OCCASION

This publication has been made available to the public on the occasion of the 50th anniversary of the United Nations Industrial Development Organisation.

DISCLAIMER

FAIR USE POLICY

CONTACT

Please contact publications@unido.org for further information concerning UNIDO publications.

For more information about UNIDO, please visit us at www.unido.org

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

[Mexico. Use of plastics in agriculture.]

1985

14953

CONSULTANTS REPORT

Consultant: Ronald G. Cummings

UNDP Mission: DP/MEX/78/017/11-06/321H
June 9, 1985 to July 8, 1985

I. CHRONOLOGY OF ACTIVITIES

June 9 Arrived Mexico City

June 10 Meetings with: Dr. Javier Salas Martin del Campo, Economist, Banco de Mexico, Condessa #6, D.F. (discussions concerning methods for assessing plastics in agriculture from a Mexico-wide, "social benefits" perspective--interchange concerning "best" methods for estimating the shadow price of foreign exchange in Mexico); (representatives for) Lic. Carlos Vidali C., Dir. Gen. de Asuntos Internacionales, SAGRH, Carolina 132, D.F.(bibliographical research for background agricultural data that will be required for extrapolating CIQA research results to "Mexico's agricultural sector"); Dr. D. Winklemann, Director of Economic Studies, CIMMYT, El Baton (methods related to technology transfer issues.

June 11 Agricultural Economists at the Collegio de Postgraduados, Centro de Economia Agricola, Chapingo (Dr. Luis Chalita, primary contact). Arrangements with Dr. Jose Silos, Director de Banca Agropecuaria, Sria de Hacienda y Credito Publico, Netzahualcoyotl No. 127, D.F. for collaboration in setting out policy issues in Mexican agricultural which may relate to the use of plastics in the agricultural sector.

June 12 Second visit with personell (Dr. Javier Salas) at the Banco de Mexico; Dr. Jaime E. Alatorre Cordoba, Dir. de Contabilidad Nacional Y Estadisticas Economicas, Instituto Nacional de Estadistica Geografia E Informatica, Insurgentes Sur 795, D.F. (assistance in putting together agricultural statistics for economic studies of plasticulture). Office of Lic. Shigeru Yoshioka, Dir. Gen de Informacion, Estadistica Sectorial, SARH, Paseo de la Reforma 107, D.F. (data concerning water scarcities in areas which might serve as demonstration areas for plastics use.

June 13 Travel: Mexico City-Monterrey-Saltillo.

June 14-21 Review of progress by Efrain Jimenez; meetings with Dr. S. Fernandez and other CIQA staff. Preparing data required for studies concerning On-farm and "social" assessments of the feasibility of plastics use in agriculture.

June 21-July 8 Albuquerque, N.M. (USA). Used data derived above to (i) complete draft of study concerning early-to-market benefits (foreign exchange earning) attributable to the use of Plastics in Mexico's agricultural sector; (ii) preparation and application of a Linear Programming Model for use as a computational algorythm for assessments of the economic feasibility of plastics use in agriculture with alternative criteria for feasibility; (iii) prepared draft report of feasibility study. This draft is effectively a model for later studies to be completed when experimental data from CIQA's tests are make available. Preparation of Consultants Report.

II. STATUS OF ECONOMIC STUDIES IN THE CIQA PROGRAM

At this point it is usefull to consider the progress of economic assessment studies in CIQA's research program within the context of the guidlines laid out for the program as they are spelled out in Dr.s Prrsan and Fernandez's "Programa de las Naciones Unidas Para El Desarrollo, Proyecto del Gobierno de Mexico, **Documento Del Proyecto Plasticos En La Agricultura**", Borrador , Enero 1982 (hereafter referred to as "the Guideline"). As they relate to economic studies, the Guideline's research plan defined the **sub projects** which would give rise to the following (paraphrased) **results**.

Sub Project	Result--described below
3.2 & 3.3: plan and organize collaborative research and technology transfer programs with other Mex. agencies	E.11
3.4 Study mechanisms for technology transfer to the plastics-producing industry.	E.13
3.5 Study mechanisms for technology transfer to the agricultural sector.	E.13
3.6 Study the regional impacts of technology transfers.	E.15
3.7 Analyze (benefits and)costs of plastics developed in the CIQA program and use such costs to estimate the market potential for agricultural plastics.	E.8
3.8 Study alternative construction & installation modes for agricultural plastics and determine the relative impacts on the market for plastics.	E.8

3.9 Determine the economic feasibility, relative to conventional practices, of using plastics in the agricultural sector. Use these results to determine (a la 3.8) the potential extent of the market for agricultural plastics.

Description of "Results"(or research outputs/deliverables).

E.8 A study of the economic feasibility of the use of plastics in agriculture, wherein data from Experiment Stations are used.

E.11 Obtain cooperative agreements for research/development activities with other agencies and businesses.

E.13 A study of alternative mechanisms for transfering technology to plastics and agricultural industries.

E.15 A study of regional impacts that may be expected to attend the transfer of agricultural plastics technology toplasticsand agricultural industries.

At the outset of this assessment, two general comments might be warrented. First, the failure of PEMEX to follow through with their commitment of funds required for travel and personnell support for the completion of efforts to collect experimental data concerning winter crops grown with plastics (and testigos) has obvious implications: analyses dependant upon these data have not been initiated. Assuming that ongoing efforts to salvage these experimental data are successful, however, these problems need not have disasterous effects on the timing of economic studies. This relates to the second general observation, viz., that Ing. Efrain Jimenez has been successful in continuing efforts to amass all other data required for the economic studies and, in collaboration with the Consultant, analytical models and reporting frameworks have been established which will allow for (i) the rapid analytical exploitation of the experimental data when they become available and (ii) reasonably quick completition of written reports required by the Guideline.

In terms of sub-projects 3.2 and 3/3, and the corollary Result E.11, the consultant has had little direct involvement in these projects. The consultant has established informal contacts with a number of economic research groups in Mexico--Dr. Salas with the Banco de Mexico; Dr. Winklemann with CIMMYT; Dr. Chilita with Chapingo; Dr. Silos with Banco de Credito in Hacienda, to name but a few. Cooperative agreements such as those sought as Result E.11 have been forthcoming as a result of Dr. Fernandez's efforts, however(in the consultant's understanding). Examples include the (regretably , unhonored) agreement with PEMEX and the contemporary agreement with INIA. In any case, the potential for reasonable success in sub-projects 3.2 and 3.3 would seem to clearly exist.

The consultant suggests that sub-project 3.4, and the attendant Result E.13, is effectively completed. E.13 is satisfied by the two earlier reports prepared by Dr. Robert Anderson, along with his Cost-Efficiency model for a plastics manufacturing plant, the algorythm for which is in written form and is on CIQA's computer system. In large part, technology transfer issues relevant for the manufacturing sector revolve around the compelling demonstration of a profitable operation. Such a demonstration, the analytical framework for which is nicely provided by Dr. Anderson's earlier work, requires data related to costs (data which is reasonably available and, in any case, internal to the firm) and to market prices for agricultural plastics. Market prices, however, depend upon adoption rates (technology transfer)in the agricultural sector (how much plastics will farmers want to buy--what is the extent of the market?). Thus, while sub project 3.4 may be considered to be accomplished in a structural sense, final conclusions regarding project 3.4's topic must await the completition of sub project 3.5 (as well as 3.6 and 3.9).

As set out in the Guidline, the remaining five sub projects 3.5 through 3.9 would culminate in three research "deliverables": a study of technology transfer issues (agriculture); a study of the on-farm economics of plasticulture; and a study of regional effects that might attend the development of a viable agricultural plastics industry in Mexico. The topics addressed by sub projects are highly interrelated and, together, imply lines of inquiry that address the following questions.

A. Given prices and production costs, would a farmer reasonably expect to make more profits with plastics than without them? Under what circumstances is "plasticulture" profitable? Of interest are the economic implications of the effects that attend plastics use: reduced input/production costs (for fertilizers,other chemicals, electricity for pumping, costs for weed control and early-to-market (early harvests due to shorter germination periods when plastic mulches are used) effects.

B. Does the use of plastics in agriculture give rise to effects that, while not translated directly into profits for a farmer, are substantially important to Mexico per se? Examples include the "social" value of foreign exchange; the non-market scarcity value of water in areas of extreme water shortage (as along the Northwest Coast of Mexico);and social costing of labor resources in areas of labor surplus. In such instances, it may be in the national interest to offer subsidizes that would make feasible an agricultural plastics industry.

C. Both in the case of the farmer and in instances where "social" values are relevant, given the conditions under which the use of plastics might be economically feasible, how much plastics would be used under these conditions--would this demand for plastics be sufficient to justify the existence of an agricultural plastics industry in Mexico?

D. Do non-economic impediments to the adoption of the plastics technology in agriculture exist; if so, how might such impediments be removed or mitigated?

Considering sub projects 3/5-3.9 within the context of the four questions posited above, the status of CIQA's economic assessment efforts may be summerized as follows.

A. On-farm feasibility issues. The consultant has completed a draft report (enclosed) of a study for this class of issues. Given that CIQA's experimental data are not yet available, analyses in this study are based on assumed values for most parameters and coefficients. Moreover, the analyses are limited to but three crops (tomatoes, cantelope and watermelon) under production conditions found in only one agricultural region: the Comarca Lagunera irrigation district. The draft report serves two important purposes, however. First, analytical and computational tools/programs are shown to be operational; once available,the experimental data can be processed in a reasonably short time. Second, expository structures for the economic reports are well established, thereby easing the logistical problems of report preparation that may arise after the processing and analysis of CIQA's experimental data. Thus, given access to the experimental data by early fall, 1985, this class of studies/reports may be completed in a timely fashion.

B. Social Accounting and the Feasibility of Plasticulture. Discussions of social accounting issues are included in the (enclosed) feasibility study conducted by the Consultant (with the collaboration of Ing. Jimenez, of course). At this juncture, solutions involving dominant use of plastics are obtained for the study of vegetables grown in the Comarca Lagunera. This being the case, CIQA may choose to give less emphisis to social accounting issues--social accounting does not alter the feasibility of plastics use in agriculture. Once the experimental data become available, these conditions may change. Thus, the decision as to the weight to be given social accounting issues, and whether a seperate report will be needed, must await the processing of CIQA's experimental data.

Relevant for both the on-farm and social accounting sets of issues described above is the impact on market prices of changes in the time-profile of market deliveries of crops which may attend the use of plastics in agriculture. CIQA economists have yet to discover data concerning domestic markets of sufficient quality to allow for studies of domestic demand relations. Data do exist that relate to the export market--specifically, Mexico's marketing of fruits and vegetables in the United States. The consultanthas completed a draft of a study which examines the relationship between the timing of market "supplies" of various crops offered by Mexican producers and the price, f.o.b. Nogales port of entry, recieved by Mexican producers for their produce (see enclosed market study). This study will undergo expositional changes, but is effectively in final form.

C. The Question of Market Size. Completion of the on-farm and social accounting feasibility studies (topics A and B above) will allow analytical focus on the question: holding market prices fixed, is the use of plastics economically feasible and, if so, for how many hectares? The (enclosed) marketing study addressed the question: assuming on-farm feasibility, how many hectares of Mexican crops should be under plastics in order to maximize profits--and foreign exchange earnings--from the marketing of Mexican fruits and vegetables? A credible, comphrensive response to the "how much plastics" question is then seen to be lacking in any one of the above cited studies: what is required is an analytical framework wherein on-farm feasibility and market prices are determined simultaneously. The analytical model for providing these simultaneous solutions has not yet been developed.

D. Non-market Impediments to Technology Adoption. One of the more important dimensions of CIQA's assessment of the feasibility of an agricultural plastics industry in Mexico may be it's treatment of the non-market aspects of technology adoption, particularly as they relate to the agricultural sector. Basic data, and initial formation of ideas, have been accumulated by the consultant via his interactions with Mexican (and other) economists who specialize in this area, as examples: Winklemann at CIMMYT, Silos in Hacienda and McFarland at the University of Houston. The structure and completion of this study has yet to be formalized, however.

III. CONSULTANTS RECOMMENDATIONS.

As implied in the above, the Consultant finds CIQA's economic assessment studies--as they are mandated in the Guidline--to be in a reasonably advanced state, notwithstanding the delays in completing the process of collecting experimentil data from winter crops. The structure for the on-farm feasibility study and the social accounting--social feasibility--study is set in expository terms and assessment tools for necessary analyses using the experimental data are on-line. Assuming access to the experimental data, these two studies/reports should be finished on schedual. The same applies to the companion study of export prices. This study is close to final form. The completion of these works, along with remaining areas requiring research attention, form the substance of the Consultant's recommendations which are as follows.

Recommendation 1. CIQA, along with UNDP personell and project managers, should assure access by Ing. Jimenez and the Consultant to winter-crop experimental data by early fall, 1985. CIQA's economics team should aim for the completion of the on-farm and social accounting feasibility studies for these crops by December 31, 1985; this same date should apply to the completition of the international market study.

Recommendation 2. Timely focus on the critical "how much plastics" --market size--question will require that CIQA's economists complete the development of an analytical framework for the simultaneous solution of on-farm production patterns and optimal time profiles for market deliveries (as determined by the proportion of hectares under plastics) by no later than late fall, 1985. This schedual would allow for the completion of this line of inquiry by early Spring, 1986, as schedualed.

Recommendation 3. CIQA should set a deadline of early fall, 1985, to make arrangements for having access to personell required to complete the non-market technology transfer study. It is likely that completition of this study will require collaboration with other Mexican and Latin American scientists experienced in this line of inquiry as it applies to the agricultural sector. Efforts beginning in early/late fall, 1985 should allow for the study's completition by Spring/summer, 1986, as schedualed in the Guideline.

DRAFT

Date ____________

NET FARM AND SOCIAL RETURNS TO THE USE OF PLASTIC MULCH IN MEXICO'S AGRICULTURAL SECTOR

By Ronald G. Cummings

INTRODUCTION

The use of plastics for mulch in agriculture began in the late 1950's, primarally in the production of vegatable (see, e.g., Ilic, Dubois, Spice and Coffey). In the agricultural community it is generally accepted that the use of plastic mulches results in benefits to the farmer: yields are enhanced (Nicholas, June 17, 1983,Anderson and Fernandez, Clarkson, and Harris); earlier harvests may be obtainable (Spice, Nicholas, June 17, 1983, Trujillo and Corgan and Hopen and Oebker); higher quality crops are obtainable (Ilic and Coffey); and reductions in the use of some inputs (primarilly water, insecticides/fungacides, weed control, and fertilizers) can be achieved with good management (Anderson and Fernandez, Coffey and Dubois). What is not generally accepted , however , is the economic feasibility of plastics use in agriculture : the value of the above-described benefits may or may not cover the costs of plastics (typically , with polyethylene plastics costing U.S.$2.00/kilo and assuming plastic mulch requirements for single crop agriculture at 400 kilos per hectare, plastics cost would run some US$800/ha.).

The question as to the economic feasibility of using plastic mulches in agriculture is shown to hold for high valued crops is some circumstances, but the general feasibility of the technology remains as an open question. In this study the economic feasibility of "plasticulture" is examined within the setting of Mexican agriculture. More specifically, the feasibility of using plastic mulch for tomatoes, cantelope and watermelon in the Comarca Lagunera region of North Central Mexico is analyzed. "Feasibility" is considered in two contexts: feasibility as measured by farm profits, and feasibility from the standpoint of net social benefits attributable to the use of plastics in Mexicos' agricultural sector.

To the ends described above, this paper is organized in the following manner. Section II sets out the feasibility problem for the "net farm income" and "net social benefit" contexts alluded to above and presents a structure for an analytical model for assessing the feasibility of using plastics in Mexicos' agricultural sector. Data required for the application of this assessment model are developed in Section III; these data are structured for use in a Linear Programming solution algorythm. Section IV presents results from the assessment model as they apply to alternative scenarios related to Mexican agriculture. Conclusions and recommendations are offered in Section V.

II. THE ASSESSMENT MODEL

For any given crop, let y and y' be yield/ha. with and without the use of plastic mulch, respectively. M is the number of hectares under plastics; with hectares in this crop fixed at C-hectares, the number of hectares not in plastics is A = C - M. With the farmgate price of the crop (in units of y) measured by p, gross farm revenues are given by

(1) $GFR = p[\ yM + y'A\ ]$

From a societal standpoint, however, p may understate the value to society from the production of the crop in question. When the crop is exported, for example, the value of foreign exchange earned by selling the crop in the international market may exceed p. If p* measures the true value of foreign exchange (technically referred to as the "shadow price " of foreign exchange; see Howe, Dasgupta and Heal and Howe and Easter), the social counterpart to the measure of gross farm revenue given in (1) --commonly called gross social benefits--is given by the following, where $L = p^* - p$.

(2) $GSB = pL[y'A + yM\ ]$

Total farm costs, TFC , are given by the following.

(3) $TFC = c1(A + M) + c2FER + c3INS + c4FUG + c5WATER + c6WEED + c7LABOR + c8HARV + c9PLASTIC$

where in (3):

(4) $f'A + fM = FER$

(5) $i'A + iM = INS$

(6) $g'A + gM = FUG$

(7) $w'A + wM = WATER$

(8) $j'A + jM = WEED$

(9) $l'A + lM = LABOR$

(10 $h'A + hM = HARV$

(11) $qM = PLASTIC$

(12) $A + M = C$

In (3), c1 through c9 are unit costs for non-plastic related inputs (c1), fertilizers (FER), insecticides (INS), fungicides (FUG), water (pumping/distribution costs, WATER), weed control (WEED), labor, harvesting costs (HARV) and plastics. Equations (4) through (12) serve two purposes: to define levels of input use (which is then costed in (3); and to constrain the problem (equations 11 and 12). In (4)-(12), lower case letters denote p technical coefficients: input use per hectare of land without plastics (A, coefficients are denoted by ') and land with plastics. Thus, (4) defines the total level of fertilizer use, FER, as total fertilizer use on lands without plastics (f'A) plus lands with plastics (fM); (7) defines total water use as water use on lands with (wM) and without (w'A) plastics, etc.. Equation (11) defines total plastics use; (12) requires that total land in use not exceed the number of allotted hectares C.

As in the case of gross farm revenues, social costs may well differ from those viewed by the farmer. To the extent that the cost of any input is subsidized, social costs for an input k may exceed the cost ck seen by the farmer. If inputs are purchased in international markets, the loss of foreign exchange may increase the social cost of the input over that seen by the farmer. When inputs are scarce, but their scarcity is not reflected in production costs, social costs may exceed private costs. In this latter regard, a classic example is groundwater used for irrigation: pumping costs, c5, paid by the farmer, will exclude the future costs of an exhausted aquifer and the higher pumping costs imposed on all future years as a result of current lowering of the water table (see Kelso, Martin and Mack, Cummings, 1972, 1974, Scott). On the other hand, in some instances social costs for particular inputs may be <u>less</u> than those seen by the farmer. For example, if agricultural production makes use of previously unemployed (or underemployed) labor, the social costs of these particular inputs is the opprotunity cost of labor which may be at or near zero (Howe and Easter, Dasgupta and Pearse and Howe).

Let Lk denote the factor which adjusts private costs for social costs for inputs k, k = 1, 2, .., 11. Total social costs, the social counterpart to total farm costs given in (3), takes the following form.

(13) TSC = c1L1(A + M) + c2L2FER + c3L3INS + c4L4FUG +
c5L5WATER + c6L6WEED + c7L7LABOR + c8L8HARV +
c9L9PLASTIC

Conditions (4)-(12) are unchanged for expressions of total social costs.

We add to the systems described above the following conditions:

(14) FER < FIXFER

(15) INS < FIXINS

(16) FUG < FIXFUG

(17) WATER < FIXWATER

(18) WEED < FIXWEED

(19) LABOR < FIXLABOR

(20) HARV < FIXHARV

(21) PLASTIC < FIXPLASTIC

The set of equations (14) - (21) allow for analyses of the impacts that may attend scarcities that may attend some (or all) of the resources used in producing the crop in question. Thus, (14) requires that resources used for fertilizers may not exceed the quantity FIXFER; water use (17) may not exceed the quantity FIXWATER. Moreover, for those resource-activities which are scarce, our later-described use of linear programming as a solution algorythm allows for the calculation of imputed scarcity values for these resources(see Dorfman, Samuelson and Solow). We will be particularly interested in such scarcity values for : water, labor and plastics.

Consider now the following two questions concerning the feasibility of using plastics in Mexico's agricultural sector: IS THE USE OF PLASTICS FEASIBLE -- IN THE PROFIT MAXIMIZING SENSE -- FOR INDIVIDUAL FARMERS IN MEXICO'S AGRICULTURAL SECTOR ? ; IS THE USE OF PLASTICS FEASIBLE FROM A NATION-WIDE OR SOCIETAL PERSPECTIVE; I.E. IS THE USE OF PLASTICS IN MEXICO'S AGRICULTURAL SECTOR SOCIALLY FEASIBLE ? These questions may be addressed via analyses of the following two criteria:

(C.1) MAXIMIZE NET FARM INCOME

(C.2) MAXIMIZE NET SOCIAL BENEFITS

Within the context of our inquiry, C.1 and C.2 refer to the determination of values for A and M --hectares without and with plastics, respectively--which are solutions to the systems : maximize (1) minus (3) subject to (4) through (12) and (14) through (21) for C.1; and maximize (2) minus (13) subject to (4)-(12) and (14)-(21) for C.2. Thus, attention is now turned to a discussion of data required for solving these systems.

III. DATA FOR THE ASSESSMENT MODEL

Data to be used in the Assessment Model developed in section II are given in Tables 1, 2 and 3. In Table 1 prices, yields (per hectare) and revenue/ha. are given for Gross Farm Returns and Gross Social Benefits with and without plastics are given for the crops of concern here: tomatoes, cantelope and watermelon. Prices are 1985 farmgate prices; yields, obtained from the Torreon office of the SAGRH, reflect average yields in the Comarca Lagunera district during the 1984-85 agricultural cycle. Note also that yields are averaged across ejidatario and pegueno propietario producing units. Yields with plastics are assumed to be 20% higher than those from acerage without plastics. In light of the literature cited in section I, the assumed 20% yield increases from plastics may be quite conservative.

Taking 1970 as a base year, the author considered the rate of exchange between the U.S. dollar and the Mexican peso which would have maintained the 1970 parity between domestic prices in Mexico and the U.S.. These analyses suggested that, on average, the official exchange rate in Mexico was some 15% too low. Thus, an appropriate "shadow price" for foreign exchange in Mexico would be 1.15. Therefor, "Social Revenue" given in column 6 of Table 1 is obtained by weighting Farm Revenue by the factor 1.15.

Technical coefficients, and imput costs, were again obtained

TABLE 1

PRICES AND YIELDS FOR STUDY CROPS*

CROP	PRICE (1985 Mex. pesos)	YIELD PER HECTARE WITHOUT PLASTIC(y')	YIELD PER HECTARE WITH** PLASTIC(y)	REVENUE/HA. ('85 Mex. pesos 000) FARM	REVENUE/HA. ('85 Mex. pesos 000) SOCIAL
Tomato	$25,000	16 Ton	19.2	$400	$460
			(with plastics:	480	552)
Cantelope	15,090	14.2	17	214	247
			(with plastics:	257	295)
Watermelon	16,000	25	30	400	460
			(with plastics:	480	552)

SOURCE: Data from the Torreon office of SAGRH

*Yield/input data are for averages across ejidatario and pegueno propietario units in the Comarca Lagunera (Coahuila and Durango States) irrigation district. Gravity irrigation is assumed.

**Assumes 20% yield increase with plastics.

TABLE 2

TECHNICAL COEFFICIENTS FOR AGRICULTURAL PRODUCTION

OF SELECTED CROPS: GRAVITY IRRIGATION IN THE

COMARCA LAGUNERA REGION

CROP	GENERAL (1985 Mex. pesos 000)	FERTILIZERS, INSECTICIDES, FUNGICIDES, ETC.** ('85 Mex pesos 000)	WATER USE (M3)	COST
Tomatoe	$80.1	$30.2	11,000	*
Cantelope	66.0	34.9	9,700	*
Watermelon	71.5	30.2	9,700	*

CROP	HARVEST	PLASTICS QUANTITY (kilos/ha)	PLASTICS COST ('85 Mex pesos 000)	LABOR: MAN DAYS	LABOR: COST*** ('85 Mex pesos 000)
Tomatoe	*	400	$105.6	89	$58.4
Cantelope	*	400	105.6	53	34.6
Watermelon	*	400	105.6	53	34.6

SOURCE: Data from the Torreon office of SAGRH

*Costs reported only as a labor cost.

**Note that we abstract here from the possible effects on weed control, fertilizer use, etc., from the use of plastics

***Mex$660/day.

from the Torreon office of the SAGRH and they reflect agricultural conditions in the Comarca Lagunera region during the 1984-85 agricultural cycle. All costs and coefficients are on a per-hectare basis. Fertilizers, insecticides, fungicides and other chemical inputs are lumped together given the manner in which these data are reported. Such costs per hectare are for purchased chemicals only; related labor and/or machinery costs for applications are included in the Labor or General columns, respectively. Chemical costs are treated in this manner to allow for later analyses of scarcity values associated with inputs from petroleum sources and/or imports. Since data in Table 2 relate to irrigation via gravity methods, water is not directly costed. As we will show later, however, water inputs have substantial imputed costs. As reported by the SAGRH, harvest costs include only labor costs; thus, their inclusion in Table 2 under column 9. Unless otherwise specified, labor is costed at $660/day (1985 Mexican pesos).

Plastics are assumed to be used for single cropping cycle at 400 kilos per hectare per growing season. Plastics costs, which are assumed to include installation, maintanence and removal, are taken to be $480/kilo (1985 Mexican pesos).

One should note, referring to Table 2, that this representation of agriculture under plastics abstracts from all potential effects from plastics use other than yield-effects. Examples, noted in earlier sections of this report, include reduced uses of fertilizers and other chemicals, reduced water use, fewer resources required for weed control and increased managerial inputs (and, therefor, higher returns required for entrepreneurship/management). Later refinements of this work should attempt to include these effects.

Finally. restrictions to be imposed on our model are given in Table 3. The "fix" restrictions serve two purposes. First, they bound the problem. Thus, we cannot produce unlimited hectares of tomatoes or watermelon. Based on actual acerage in these crops in the Comarca Lagunera during recent times, we allow but 100, 160 and 80 hectares for tomatoes, cantelope and watermelon, respectively.

Secondly, these restrictions allow for the parametric variation of key parameters in efforts to test the sensitivity of results to changes in the parameters and for the calculation of imputed values for these resource parameters at various levels of availability. Thus, we allow the land resource to be available at levels of 200 and 340 hectares. We will then examine the effects on levels of usage of other resources as land availabilities change. The same analyses will be conducted for the water resource at availability-levels of 2.2 and 3.4 million cubic meters.

The data given in Table 1-3 are used as inputs for a linear programming solution algorythm. Linera Programming (LP) is a commonly used analytical tool for problems that have, or can be given, a linear structure (see Dorfman, Samuelson and Solow, Cummings, 1972, 1974 and Gale) The model described in section II is readily adaptable to the LP format. The relevant LP

TABLE 3

FIX-RESTRICTIONS TO BE IMPOSED ON RESOURCE USE

IN THE ASSESSMENT MODEL

ITEM	FIX VALUE (hectares)
Acerage in Tomatoes	100*
Acerage in Cantelope	160*
Acerage in Watermelon	80
Total acerage:	
Scenario 1	200
Scenario 2	340
Water Availability: (thousands of cubic meters)	
Scenario A	2,200
Scenario B	3,400

*These numbers approximate acerage in these crops in the Comarca Lagunera region during the 1982-83 agricultural cycle.

"tablaeu", using data from Tables 1-3, is given in Table 4. The following notation is used in Table 4.

ROWS

OBJ FCN	The "objective funtion" which is to be maximized.
LABOR	Man-days of labor inputs per hectare of each crop included in the agricultural program.
ACTOM	Total hectares (ACerage) in TOMatoes.
ACCAN	Total hectares (ACerage) in CANtalope.
ACWAT	Total hectares (ACerage) in WATermelon.
TOTAC	TOTal ACerage (number of hectares) in all crops.
CUMET	Water use, in CUbic METers, per hectare of each crop included in the agricultural program.
CIQA	Plastics, in kilos, required for each hectare for each crop included in the agricultural program.

COLUMNS

AT	Acerage in Tomatoes--no plastics.
MT	Acerage in tomatoes--with plastics.
AC	Acerage in cantalope--no plastics.
MC	Acerage in cantalope--with plastics.
AW	Acerage in watermelon--no plastics.
MW	Acerage in watermelon--with plastics.
PLAS	Total plastics use--the sum across all crops of plastics use in each crop category.
OBRA	Total use of labor--the sum across all crops of labor used for each crop.

RHS: Restrictions on resource availability.

Attention is now turned to an analysis of results derived from this model.

TABLE 4. THE LINEAR PROGRAMMING TABLAU

************ TRANCOL OF LP MATRIX ************

LP PROBLEM FILE NAME: PLASTICS.DAT
PROBLEM TYPE: MAX

ROW		AT	MT	AC	MC	AW	MW	PLAS	OBRA	R H S
OBJ FCN		290.0000	370.0000	113.0000	156.0000	296.0000	378.0000	0.4800	0.6600	********
LABOR	E	89.0000	89.0000	53.0000	53.0000	53.0000	53.0000	.	-1.0000	.
ACTOM	L	1.0000	1.0000	.	.	.	.	.	.	100.0000
ACCAN	L	.	.	1.0000	1.0000	.	.	.	.	160.0000
ACWAT	L	.	.	.	.	1.0000	1.0000	.	.	80.0000
TOTAC	L	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	.	.	200.0000
CUMET	L	11.0000	11.0000	9.7000	9.7000	9.7000	9.7000	.	.	2200.0000
CIGA	E	400.0000	400.0000	400.0000	400.0000	400.0000	400.0000	-1.0000	.	.

NUMBER OF ROWS = 7
NUMBER OF COLUMNS = 8

NUMBER OF < CONSTRAINTS = 5
NUMBER OF = CONSTRAINTS = 2
NUMBER OF > CONSTRAINTS = 0

**** END OF DATA ****

IV. ANALYSIS OF RESULTS

Results from our initial solution of the assessment model--where upper limits on land(totac) and water(cumet) are 200 hectares and 2.2 million cubic meters, respectively--are given in Table 5. Referring to Table 5, upper limits on acerage in tomatoes and watermelon are exhausted--the optimal solution requires 80 hectares in watermelon and 100 hectares in tomatoes; the remaining 20 hectares of allowable "total acerage" is dedicated to cantelope. Note that optimality requires that all acerage must use plastics! Under a program of optimal resource use, the scarcity value of land with plastics is MN$238 when the land is to be used for tomatoes and MN$222 when land is to be used for watermelon. The gross, imputed scarcity value of land is MN$383/ha.. Under this program of optimal resource use, net income to farmers would be MN$118,132, or MN$591/ha.. Net social benefits would be 15% higher(by assumption), or MN$135,852 (MN$679/ha.).

Data in Table 6 relate to the sensitivity of the above-described "optimal" solution to changes in key parameters. Thus, one might inquire as to the dependance of our solution, which requires all acerage in plastics, to the net returns assigned to acerage in any of the three crops with and without plastics. The following are net returns to crops without (A-hectares) and with

TABLE 5. RESULTS FROM THE BASIC ASSESSMENT MODEL

OBJECTIVE FUNCTION = 1181[illegible].00000

SECTION 1 - ROWS

NUMBER	TYPE	...ROW..	AT	...ACTIVITY...	SLACK ACTIVITY	..LOWER LIMIT.	..UPPER LIMIT.	.DUAL ACTIVITY
1.	E	LABOR	EQ	.	.	.	.	-0.66000
2.	L	ACTOM	UL	100.00000	.	NONE	100.00000	237.76000
3.	L	ACCAN	BS	20.00000	140.00000	NONE	160.00000	.
4.	L	ACWAT	UL	80.00000	.	NONE	80.00000	222.00000
5.	L	TOTAC	UL	200.00000	.	NONE	200.00000	382.98000
6.	L	CUMET	BS	2069.99998	130.00002	NONE	2200.00000	.
7.	E	CIQA	EQ	.	.	.	.	-0.48000

SECTION 2 - COLUMNS

NUMBER	.COLUMN.	AT	...ACTIVITY...	..INPUT COST..	..LOWER LIMIT.	..UPPER LIMIT.	.REDUCED COST.
1.	AT	LL	.	290.00000	.	NONE	-80.00000
2.	MT	BS	100.00000	370.00000	.	NONE	.
3.	AC	LL	.	113.00000	.	NONE	-43.00000
4.	MC	BS	20.00000	156.00000	.	NONE	.
5.	AW	LL	.	298.00000	.	NONE	-80.00000
6.	MW	BS	80.00000	378.00000	.	NONE	.
7.	PLAS	BS	80000.00000	0.48000	.	NONE	.
8.	OBRA	BS	14200.00000	0.66000	.	NONE	.

******** END OF SOLUTION OUTPUT ********

TABLE 6. SENSITIVITY ANALYSIS OF THE BASIC ASSESSMENT MODEL

********** RANGES OVER WHICH THIS SOLUTION REMAINS OPTIMAL **********

LP PROBLEM FILE NAME: FLASTICS.DAT

..................OBJECTIVE FUNCTION (CJ) RANGES.............

VARIABLE NAME	SOLUTION VALUE	LOWER LIMIT	UPPER LIMIT
........NON-BASIC ACTIVITIES........			
HL	113.00000	NONE	156.00000
HT	290.00000	NONE	370.00000
HW	298.00000	NONE	378.00000
..........BASIC ACTIVITIES..........			
MT	370.00000	290.00000	NONE
FLAS	0.48000	-0.47745	NONE
MW	378.00000	298.00000	NONE
MC	156.00000	113.00000	378.00000
OBRA	0.66000	-5.94444	NONE

..................RIGHT HAND SIDE (RHS) RANGES.............

ROW NAME	CONSTRAINT TYPE	SOLUTION VALUE	LOWER LIMIT	UPPER LIMIT
LABOR	E	0.00000	NONE	14200.00000
ALTOM	L	100.00000	0.00000	120.00000
ALCAN	L	160.00000	20.00000	NONE
ACWAT	L	80.00000	0.00000	100.00000
TOTAC	L	200.00000	180.00000	213.40206
LUMET	L	2200.00000	2069.99998	NONE
LIDA	E	0.00000	NONE	80000.00000

******** END OF RANGE OUTPUT ********

(M-hectares) plastics used in the assessment model (see Table 4).

CROP	NET FARM PROFIT	SENSITIVITY RANGE
tomatoes-no plastics (AT)	MN$ 290	MN$ 370
tomatoes-with plastic(MT)	370	290
watermelon-no plastics(AW)	298	378
watermelon-with plastics(MW)	378	298
cantelope-no plastics(AC)	113	156
cantelope-with plastics(MC)	156	113
ACTIVITY		
Plastics	MN$480/kilo	MN$ 477/kilo
Labor	660/day	594/day

From the above, taken from Table 6, the use of plastics for any of the included crops--tomatoes, watermelon and cantelope--is optimal irregardless of the amount by which net returns for an M-hectare exceeds those for an A-hectare. Thus, all else equal, the optimality of using plastics is independant of the 20% yield differential used in the model: the yield differential could equally well have been 10% or even 1%--the use of plastics would have remained optimal.

Our optimal solution is sensitive to cost estimates used for labor and, most importantly, plastics, however. With 53 to 89 man-days per hectare of labor required for any of the included crops (Table 4), small changes in wages--2 to 3 pesos per day--could quickly absorb the returns per hectare associated with any of the crops. In terms of plastics use, with 400 kilos of plastics required per hectare, small changes in the cost of plastics could quickly erase the difference in returns between crops grown with and without plastics (see above and Table 4).

This observation points to the critical importance of further inquiry into the likely on-farm costs of agricultural plastics given a fully developed producing industry for such materials.

Data in Table 7 provide results from the assessment model under the scenario wherein 340 hectares of land are in production and 3.4 million hectares of water are available for irrigation; Table 8 provides sensitivity analyses for this scenario. There is little qualitative difference between the characteristics of optimality in this scenario and the basic scenario described above. Land available for tomatoes and watermelon are used to the limit with any remaining lands put into cantelope. All available water is used and plastics are used on all hectares in production. Sensitivity conditions are unchanged from those described above. It may well be the case then that the optimality of using plastics in agriculture is insensitive to linear expansions in land and water resources--note that this obtains under conditions where the water-conservation benefits from plastics use is not included in the model.

One from both of the solutions described above (Tables 5 and 7) may be of interest for later analyses. In both cases, the imputed scarcity value of water was on the order of MN$40 per cubic meter. This datum allows for order of magnitude estimates of the on-farm benefits attributable to the water-conservation effects of plastics use. Thus, if the use of plastics results in a 10% (20%) reduction in water use--some 1,000 (2,000) cubic meters per growing season--the value of this effect is on the order of MN$40,000 (MN$80,000).

TABLE 7. RESULTS FROM THE EXTENDED ASSESSMENT MODEL

OBJECTIVE FUNCTION = 170643.69251

SECTION 1 - ROWS

NUMBER	TYPE	...ROW..	AT	...ACTIVITY...	SLACK ACTIVITY	..LOWER LIMIT.	..UPPER LIMIT.	.DUAL ACTIVITY
1.	E	LABOR	EQ	.	.	.	.	-0.66000
2.	L	ACTOM	UL	100.00000	.	NONE	100.00000	186.43277
3.	L	ACCAN	BS	157.11341	2.88659	NONE	160.00000	.
4.	L	ACWAT	UL	80.00000	.	NONE	80.00000	222.00000
5.	L	TOTAC	BS	337.11341	2.88659	NONE	340.00000	.
6.	L	CUMET	UL	3400.00000	.	NONE	3400.00000	39.48248
7.	E	C[illegible]GA	EQ	.	.	.	.	-0.48000

SECTION 2 - COLUMNS

NUMBER	.COLUMN.	AT	...ACTIVITY...	..INPUT COST..	..LOWER LIMIT.	..UPPER LIMIT.	.REDUCED COST.
1.	AT	LL	.	290.00000	.	NONE	-80.00000
2.	MT	BS	100.00000	370.00000	.	NONE	.
3.	AC	LL	.	113.00000	.	NONE	-43.00000
4.	MC	BS	157.11341	156.00000	.	NONE	.
5.	AW	LL	.	298.00000	.	NONE	-80.00000
6.	MW	BS	80.00000	378.00000	.	NONE	.
7.	PLAS	BS	134845.36269	0.48000	.	NONE	.
8.	OBRA	BS	21467.01056	0.66000	.	NONE	.

******** END OF SOLUTION OUTPUT ********

TABLE 8. SENSITIVITY ANALYSIS OF THE EXTENDED ASSESSMENT MODEL

********** RANGES OVER WHICH THIS SOLUTION REMAINS OPTIMAL **********

LP PROBLEM FILE NAME: PLASTICS.DAT

...................OBJECTIVE FUNCTION (CJ) RANGES..............

VARIABLE NAME	SOLUTION VALUE	LOWER LIMIT	UPPER LIMIT
........NON-BASIC ACTIVITIES........			
AL	113.00000	NONE	156.00000
AT	290.00000	NONE	370.00000
AW	298.00000	NONE	378.00000
..........BASIC ACTIVITIES..........			
MT	370.00000	290.00000	NONE
FLAS	0.48000	-0.47745	3.95769
MW	378.00000	298.00000	NONE
MC	156.00000	113.00000	320.39981
OBRA	0.66000	-5.79165	NONE

...................RIGHT HAND SIDE (RHS) RANGES..............

ROW NAME	CONSTRAINT TYPE	SOLUTION VALUE	LOWER LIMIT	UPPER LIMIT
LABOR	E	0.00000	NONE	21467.01056
ACTOM	L	100.00000	97.45455	238.54546
ALCAN	L	160.00000	157.11341	NONE
ACWAT	L	80.00000	77.11341	237.11341
TOTAC	L	340.00000	337.11341	NONE
CUMET	L	3400.00000	1875.99998	3427.99995
CIQA	E	0.00000	NONE	134845.36269

******** END OF RANGE OUTPUT ********

At this point, few purposes are served in extending the analysis to include "social" values. This is to say that if the use of plastics in Mexican agriculture (for the crops described above) are shown to be feasible under reasonable robust conditions, they will surely continue to be feasible under social accounting practices wherein net returns are (arguably) inflated. Future extensions of this work may result in the critical need for such extensions, however. At a minimum, the model developed in earlier sections provides the analytical framework necessary for analysis of social returns to plasticulture when the need arises.

V. CONCLUSIONS AND RECOMMENDATIONS

REFERENCES

Anderson, R.J. and S. Fernandez. no date. "An Illustratioin of the Potential Effects of Plastics Mulch Technology on Farm Income and Consumption of Plastics in Mexico. mimeo. Centro de Investigacion de Quimica Aplicada, Saltillo, Mexico.

Clarkson, V.A.. 1960. "Effect of Black Ployethylene Mulch on Soil and Microclimate Temperature and Nitrate Level", Agronomics Journal, 52: 307-09.

Coffey, David L.. 1984. "Making the Most of Mulch", American JVegetable Grower, April.

Cummings, Ronald G.. 1972. Water Resource Management in Northern Mexico, Johns Hopkins Press, Baltimore.

Cummings, Ronald G.. 1974. Interbasin Water Transfers: A Case Study in Mexico, Johns Hopkins Press, Baltimore.

Dasgupta, A.K. and JD.W. Pearce. 1978. CJost-Benefit Analysis: Theory and Practice, MacMillan, New York.

Dubois, P.. 1978. Plastic in Agriculture, Applied Science Publishers Ltd.,Ripple Road Barking, Essex, England.

Dorfman, Robert, Paul A. Samuelson and Robert M. Solow. 1958. Linear Programming and Economic Analysis, McGraw-Hill, New York.

Gale, David. 1960. The Theory of Linear Economic Models, Mc-Graw-Hill, New York.

Harris, R.E.. 1965. "Polyethylene Covers and Mulches for Corn and Beans Profuction in Northern Regions", Proc. Amer. Soc. Host. Sci., 87: 288-94.

Hopen, H.J. and N.F. Oebker. 1976. "Vegetable Crop Responses to Synthetic Mulches: An Annotated Bibliography", Spec. Pub. No. 42, Illinois Agricultural Experiment Station, Urbana.

Howe, Charles W.. 1971. Genefit-Cost Analysis for Water System Planning, Water Resources Monograph 2, American Geophysical Union, Washington, D. C..

Howe, Charles W. and K. William Easter. 1971. Interbasin Transfers of Water, Johns Hopkins Press, Baltimore.

Ilic, Pedro. 1983. "Temperature Studies Under Tunnels Mulches: The Long and Short of It", Noticiero Agricola de Su Oficina de Extension Agricola, University of Cali*ɔrnia, Fresno, Winter.

Kelso, M. M., William ;. ɯartin and Lawrence E. Mack. 1973. Water Supplies and Economic Growth in an Arid Environment, An Arizona Case Study, University of Arizona Press, Tucson.

Nicholas, George. 1983. "Profit from Plastics", Farmers Weekly, June 17.

Scott, A. D..1953. "Notes on User Cost", Economic Journal, 63:368-84.

Spice, H.R.. 1977. Ployethilene Film in Horticulture, Latimer Trend and Co., Plymouth, London.

Trujillo, P. M. and J. N. Corgan. 1981. Plastic Mulches, Hot Kaps andTransplants for Vegetables in Northern New Mexico, Bulletin 682. New Mexico State University Agricultural Experiment Station, Las Cruces. May.

DRAFT

SELECTING OPTIMAL ACREAGE Date ~~ON WHICH TO~~ USE PLASTIC MULCH FOR CROPS SOLD IN INTERNATIONAL MARKETS

by

Ronald Cummings

I. INTRODUCTION

In crop production, when a barrier is placed between the soil and the air, it is called "mulching". Such a barrier affords several advantages. It improves the soil structure, aids in the maintenance of even soil temperature, limits the loss of soil nutrients through leaching, militates against weed growth, and reduces the unnecessary loss of moisture from the soil through evaporation (Nicholas,June, 1983). Historically, the term mulch has been used in connection with a layer of <u>organic</u> matter placed on top of the soil (Ilic), with popular mulching materials being straw, cut grass, sawdust, pine needles, compost aluminum, stones, and even paper (Nichloas, June, 1983). Since 1950, plastic sheeting has also been used as a mulch.

Since growing vegetables under black polyethylene plastic film was introduced in the late 1950s, it has been used for many crops.[1] Several important benefits seem to result from the use of plastic mulch. First, in a wide range of studies improved yields have been reported for Squash (California), tomatoes (Tennessee),tomatoes, squash, cucumbers, onions, asparagus, oranges, apples, grapes, and macadamia nuts (South Africa), pineapples and peaches (Australia), pineapples (Hawaii), as well as for melons, sweetcorn, asparagus, and strawberries (France)[2]

[Trujillo and Corgan, Ilic, Dubois, Spice, Coffey and Nicholas, June 17, 1983]. Increases have generally ranged up to about 25%, but some experimental evidence indicates a much wider possible range of yield increases, with yield growth on the order of 50 to 100 percent [Anderson and Fernandez; Nicholas, June 17, 1983]. Improved growth under plastic mulch has been attributed to reduced movement and leaching of nitrates [Clarkson], moisture conservation [Harris] and elevation of microclimate CO_2 levels [Schelddrake]. The economic advantages of higher crop yields to the individual farmer are obvious.

Secondly, not only might plastic mulch produce greater yields, it may also tend to promote an earlier crop harvest. In France, for example, the effects of plastic mulch use on maize were to decrease seed germination from 20 to 15 days, with harvesting occurring 3 weeks earlier than normal [Spice]. In controlled experiments in South Africa, carrots under mulch matured two weeks earlier, radishes one week, lettuce and cabbage two weeks, and rhubarb up to four weeks [Nicholas, June 17, 1983]. And in a research program initiated in the Espanola Valley Branch Experiment Station (New Mexico) plastic mulch treatments were observed to promote more rapid early growth for tomatoes, cantaloupe, and watermelon, with greater early yields obtained [Trujillo and Corgan]. Finally, in a work by Hopen and Oebker [2] over 200 research studies regarding the use of plastic mulches in vegetable crop production are cited. Most of the studies show earlier maturity and a stimulation of growth in response to mulching.

An early harvest can have important economic ramifications, especially for commonly grown crops, as it allows farmers to take advantage of higher prices in the early weeks of the marketing season. In Central Texas, for example, it has been estimated that a two-week advance in the first three tomato harvests could easily increase returns by up to $.15 per pound or more on 50% of the crop [McCraw]. This translates to an increase of more than $500 per acre in the first half of the season. In Northern Mexico, if warm-season crops (tomatoes, watermelon, cantaloupe and chile) could be made to mature earlier, the marketing season could be extended, with a resultant increase in income potential for farmers [Trujillo and Corgan].

Thirdly, plastic mulch may also have beneficial effects related to crop quality and the overall efficiency of input use in crop production. In a series of studies in California, for example, while sizes of tomato and squash were not significantly affected, overall tomato and squash quality was rated higher in mulched plots [Ilic]. And in several studies at the University of Tennessee, a noticeable effect of plastic culture over conventional culture was a decrease in the percentage of culled fruits [Coffey]. This decrease was due partly to the preventing of fruit from coming into contact with the soil, thus reducing the incidence of certain diseases, such as fungal rotting. Early blight, the leading foliage disease of tomatoes in the Southeastern U.S., was also reduced substantially when tomatoes were grown on black plastic [Coffey].

Fourth and finally, the use of mulch makes possible the conservation of other inputs. Tests have demonstrated that certain crops grown under black mulch require one-third to one-half less irrigation water than needed normally. And some herbicides are more effective under the mulch, as the increased soil moisture promctes their action and distribution in the soil.

Of course, any effort to assess the economic feasibility of using plastic mulches would involve quantifying the above-described benefits and their comparison with the (non-vial) costs of plastic mulch. Define A as acreage without mulch, M as acreage with mulch, P as farmgate price, Y(Y') as yield with (without) mulch, C[Y] (C[Y']) as total production costs with (without) mulch and CM as costs for plastic mulches(including installation and maintenance). The feasibility of using plastic mulches then involves, in the most simple terms, comparison of (1) with (2).

(1) $PY' - C[Y'], \quad Y'=y'A$

(2) $PY - C[Y] - CM, \quad Y=yM$

The comparison of (1) and (2) abstracts from two issues hat, in some applications, may be of particular importance in ssessing the economic feasibility of using plastic mulches. irst, and most obvious, decision makers may not be price-takers n many applications. Thus, the level of production and the iming (vis-a-vis the market) will become important. With erishable goods, greater yields from mulches may or may not be a rofit) blessing, absent substantial storage costs : at issue in hese instances is when the yields obtain. Secondly, but related o the above, profits may not necessarily be maximized by the all or none" choice of acreage to put in mulches (A or M in equations 1 and 2 above). Given the seasonal pattern of prices, profits may be maximized by putting some proportion of total acreage A in mulch.

The purpose of this paper is to examine the two, related issues described above. This focus is admittedly limited; we noted above the many on-farm production issues relevant for assessing the viability of plastic mulches. This more limited nquiry may be justified, however, by at least two onsiderations. First, many of the yield/cost issues relevant or plastic mulches have received considerable attention in the iterature (see, as examples, Ilic, Dubois and Spice)--we hasten o add that the fact that these issues have received considerable attention" does not imply that they have been esolved in any general way (see Ilic and Coffey). Secondly, for he purposes of the case study to be used as an expository ehicle in the discussions that follow--the vegetable/fruit xporting States of Sonora and Sinaloa in Mexico-- efforts to ollect experimental data for the technical coefficients equired for studies of on-farm use of plastics have only ecently been initiated in Mexico. Thus, in what follows we ssume that the use of plastic mulches is economically feasible t the farm level for any set of price conditions, and consider he issue of determining optimal acreage under mulch within the ontext of a revenue maximization problem.

To these ends, the paper takes the following form. In ection II, a sketch of our case study problem is given, along ith a description of a model for determining the optimal acreage to be put under mulch. This model identifies parameters required if estimates for optimal mulch acreage are to be derived. Particularly important parameters are those drawn from periodic demand functions for crops to be marketed. Thus, in section III, an empirical example is provided with demand curves (f.o.b. Nogales port-of-entry) prices estimated for Mexican tomatoes--one of the major crops exported by to the U.S. from this multi-state study area. Parameters derived in section III are utilized in section IV to derive estimates for optimal acreage in plastic mulch in the study area. Concluding remarks are offered in section V.

II. OPTIMAL MULCH ACREAGE IN NORTHWEST MEXICO

Mexico's national institute for research in applied :hemistry (Centro de Investigacion de Quimica Aplicada: CIQA), ith financial support from the United Nations Development rogram, is charged with the task of determining the technical nd economic feasibility of using plastics in Mexico's gricultural sector. Mexico's interest in such uses of plastics eflects their concern with, first, petrochemical applications hat broadens the contribution of their oil production to the evelopment of other sectors of the Mexican economy and, second, heir concern with balance of payments problems which might be lleviated with increases in products exported to the U.S.. In his latter regard, agricultural authorities impose quotas for ectares in the States of Sonora and Sinaloa which are to be lanted in tomatoes,cucumbers,watermelon and cantaloupe wherein he harvest is to be exported to the U.S.. Given the relatively igh value of these crops--and their importance in terms of oreign exchange earnings--CIQA's initial research focus is on he feasibility of using plastics in this particular area. Moreover, insight as to optimal acreage under plastics in this area rovide some idea as to whether or not the demand for gricultural plastics could support an a plastics industry in exico.

The intra-seasonal pattern for the timing at which Mexican omatoes--the crop of interest in this work-- from the

Sinaloa/Sonora area arrive at the U.S. market (the Nogales port of entry) is given for selected years in Figure 1. As seen in Figure 1, harvesting of early growths result in relatively small numbers of truckloads (250 to 300) arriving at the market during the weeks of early January; as the full harvest proceeds, the number of truckloads arriving at the market increases, peaking at some 1,400 to 1,500 truckloads during the weeks of late March. Figure 2 presents the intra-seasonal prices received (f.o.b. Nogales) for Mexican tomatoes; as one might expect, the plot for prices received is essentially the mirror image of truckloads arriving at the market (Figure 1). Data in Figures 1 and 2 may serve to explain CIQA's interest in the question as to how one might exploit the "early harvest" benefits of using plastic mulches: if one could "flatten out" the curves in Figures 1 and 2, substantial returns to Mexico might result. Optimality, in this case, would require an allocation of acreage devoted to plastic mulch so as to effectively equate marginal revenue across weeks.

The problem sketched above is formalized as follows. Let C denote the total acreage (in hectares) to be put into a given crop. The values of C established by the Mexican government for the crops of interest here for the agricultural year 1982/83 are given in Table 1. If K and N measure, respectively, acreage with and without plastic mulch, then

(3) $C = K + N$

Let x_i and y_i measure the yield from N and K lands, respectively, which arrives at the market in week i. Mexico's

TABLE 1

PROGRAMMED ACREAGE FOR EXPORT CROPS IN NORTHWEST MEXICO*:

1982-83 AGRICULTURAL YEAR

CROP	PROGRAMMED ACREAGE (HECTARES)
Tomatoes	24,632
Cucumbers	11,086
Squash	10,800
Cantaloupe	18,306
Onions	3,726
Garlic	2.674
Watermelon	15,717

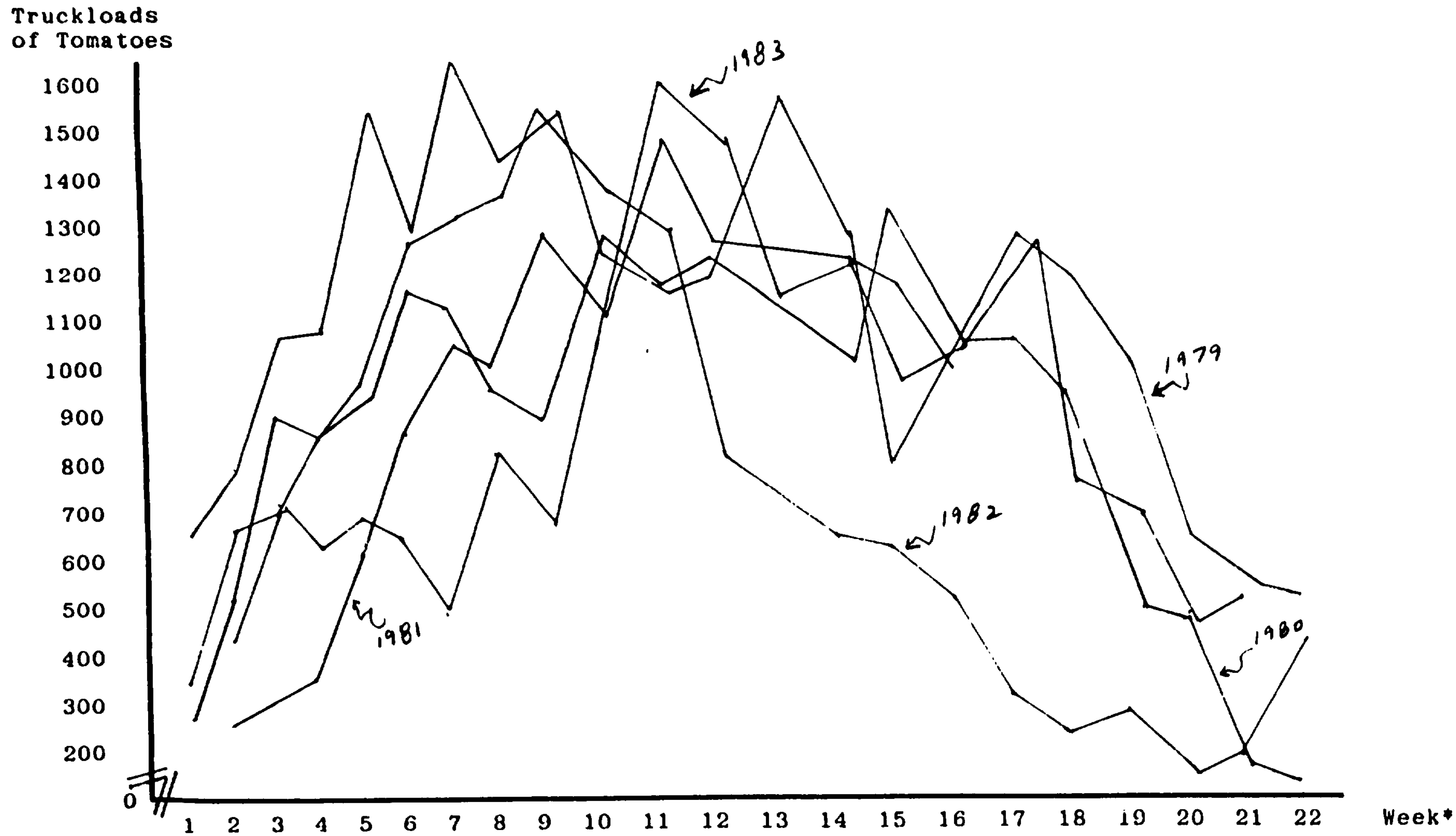
Source: Union Nacional de Productores de Hortalizas.

*Includes the States of: Sinaloa, Jalisco, Baja California, Sonora, Tamaulipas, Guanajuato, Nayarit, Michoacan, Morelos, San Luis Potosi, Veracruz and Chihuahua. The bulk (c90%) of the programmed acreage, however, is in the first four-listed States.

WEEKLY TRUCKLOADS OF MEXICAN TOMATOES

AT NOGALES PORT-OF-ENTRY

1979 - 1983



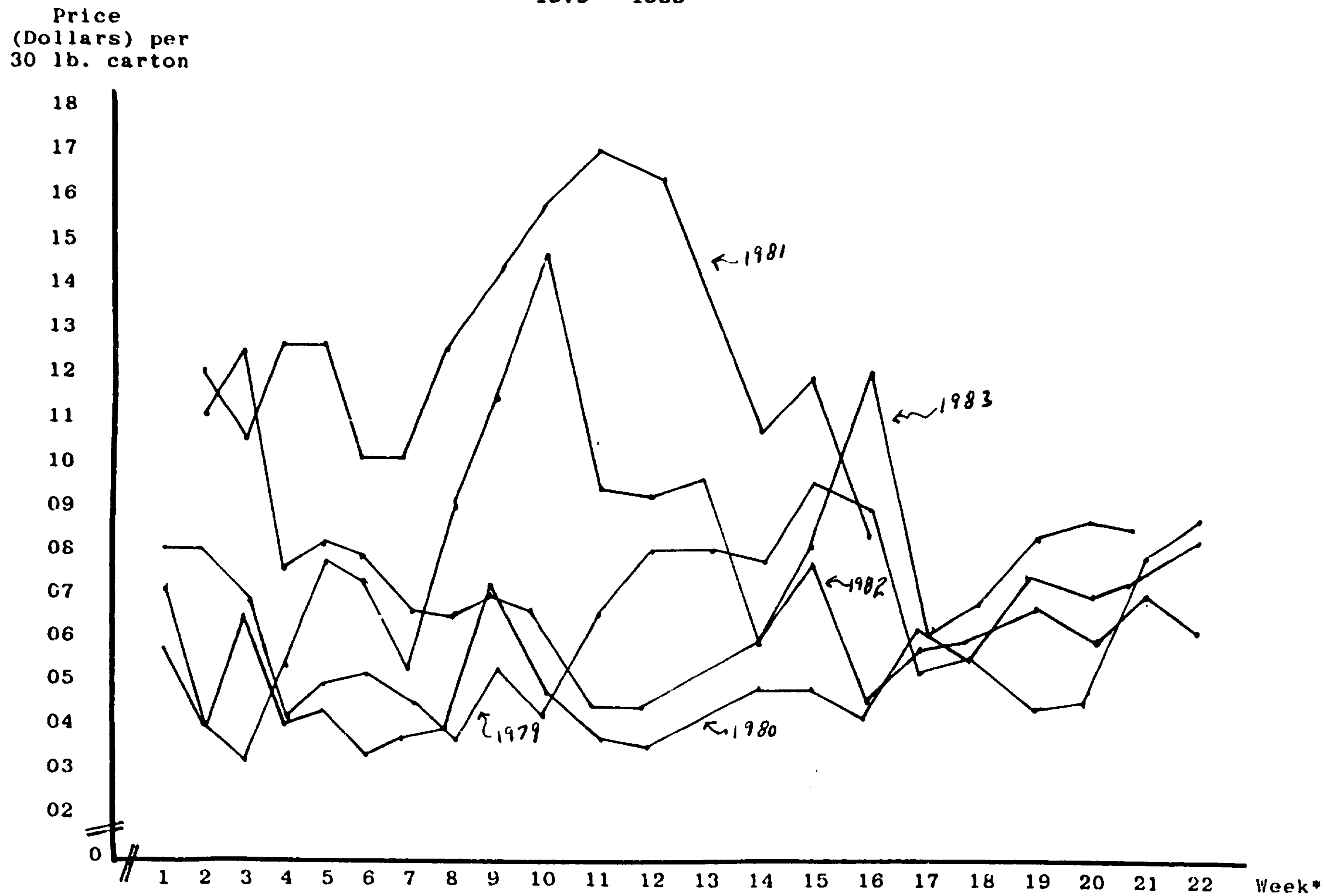
1979 blue
1980 red
1981 black
1982 green
1983 purple

FIGURE 2

PRICES F.O.B. NOGALES, RECEIVED

FOR MEXICAN TOMATOES, BY WEEK

1979 - 1983



"supply" of this crop offered in week i is then given by

(4) Qi = xiN + yiK,

or using (3),

(5) Qi = xiC + (xi-yi)K

Total revenue is then given by

(6) TR = SUMi Pi(Qi)Qi

With a linear periodic demand function of the form Pi = ai + wiQi, ai > 0 and wi < 0, (6) becomes

(7) TR = SUMi [(ai + wiQi)Qi]

= SUMi [ai§xiC + (yi-xi)K† + wi§xiC + (yi-xi)K†^{2}]

Our concern, of course, is with the optimal value of K; given C constant, the optimal value of K implies an optimal value of N by (3). First order conditions for a maximum of TR [K] in K are given by the following.

(8) &R/&K = SUMi [xi(yi-xi) + 2wi§xiC + (yi-xi)K†(yi-xi)],

and

(9) $K = - \frac{\text{SUMi [ai(yi-xi) + 2wiaiC(yi-xi)]}}{\text{SUMi[2wi(yi-xi)2/]}}$

Determination of the optimal acreage in plastic mulch is then seen to depend upon the parameters xi and yi --relative yields (measured in terms of when such yields arrive at the market)--and parameters from the periodic demand curve: the intercept ai and the slope wi. Attention is now turned to the estimation of these parameters.

III. PARAMETER ESTIMATION

In terms of the yield parameters xi and yi, CIQA's research to date has yet to establish unequivocally the impact on yields from the use of plastic mulches. While experimental data from studies in other parts of the world (cited above) suggest yield ncreases from 10% to 50% from the use of plastics, for our urposes of focusing on price effects as they relate to the hoice of optimal values of K we choose to assume that .e use of lastics leaves unaffected total yields and simply affects the iming of yields. In other words, we take as given the time rofile of yields and simply shift them forward for lands under lastics. Values of xi and yi relevant for analyses of optimal alues of K are given in Table 2.

Referring next to the demand parameters ai and wi, our task ecomes that of estimating demand conditions for the crop nder study. Single equation demand functions for fruits and egetables have been estimated in a variety of ways in the past. quations using weekly data [Firch and Young, Mehren and Erdman, hafer and Carlson and Foytik,1969], monthly observations Foytik, 1964, Simmons and Pomareda, Fajardo-Cristen, Foytik, oytik et. al. 1967, and Pomareda and Simmons], yearly data Shuffett, Waugh, Hoos, Hoos and Alpin,McGlothlin, Hartmanand athia and Shrimper], and even daily observations [Goodwin and anley] have been tested. Several different functional forms

TABLE 1

Truckloads of Tomatoes (per Harvested Hectare) Arriving at Nogales With (yi) and Without (xi) Plastic Mulch

	Truckloads (per harvested hectare) of Tomatoes Arriving at Nogales:	
WEEK	(yi)	(xi)
- 3	403.8	0
- 2	515.31	0
- 1	722.67	0
1	737.81	403.8
2	927.33	515.31
3	1017.52	722.67
4	1101.69	737.81
5	1106.32	927.33
6	1180.61	1017.52
7	1176.9	1101.69
8	1317.35	1106.32
9	1171.58	1180.61
10	1346.05	1176.9
11	1095.56	1317.35
12	987.01	1171.58
13	971.35	1346.05
14	1005.11	1095.56
15	779.17	987.01
16	631.29	971.35
17	466.39	1005.11
18	396.79	779.17
19	377.02	631.29
20	0	466.39
21	0	396.79
22	0	377.02

ource: U.S.Department of Agriculture; averages for years 1979-3.

have been tried, including linear [Simmons and Pomareda, and laugh], log-linear [Hoos and Alpin] logarithmic first differenced Sheffett] and parabolic [Foytik, 1964]. In addition to the usual explanatory variables (quantity demanded, income and prices of substitute goods)some demand models have incorporated weather variables --rain fall and temperature-- to proxy quality differences [Bohall], shipment records to capture supply buildups in marketing channels , lagged prices [Hartman], time trend variables [Firch and Young and Foytik, 1964], and different breakdowns of the quantity variable [Hartman].

Extensive use has also been made of dummy variables which allow the intercept and quantity slope of the demand relationship to shift over time. In many cases, these dummies have proven effective in capturing demand "shifts" not easily explained by the conventional explanatory variables. In a very early demand study of strawberries, for example, Mehren and Erdman used weekly slope-shifters in showing that for constant prices, elasticity of emand increased as the market season advanced. Many other ombinations of dummy variables have also been used. Regressions sing weekly data have incorporated yearly dummy variables [Firch nd Young and Shafer and Carlson], and dummy variables for weekly ntercept shifters [Allen and Seale]. Monthly dummy variables ave captured demand changes in tests using monthly data [Foytik, 964,1969 and Simmons and Pomareda]. Finally, seasonal dummies ave improved the overall model specification in certain annual emand estimations.

Given the ability of plastic mulch to modify the timing of otal crop harvests, any intraseasonal demand movements obviously assume significant importance to producers. If the demand does vary within the season, knowledge of those variations can be essential to maximizing revenues obtained from the intraseasonal marketing of a given amount of product. To test for the existence of such demand variations, this study makes use of both weekly intercept-shifting dummy variables and weekly slope-changing dummies to help explain weekly movements in prices.

The basic demand model which allows for changes in slope and intercept can be expressed as follows:

$$(10)\quad Pit = ao + SUM(j=1..N)\ ajDjit + woQit + SUM(j=1,..N)wjSjit + cXit + Uit,$$

where the following notation is used.

i,j = 1,2,..,N: the number of distinct demand periods - weeks - within the marketing season.

t = 1,2,..,T: number of marketing seasons.

Pit = price (f.o.b. Nogales port of-entry) of Mexican tomatoes during week i of season t.

Qit = quantity of Mexican tomatoes marketed during week i of season t (measured at Nogales).

Djit = intercept-shifting variable for week j, where

Djit = 1 when i=j
0 when i=j

Sjit = slope-changing dummy variable, where

Sjit = DjitQit = Qit when i=j
0 when i=j

Xit = any other predetermined variable(s)

Uit = disturbance term.

Of course, the coefficients for the above model cannot be estimated directly, since the equation includes some variables that are linear combinations of others. For example, the sum of the D variables is equal to the "variable" associated with the constant term; likewise, the sum of the S variables equals the corresponding observation on Qi. To estimate the demand parameters, it is necessary to place some sort of restriction on the dummy variables. A commonly used restriction, and the one employed in this study, is to set one of the parameters in each group of dummies equal to zero. Here, we have set aN=0 and wN=0. The equation to be estimated then becomes:

$$(11)\ Pit = ao + Sum(j=1,..,N-1)ajDjit + woQit + SUM(j=1,..,N-1)wjSjit + cXit + Uit$$

The dummy variables are all as defined earlier, except for the observations on demand period N, which now takes on the value zero.

In interpreting results, it must be remembered that when a restriction is applied (aN=0 and wN=0, for example) the first N-1 equations remain:

$$
\begin{aligned}
(11)\ P1t &= (ao + a1) + (wo + w1)Q1t + cX1t \\
P2t &= (ao + a2) + (wo + w2)Q2t + cx2t \\
&\vdots \\
PN-1,t &= (ao + aN-1) + (wo + wN-1)QN-1,t + cXN-1,t
\end{aligned}
$$

For time period N, however, the equation is:

$$(12)\ PNt = ao + woQNt + cXNt$$

Thus, ao is the estimated intercept parameter for time period N and wo is the estimated slope. The other a and w coefficients represent weekly <u>deviations</u> from ao and wo; in other words, period N has been made the "base period".

The hypothesis that is of the most interest regarding these dummy variables is the null hypothesis that all of the intercept and slope deviations are equal to zero:

Ho: a1=a2=....aN-1=w1=w2=....wN-1=0

This hypothesis states that there is no difference in intercept or slope between demand periods. It can be tested using an F-test, with the appropriate test statistic given by

F(v1,v2)= [(RSS1-RSS2)/RSS2][V2/V1]

where:

RSS1 = sum of squared residuals based on the estimated model under the assumption that there are differential intercepts and slopes.

RSS2 = as RSS1 but under assumption that estimated model has a common intercept and slope for all periods.

V1 = number of independent restrictions involved in going from the unrestricted to the restricted model; the degrees of freedom of the differentiated model minus the degrees of freedom of the common slope/intercept model.

V2 = degrees of freedom in the common intercept/slope regression model; the number of observations minus number of parameters to be estimated.

Results from the estimated model. The results of several demand estimates for Mexican tomatoes appear below. In attempting to explain weekly variations in price, three explanatory variables are included (in addition to the dummy variables):

q.mex = quantity of Mexican tomatoes marketed in the U.S.(Nogales port of entry).

q.other = quantity of tomatoes marketed in the U.S. from all other sources.

com.veg = an index of commercial vegetable prices in the U.S.--a proxy for prices of goods that are compliments or substitutes for tomatoes.

Other quantity breakdowns were tried as well. In addition to testing price as a function of Mexican production and other production for U.S. markets, one set of regressions explained Mexican price as a function of total tomato production for U.S. markets; another equation set regressed prices received for Mexican tomatoes against the share of total tomato marketings in the U.S. represented by Mexican imports. In each case, the results were similar to those seen below. Weekly data for five marketing seasons, 1978-79 through 1982-83, were obtained from the U.S.D.A.'s market news service publication Marketing Mexico Fruits & Vegetables.

Our ultimate estimate for equation (12) is as follows.

$$(13)\ Pmex = \underset{(-.031)}{-0.067} - \underset{(-3.73)}{0.00294Qmex} + \underset{(7.28)}{0.09COMVEG} - \underset{(-2.64)}{0.00168Qother}$$

$$\bar{R}^2 = 0.424 \qquad R^2 = 0.441 \qquad F = 26.03$$

Equation (13) presents a simple demand specification without any dummy variables included. It can be seen that all of the explanatory variables are of the sign expected *a priori* and are statistically significant as "significance" is indicated by the t-statistics given in parentheses. The adjusted R^2 value is higher than 0.4, which reflects reasonably good performance for a regression equation based on weekly specifications.

When the dummies are added, our estimated equation takes the form given by equation (14).

(14) Pmex = -.13 +.096COMVEG - .0025Qother -.0026QMex
(-.06) (8.48) (-3.92) (-3/37)

+9.01WD10 +6.53WD11 +2.16WD21+2.1WD22
(1.96) (1.84) (1.83) (1.66)

-.003SP6-.002SP8-.002SP9-.01SP10
(-2.66) (-2.07) (-2.70) (-2.35)

-.005SP11 + .002SP18
(-1.81) (1.90)

$R^2 = .60$ $R^{*2} = .54$ F = 10.27

n (14), dummy variables with insignificant t-statistics have een eleminated. Seasonal influences are then seen to effect the lope(SP) during marketing weeks 6,8,9,10,11 and 18. For the irst five of these, seasonal effects are of the type wherein the ensitivity of prices received by Mexico to the quantity of omatoes marketed is enhanced: the slope becomes more negative, eflecting (amoung other things) increased competition from U.S. roducers. During week 18, however, prices become less sensitive less negative) to quantities marketed. Intercept (WD) effects ccur only in weeks 10,11,21 and 22.

Equally important are the test results concerning the significance of the dummy variables as a whole. The procedure for statistically testing whether or not changes in the intercept and slope are significant from week to week includes, first, the null hypothesis Ho, given above, and secondly the calculation of the test statistic F(V1,V2), also described above. With V1=53, V2=99, the critical values for the F-statistic are 1.48 and 1.63 for confidence levels of 5% and 1%, respectively. The calculated value for F is given by

(16) F(53,99) = [(529.935 - 218.389)/218.389][99/53]
= 2.665

ith F(53,99) > F(critical), we reject the null hypothesis that eekly slopes and intercepts are the same. In other words, here is a statistically significant intraseasonal movement of emand taking place within the marketing season. We then use quation (14) for addressing the issue of optimal creage in mulch--the topic of the following section.

IV. OPTIMAL ACREAGE IN MULCH

Referring to equation (9) above, optimal acreage under plastic mulch is dependent upon: (i) yi and xi--production arriving at the Nogales port of entry per hectare with and without, respectively, plastic mulch ; (ii) ai and wi--the intercept and slope, respectively, from the demand function for U.S. imports of Mexican tomatoes; and (iii) C--the total acreage of tomatoes for export in Mexico. As an example, values for xi, and (assumed values for)yi are given in Table 3 for the crop year 1982-83; also given in Table 3 are weekly values for Qother and COMVEG for 1982-83--these values are required to determine the weekly intercept parameter ai from equation (14). We assume an annual quota for tomatoe acreage (C) of 24,632 hectares (see Table 1).

With the assumptions given above, along with the data in Table 3, equation (9) can be solved for the optimal value of K: acreage under plastic mulch. That value is given by:

(15) $K^* = 17{,}838$ hectares.

Thus, under the above conditions, which more or less typify an average year over the period 1979-83, revenues (foreign exchange earnings) to Mexico are maximized by putting 72.4% of their 24,632 hectares of tomatoes under plastic mulch. To appreciate the logic of this solution, consider the data in Table 4. For the "regular" --non-mulch--22 week marketing season and for the mulch-related 3 early-market weeks, Table 4 provides weekly marketings of tomatoes with and without mulch, the weekly price that would be received for marketings and total revenues to Mexico from 24,632 hectares of tomatoes with all acreage not

TABLE 3

PARAMETER VALUES FOR DETERMINING OPTIMAL K

Week	Xi (cartons/ha)	Yi (cartons/ha)	Qother (000 cartons)	COMVEG (1970=100)
-1		10.82	998	112
-2		22.51	926	164
-3		36.58	800	171
	10.82	45.24	603	179
[illegible]	22.51	49.57	680	173
[illegible]	36.58	65.10	556	168
[illegible]	45.24	68.35	360	162
[illegible]	49.57	71.59	480	156
[illegible]	65.10	79.88	436	150
[illegible]	68.35	71.60	620	144
[illegible]	71.59	68.19	806	137
[illegible]	79.88	43.29	1273	131
0	71.60	36.96	1316	130
1	68.19	36.26	1426	130
2	43.29	30.46	1343	129
3	36.96	20.35	1603	129
4	36.26	20.35	1603	128
5	30.46	12.23	2066	126
6	20.35	17.64	2090	125
7	20.35	13.85	2140	124
8	12.23	14.01	1603	122
9	17.64	23.59	1776	121
:0	13.85	-	1160	126
:1	14.01	-	1326	129
:2	23.59	-	1326	129

TABLE 4

REVENUE COMPARISONS WITH AND WITHOUT PLASTIC MULCH

1982-83 AGRICULTURAL SEASON

Week	Marketings at Nogales: Actual 1982	Estimated, 17,838 ha. under mulch	Estimated Price: Without mulch	With mulch	Total Rev: Without mulch	With mulch
	(thousands of cartons)		(U.S. Dollars)		(millions, $)	
-3	-	193.0	$ -	$10.22	$ -	$ 1.97
-2	-	402.5	-	9.59	-	3.86
-1	-	653.4	-	8.84	-	5.77
[illegible]	260.6	878.8	10.02	8.16	2.61	7.17
[illegible]	555.9	1037.4	16.33	14.88	9.08	15.44
[illegible]	901.1	1409.7	16.76	15.23	15.10	21.47
[illegible]	1114.4	1526.5	17.98	16.75	20.04	25.57
[illegible]	1221.0	1613.8	16.47	15.29	20.10	24.67
[illegible]	1603.6	1867.1	9.73	8.04	15.61	15.02
[illegible]	1683.6	1741.5	14.94	14.77	25.16	25.72
[illegible]	1763.6	1702.8	10.02	10.32	17.67	17.57
[illegible]	1967.5	1315.1	7.70	11.16	15.15	14.67
0	1763.6	1145.9	6.48	14.20	11.43	16.27
1	1679.6	1110.2	9.65	14.38	16.21	15.96
2	1066.4	837.7	9.06	9.75	9.67	8.17
3	910.4	614.1	9.13	10.02	8.31	6.15
4	893.1	609.4	8.78	10.04	7.85	6.12
5	750.5	452.3	9.34	10.11	7.01	4.57
6	501.2	453.0	9.16	10.24	4.59	4.64
7	501.2	385.4	9.03	9.51	4.52	3.66
8	301.3	334.1	8.13	8.10	2.45	2.71
9	434.6	540.7	6.83	6.51	2.97	3.52
0	341.2	-	6.84	-	2.33	-
1	346.6	-	11.49	-	3.98	-
2	581.2	-	9.99	-	5.81	-
	TOTAL REVENUE:				$227.65	$250.67

using plastics and with 17,838 hectares under mulch (6,794 ectares without mulch). As seen in Table 4, the optimal use of lastic mulch has the effect of increasing revenues from the arketing of Mexican tomatoes by some 10%--from $227.65 million o $250.67 million (U.S. dollars).

The source of increased revenues from plastics is made mmediately apparent from data in Table 4. The use of plastics llows for the marketing of more Mexican tomatoes during the arly weeks during which alternative supplies of tomatoes are carce--better than half of Mexico's marketings are in the market efore produce from U.S. harvests begin to substantively hit the arket.

V. CONCLUDING REMARKS

The bits and pieces of technology assessment will often nvolve research questions that are complex. To results from arlier research concerning the economic feasibility of using lastic mulches, it is hoped that results from the present study ill be useful in providing quantitative dimensions to questions bout which only speculative assertions were heretofore ossible:quantitative assessments of the potential early-to-arket effects on revenues attributable to plastics in griculture. In the case of Northern Mexico, our results suggest hat, given feasibility at the farm-level, the use of plastics an substantively increase revenues from marketings by taking dvantage of periods of high excess demand that obtain early in he marketing season.

FOOTNOTES

[1]Plastic mulches come in a variety of colors. These include white, green, clear, and combinations of more than one color. (Other colored plastics are used as well). For some comparisons and further details, see Hopen and Oebker, Emmert, Ilic, Dubois and Nicholas, June 17, 1983..

[2]Plastic mulch treatments have even had beneficial effects on the survival, growth, and development of certain species of fir, spruce, and pine trees, many of which are used for our Christmas trees; see Matta, et. al., Stephens, Lewis and Lopushinsky and Beebe. 4,5,9,10].

3 Weekly and monthly demand shifters were also tried, but proved to be insignificant statistically as explanatory factors on price. Also, annual Mexican quantity-slope dummies were tried. While some of these dummies improved the fit of the demand specification, collinearity problems between the dummies and the Mexican quantity variables rendered these results unusable.

4 The model can of course also be specified so that the slope varies between time periods, with the intercept remaining unchanged.

5 A parallel analysis could be conducted for the changing slope-constant intercept case, and for the case where both slope and intercept are allowed to vary.

REFERENCES

Allen, M.B. and A.D. Seale, Jr. An Evaluation of the Competitive Position of the Cabbage Industry in Mississippi and Competing Areas. Mississippi Agricultural Experiment Station, Agricultural Economics Technical Publication No. 2, September 1960.

Anderson, R.J. and S. Fernandez. "An Illustration of the Potential Effects of Plastics Mulch Technology on Farm Income and Consumption of Plastics in Mexico."

elsley, D.A..1980. Regression Diagnostics,John Wiley & Sons,New York.

ohall, Robert W., Pricing Performance In Marketing Fresh Winter Tomatoes. USDA, ERS, Market Research Report No. 977, 1972.

larkson, V.A. 1960. "Effect of black polyethylene mulch on soil and microclimate temperature and nitrate level," Agronomics Journal 52: 307-309

offey, David L. "Making the Most of Mulch," American Vegetable Grower, April 1984.

ubois, P. 1978. Plastic in Agriculture. Applied Science Publishers Ltd., Ripple Road Barking, Essex, England.

mmert, E.M. 1972. "Use of clear plastic over black plastic for early crops." Kentucky Agricultural Experiment Station Leaflet 242.

Fajardo-Cristen, Adrian, Demand for Honey Dew Melons. Florida Agricultural Experiment Station, Agricultural Economics Report No. 14, November 1970.

Farris, Paul L. and Richard D. Darley. 1963. "Monthly Price Quantity Relations for Broilers of the Farm Level". Journal of Farm Economics, pp. 849-856, November.

Firch, Robert S. and Robert A. Young. An Economic Study of the Winter Vegetable Export Industry of Northwest Mexico. Arizona Agricultural Experiment Station, Technical Bulletin No. 179, October 1968.

Foytik, Jerry, Demand Characteristics for Vine Vegetables in Honolulu, Hawaii, 1947-1961. Hawaii Agricultural Experiment Station, Bulletin No. 23, July 1964.

Foytik, Jerry, Monthly Variations in Demand for Hawaii Vegetables. Paper presented at the Western Agricultural Economics Association, Corvallis, Oregon, July 1969.

Foytik, Jerry, C. Velasco and L. Valenzuela. An Examination of Vegetable Price Relationships in Chile. A study conducted in cooperation with the Chile - California program, October 1967.

Goodwin, Marshall R. and William T. Manley. Demand and Competitive Relationships for Florida and Greenhouse-Grown Tomatoes. Florida Agricultural Experiment Station and the Institute of Food and Agricultural Sciences in Cooperation with the USDA, Bulletin No. 703, December 1965.

Harris, R.E. 1965. "Polyethylene covers and mulches for corn and beans production in northern regions," Proc. Amer.

Soc. Host. Sci. 87: 288-294.

Hartman, Peter, The Effects of Mexican Imports on Florida Cucumber Prices. University of Florida, Food and Resource Economics Department. Paper presented in the student section of the Amer. Ag. Econ.. Assoc. Annual Meeting, August 1978.

Hoos, Sidney, Tomatoes and Tomato Products - Economic Trends and F.O.B. Price Relationships. California Agricultural Experiment Station, Giannini Foundation of Agricultural Economics, Mimeographed Report No. 185, March 1956,

Hoos, Sidneyand R.D. Aplin. California Canned Tomatoes: Analysis of FOB Price Relationships. California Agricultural Experiment Station, Giannini Foundation of Agricultural Economics, Mimeographed Report No. 156, June 1953.

Hopen, H.J. and N.F. Oebker, 1976. "Vegetable crop responses to synthetic mulches," an annotated bibliography. Illinois Agricultural Experiment Station Special Publication 42.

Ilic, Pedro. "Temperature Studies Under Tunnels Mulches - The Long and Short of It," Noticiero Agricola de Su Oficina de Extension Agricola, Universidad de California, Fresno, CA, Winter 1983.

Lewis, C.E. 1976. "Black plastic as a mulch around slash pine seedlings," Amer. Christmas Tree Journal 20 (1): 11-13.

Logan Samuel H. and James N. Boles. 1962. "Quarterly Fluctuations in Retail Prices of Meat," J Farm Economics, pp. 1050-60, November.

Daniel B. Suits, "Use of Dummy Variables in Regression Equations," J Am. Stat. Assoc., Dec 1957, pp. 548-551.

.opushinsky, W. and T. Beebe, 1976. "Effect of black polyethylene mulch on survival of Douglas fir seedlings, soil moisture content, and soil temperature," Tree Planters' Notes 27: 7-8.

lathia, Gene A. and Ronald A. Schrimper.1974."Analysis of Shifts in Demand and Supply Affecting US and NC Vegetable Production and Price Patterns",North Carolina State University, Economics Information Report No.35, January.

latta, F.B., J.T. Fisher, and J.M. Montano. "Influence of Mulching on Growth and Development of Christmas Trees," Research Report 448, New Mexico State University Agricultural Experiment Station, June 1981.

cCraw, B.D. "Row Covers Make Dollars & Cents" American Vegetable Grower, February 1984.

lcGlothlin, R.S.. 1957. "Price Relationships in the Western Lettuce Industry", Bulletin No. 287,Arizona Agricultural Experiment Station, Tucson, June.

Mehren, G. L.and H. E. Erdman. "An Approach to the Determination of Intraseasonal Shifting of Demand." Journal of Farm Economics, Vol. 27, No. 2, May 1946. pp. 586-596.

Nicholas, George. "Plastic Mulching." Farmer's Weekly, June 10, 1983.

Nicholas, George. "Profit from Plastics," Farmer's Weekly, June 17, 1983.

Pomareda, Carlosand Richard L. Simmons. "A Programming Model with Risk to Evaluate Mexican Rural Wage Policy." Operational Research Quarterly, Vol. 28, No. 4, ii, pp. 997-1011.

Schelddrake, R., Jr. 1963. "Carbon dioxide levels in the microclimate as influenced by the permeability of mulches," Proc. Nat. Agr. Plastics Conference 4: 93-96.

Shafer, Carl E.and Chriss H. Carlson. Intraseasonal Price Analysis for Texas and California Carrots. Texas A & M University, Department of Agricultural Economics and Rural Sociology, Technical Report, No. 71-5, 1975.

Shuffett, D. MiltonThe Demand and Price Structure for Selected Vegetables. USDA, Agricultural Marketing Service, Technical Bulletin No. 1105, December 1954.

Simmons, Richard L. and Carlos Pomareda. "Equilibrium Quantity and Timing of Mexican Vegetable Exports." AJAE, Vol. 57, No. 3, August 1975, pp. 472-479.

Spice, H.R. 1977. Polyethylene Film in horticulture. Latimer trend and Co. Ltd., Plymouth, London.

Springfield, H.W. 1972. "Mulching improves survival and growth of Cercocarpus transplants," USDA For. Serv. Res. Note Rm-200.

Stephens, G.R., Jr. 1965. "Accelerating early height growth of white spruce." Journal of Forestry 63: 671-673.

Tomek,William G.. 1963. "Using Zero - One Variables with Time Series Data in Regression Equations", "Journal of Farm Econ., pp. 814-822, November.

'rujillo, D.M. and J.N. Corgan, "Plastic Mulches, Hot Kaps, and Transplants for Vegetables in Northern New Mexico," Bulletin 682, New Mexico State University Agricultural Experiment Station, May 1981.

'nion Nacional De Productores De Hortalizas.1982-83."Republica Mexicana Programa de Siembra Y Exportacion de Tomate por Estados Autorizado por la Asamblea Nacional Especializada" Culiacan, Sinaloa, MEXICO.

.S. Department of Agriculture,1978-79 through 1982-83. Marketing Mexico Fruits and Vegetables,Agricultural Marketing Service. Fruits and Vegetables Division,Washington, D.C..

augh, Frederick V. Demand and Price Analysis: Some Examples from Agriculture. USDA, ERS, Technical Bulletin No. 1316, November, 1964.