura Dam.
1938	Farmers harvest 53,000 ha.
1940	Cajeme County grows to a population of 28,000.
1942	Angostura Dam is completed, adding an additional 60,000 ha of irrigated area.
1943	The government and the Rockefeller Foundation launch a collaborative agricultural research program, forerunner of the International Maize and Wheat Improvement Center (CIMMYT).
1950	Cajeme County grows to a population of 63,000.
1951	Wheat yields average 1.5 t/ha.
1951	The government creates the Yaqui Valley Irrigation District.
1953	Oviachic Dam is completed, adding 108,000 ha of irrigated area.
1955	Farmers in the Yaqui Valley harvest 210,000 ha of crops.
1960	Cajeme County grows to a population of 124,000.
1961	The government establishes the Instituto Nacional de Investigación Agrícola (INIA), the National Institute for Crop Research.
1963	CIMMYT is created.
1963	Improved seed from CIMMYT is first released to producers.
1964	100% of producers use improved seed.
1963	El Novillo Dam is completed, mostly for electricity generation, but also allowing total Yaqui Valley irrigated area to grow to 233,000 ha.
1970	Cajeme County grows to a population of 183,000.
1970	Wheat yields average 3 t/ha.
1975	The government expropriates 34,000 ha of private irrigated land, which is transferred to new ejidos. The Yaqui Valley is thus divided among the private sector (41%), ejidos (55%), and colonists (4%).
1980	Cajeme County grows to a population of 256,000.
1990	Wheat yields average 5 t/ha.
1995	Whitefly invades the Yaqui Valley.
1996-2000	Regional drought seriously depletes reservoir levels for the Yaqui Valley.
2000	Wheat yields average 6 t/ha.