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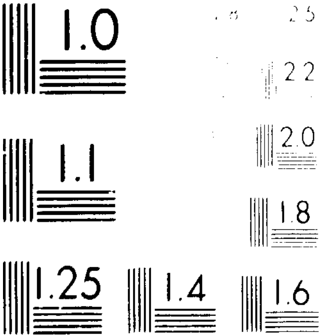
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FINAL REPORT OF EXPERT

ON

Mexico. EVALUATION, PLANNING, AND TRANSFER OF TECHNOLOGY. (Plastics for use in agriculture).

Post: 11/06

Mission: Period May 5, 1982 - September 4, 1982

R. J. Anderson, Jr.

Report Date: September 2, 1982

CHAPTER 1: INTRODUCTION AND SUMMARY

A. Introduction

This report presents the conclusions and recommendations of a four month mission to Mexico to consult on a project to encourage the manufacture and use of agricultural plastics. The terms of reference for this mission were as follows:

> The consultant in colaboration with the other experts and counterparts and the CTA will specifically be expected to:
>
> 1. Assist in planning, organization, and transfer of technology related to semi-arid zones, taking into consideration the econoic requirements to strengthen the industrial and agroindustrial development of these areas;
>
> 2. Prepare models for regional and industrial development;
>
> 3. Evaluate cost-benefit and cost-efficiency analysis of proposed industrial and agro-industrial activities;
>
> 4. Construct scenarios for the evaluation of the technological impact of such projects in these areas as well as analyze development projects;
>
> 5. Condust group meetings and workshops in which construction of scenarios and prospective evaluation of technological development are discussed.
>
> The consultant will also be requested to prepare a final report setting out the findings of his mission and his recommendations to the Government on further action that might be required.

Two caveats are in order concerning the content of this report. First, the conclusions and recommendations presented here are solely those of the author and do not necessarily reflect the views of the Centro de Investigacion en Quimica Aplicada (which is the government executing institution to which the author was assigned), UNIDO's Project Coordinator, or any other individual or organization with whom the author was privilised to work. Any errors of fact or interpretation are the sole responsibility of the author.

Second, this is a time of great uncertainty in Mexico. The mission coincided with the last months of the Lopez Portillo administration, and during the period of the mission, a sharp devaluation of the peso occurred, accompanied by the institution of multiple exchange rates, controls on foreign exchange transactions, and deep cuts in public spending. It is too soon to tell what the effects of these measures will be on the economy, and on the outlook for development of agriculture and industry over the next few years.

B. Overview and Summary

The plan of the report is as follows. Chapter 2 of the report briefly chronicles the activites undertaken and the events that occured during the period of the mission. The activities that took place may be grouped into six categories:

(i) A 'technology assessment' of the manufacture and use of plastics in agriculture was initiated.

(ii) A preliminary assessment of the opportunities for use of agricultural plastics in Mexico was made.

(iii) Contact was made with several other governmental organizations interested in agricultural plastics technology and negotiations concerning cooperative agreements were opened.

(iv) Contacts with the plastics industry were established and avenues for cooperation are to be explored.

(v) Methods for evaluating the effects of plastic mulch technology on production and income were developed, installed on CIQA's computer, and implemented (on an experimental basis).

(vi) An estimate of the demand for mulches in La Laguna was made. This estimate is based on preliminary information and is intended solely to illustrate how such estimates may be made.

(vii) A financial analysis model was developped and installed on CIQA's computer.

(viii)Scenarios for the promotion of manufacture and use of agricultural plastics were prepared.

Chapter 3 sets forth my conclusions and recommendations for the conduct of the technology assessment that CIQA has initiated. My main recommendation is that the technology assessment process be used as a way to integrate the three sub-projects (plasticos, plasticultura, and evaluacion, planeacion, y transferencia de tecnologia) that now constitute the Plastics In Agriculture Project, and to promote the the manufacture and use of agricultural plastics in Mexico.

Chapter 4 discusses, in a qualitative way, the costs and benefits associated with plastics mulch technology in the Mexican context. The discussion in this chapter attempts to clarify what costs and benefits should be evaluated in subsequent activities of the project.

Chapter 5 describes and illustrates recommended methods for analyzing some of the most important costs and benefits of use of plastics. The models are designed to estimate the effects of use of selected plastics technologies on agricultural production and on income in the agricultural sector.

Chapter 5 also illustrates how potential demand for plastics for selected applications can be estimated. Demand for mulch in analyzed for the La Laguna Region for a variety of combinations of conditions concerning the cost of mulch and the increment in yield obtained from the application of mulch.

Chapter 6 presents some illustrative estimates concerning the potential for use of plastics in selected applications on a nation-wide basis. These estimates were prepared jointly with Dr. S. Fernandez, MC Edgar Guero, and Ing Jesus Perez. While extremely rough, the estimates indicate that there is potential for a substantial level of demand.

CHAPTER 2: ACTIVITIES AND EVENTS

A. Introduction

This chapter reports the major activites and events of the past 4 months of the Plastics In Agriculture Project. Although the Project Document was not signed until the latter part of June, 1982, the project commenced in the early part of May, 1982, when the author was posted to CIQA as a UNIDO consultant under an advance project authorization. The purpose of this discussion of activities and events is to place in context the findings and recommendations contained in subsequent chapters.

B. Activities and Events

1. Technology assessment initiated

Early in 1982, CIQA negotiated an agreement with the Office of Arid Land Studies (OALS) of the Univerity of Arizona (USA) to provide support to CIQA in the conduct of an assessment of agricultural plastics technology. The objectives of this assessment, according to the initial proposal prepared by OALS, are

> ... 1) to assess the current use of plastics worldwide and in Mexico; 2) to review projected current and future demand for basic petrochemicals in Mexico; 3) to document current and project Mexican capacity to produce basic petrochemicals; 4) to review the Dentro de Investigacion en Quimica Aplicada's process research on plastic films; 5) to determine the potential consumption of plastic films and other dryland products in the dryland agricultural sector of the Mazapil region for various applications; 6) to extrapolate this use and demand to other regions of northern Mexico; and 7) to provide recommendations for linkages between the agricultural sector and the primary petrochemical produc-

ers. ("A Technology Assessment of Plastics in Mexican Arid Lands Development", A proposal submitted to the Centro de Investigacion en Quimica Aplicada by the Office of Arid Lands Studies).

The plastics technology assessment is the second technology assessment to be conducted jointly by CIQA and OALS. The first, a technology assessment of Mexican guayule, was available in draft form in May, 1982.

As originally proposed, the plastics technology assessment was slated to begin in early 1982. Start-up of the assessment had to be postponed, however, due to the devaluation which took place in mid-February, 1982, and the ensuing budgetary uncertainty.

The assessment started with the visit of Dr. Jonathan Taylor of OALS during the week of May 9, 1982. This visit was scheduled to coincide with the start of the author's mission and the originally-planned starting date of UNIDO Project Coordinator Sr. Gregorio Pruzan's mission. The week of Dr. Taylor's visit was devoted to a discussion of the objectives of the technology assessment and to the ways in which it could strengthen the Plastics in Agriculture Project.

2. Preliminary analysis of potential national demand

During the week May 9-13, the author prepared an illustrative analysis of potential nation-wide demand for plastic mulches. The results of this analysis were presented by Project Director Dr. Salvador Fernandez at an international meeting on plastics in agriculture held in Brazil.

3. CIQA Project Director attends international meeting

Dr. Fernandez represented the Mexican plastics project at a meeting on agricultural plastics in Brazil, May 16-20.

4. Model developed for regional analysis

During the period May 16-June 25, the author developed, programmed, installed on CIQA's computer, and demonstrated a model for analyzing the effects of availability of plastic mulches on regional agricultural proudction and income. A discussion of this model is contained in Chapter 5 of the present report.

5. Recommendations prepared on technology assessment

During the period May 16-May 25, the author prepared recommendations concerning the objectives, content, and conduct of the joint CIQA-OALS technology assessment of agricultural plastics. These recommendations, based on a review of the results of a previous toint TA of Mexican guayule, the proposal for the joint TA of agricultural plastics, the UNDP Plastics in Agriculture Project being executed by CIGA, and discussions held with GALS during the previous week. The author's recommendations propose that the technology assessment be used as a framework for integrating the three sub-projects of the UNDP Project. The recommendations are contained in Chapter 3 of this report.

6. Opportunity Study prepared

During the period May 25-June 25, the author assisted in the preparation of an Opportunity Study for selected agricultural applications of plastics. This study was later presented at a meeting held in Saltillo at the end of June (see paragraph 7 of this section). Due to time and resource constraints, the Opportunity Study did not cover all of the points listed in the recommended outline for the study contained in Chapter 3. The Opportunity Study that we prepared is contained in Chapter 4 of this report.

7. First technology assessment meeting held in Saltillo

A meeting was held at CIGA, June 29-30, to explain the technology assessment to potentially-interest parties and to solicit their participation. The Opportunity Study (see paragraph 6 of this section) was presented.

The most important result of the meeting was that several parties expressed interest in cooperation with CIGA. Among the organizations expressing further interest were PEMEX, IMP, CENAMAR, COPLAMAR, and PRONOFOR. Cooperative agreements are presently being negotiated with many of these organizations.

8. Financial analysis model developed

During the period July 1-July 9, the author installed a financial analysis model. This model utilizes CIGA's computer to prepare income statements and balance sheets for an enterprise. It is anticipated that this tool will be used in subsequent stages of the project to analyze financial and economic aspects of plastics manufacture and usage at the enterprise level (i.e. firm or farm), and as a tool to promote investments in plastics manufacture/use.

9. UNIDO Project Coordinator conducts interviews

During a six-week mission (approximately July 8-August 21, 1982), UNIDO Project Coordinator Sr. Gregorio Pruzan interviewed key figures in industry and government. These interviews included questions suggested by the author related to promotion. A number of promising opportunities for promotion of projects based on agricultural plastics technology were identified which will be pursued in a subsequent task of the project.

Following up on a suggestion made by the author (see Chapter 3), Sr. Pruzan, through the auspices of the SIDFA, also initiated contact with the Governors of states potentially interested in projects based on manufacture and/or use of agricultural plastics.

10. Meetings to pursue cooperative agreements

Dr. Fernandez and Sr. Pruzan met with representatives of IMP, PRONOFOR, and ENPETROL during the week of July 19 to discuss possibilities for cooperation in research relating to plastics in agriculture.

11. COMEPA meets in Guadalajara

COMEPA held a major meeting in Guadalajara, July 27-30. At this meeting, a series of technical papers, status reports, and exhibits were presented. Dr. Fernandez and Sr. Pruzan met with the Governor of the State of Jalisco and described to him some of the development opportunities potentially available in manufacture and/or use of agricultural plastics.

12. Crop yield-water stress model developed

During the period July 5-August 18, the author developed, programmed, installed on CIQA's computer, and demonstrated a model for analyzing the effect of use of plastic mulches on yield and crop water requirements. The model is described in Chapter 5 of the present report.

13. Visit to CENAMAR

Dr. Salvador Fernandez and Sr. Gregorio Pruzan visited CENAMAR to discuss possibilities for cooperation in experimentation with plasticulture. A formal agreement is being negotiated.

14. Meeting with Michoacan's Secretary of Industrial Development

Drs. Salvador Fernandez, Robert Anderson, and Sr. Gregorio Pruzan met August 19 with the Secretary of Industrial Development of the State of Michoacan. The purpose of the meeting, which was requested by the state and arranged by the SIDFA, was to discuss potential opportunities for Michoacan in the manufacture and use of agricultural plastics. It was agreed at the conclusion of the meeting that this subject would be explored further in two meetings, one in which a team of experts from CIQA would go to Michoacan, and one in which a delegation from Michoacan would visit CIQA.

15. Visit to IMP

The author visited Ing. Enrique Castro of IMP on August 20. Ing. Castro described the results of a large cooperative demonstration project in which asphalene mulch was used on a 10 hectare painted plot in the state of Mexico.

16. Visit to CIANOC

The author visited INIA's Centro de Investigaciones Agricolas del Norte-Centro (CIANOC), representing Dr. Fernandez, to summarize CIQA's work on plastics in agriculture and to open discussions concerning possible future joint work. Four possible areas of cooperation were discussed, including (i) experimentation with applications of plastics, (ii) sharing of agroclimatic data required to estimate the potential for applications of plastics, (iii) modeling of effects of usage of plastics on crop production processes, and (iv) transfer of plastics technology into agricultural use. The General Director of CIANOC is scheduled to visit CIQA during the week of September 6 to follow-up on these discussions.

17. Preparation of report

This report was prepared during the period August 23-September 4.

CHAPTER 3: RECOMMENDATIONS CONCERNING THE OBJECTIVES, SCOPE, AND CONDUCT OF THE TA

A. Introduction

As remarked in the previous chapter, one of the important activities undertaken by CIQA in connection with plastics in agriculture is the initiation of a technology assessment of plastics in Mexican agriculture. This chapter discusses the objective, scope, and conduct of CIQA's assessment of technologies for manufacture and use of selected agricultural plastics. The project to conduct this assessment is called PAZA in the following pages. The objective of the chapter is to suggest how PAZA could be defined and conducted in such a way as to integrate the three sub-projects that make up the Plastics in Agriculture Project, and to promote agro-industrial development based on agricultural plastics technology.

The technology assessment of agricultural plastics is the second technology assessment CIQA has conducted. The first, a technology assessment of production of rubber from guayule in Mexico, was completed in draft form at the time the author's mission commenced. Many of the suggestions offered in this chapter are based on a reading of that draft, and on the author's conclusions concerning ways in which the usual technology assessment process, as reflected in that draft, could be modified to better serve the objectives of the Plastics in Agriculture Project.

B. Objectives of PAZA

1. Background

CIQA was charged with the objective of developing technologies that could contribute to the economic and social development of Mexico's arid zones. It has done that effectively. It has developed and demonstrated technologies for the use of the plentiful resources of these regions.

To date, however, none of these technologies has reached implementation. Indeed, only the guayule technology has been incorporated into a serious development project proposal. CIQA's plan to conduct TA's of the technologies it has pioneered is intended to break the barriers between the R&D process and the process of formulating, evaluating, and if indicated, implementing development projects based on new technologies.

It is also important to remember that PAZA is funded, in part, by a loan from the Interamerican Development Bank, and by a United Nations Development Programme project. Both of these forms of support presume that PAZA would contribute to Mexico's economic and/or social development objectives. This, it seems to me, should also be an important consideration in framing an objective for PAZA.

2. A Statement of Objective

In light of the above considerations, I propose the following statement of objective for PAZA:

> THE OBJECTIVE OF PAZA IS TO STIMULATE THE FORMULATION, EVALUATION, AND [IF WARRANTED] IMPLEMENTATION OF AGRICULTURAL AND INDUSTRIAL DEVELOPMENT PROJECTS BASED ON PLASTICS TECHNOLOGY.

In other words, INFORMED DECISIONS CONCERNING ECONOMIC AND/OR SOCIAL DEVELOPMENT PROJECTS [which are not to be confused with decisions that any analyst working on PAZA would necessarily recommend] are the intended final product or outcome of PAZA.

The important phrase in the statement of objective proposed above is "formulation, evaluation, and ... implementation of ... development projects". CIQA's objective, as I understand it, is to stimulate productivity-improving technological innovation and diffusion in Mexico's arid regions. The above statement of objective seems to me to be an appropriate way to frame PAZA's objectives in light of this.

To clarify the above proposed statement of objective, here are two statements of objective I propose NOT be adopted:

> "The objective of PAZA is to identify and evaluate potential social, economic, political, and environmental effects of use and manufacture of agricultural plastics"

> "The objective of PAZA is to indentify and evaluate the social, economic, political, and environmental factors that could inhibit or promote technologies for the manufacture and use of plastics for agriculture".

These latter two statements leave unclear what, if any, effect on decisions is intended, and leave unclear the connenction between PAZA and economic and social development objectives. One might well conclude from them that the intended product or outcome of PAZA is a report or reports. While careful, thorough reporting of findings about economic, social, political, and environmental aspects of agricultural plastics are an absolutely necessary part of the effort. CIQA's eight-odd years of experience demonstrate that research and reporting alone are not sufficient to overcome the barriers between science and technology and development planning and project preparation.

C. Scope of the Assessment

Having proposed an objective, let us now turn to a description of technology assessment as a method for achieving this objective. First, let me define what I mean by 'technology assessment'.

> A TECHNOLOGY ASSESSMENT IS A PROCESS IN WHICH INTERESTED PARTIES JOINTLY CONDUCT AN ANALYSIS INTENDED TO FOSTER A COMMON UNDERSTANDING OF THE CONSEQUENCES OF ALTERNATIVE USES OF A TECHNOLOGY AND THE EFFECTIVENESS OF ALTERNATIVE POLICIES FOR MANAGING THESE USES, AND THEREBY TO STIMULATE IMPROVED DECISION-MAKING.

1. Stages of a TA

To achieve its purpose (i.e. common understanding leading to informed decision-making), a TA requires four basic stages. First, it requires COMPILATION OF DATA AND INFORMATION on relevant aspects of the technology. The meaning of relevant aspects is defined below. By data and information is meant an assemblage of facts [quantitative and qualitative] pertinent to the technology. Included would be a description of the technology, a description of possible applications of the technology, perfo[illegible]ce data, etc.

[illegible]d, it requires the CONDUCT OF ANALYSES OF DATA AND INFORMA[illegible] on relevant aspects of the technology. By analysis is meant critical evaluation and processing of data and information to deduce its implications about relevant aspects of the technology.

Third, it requires REACHING CONCLUSIONS concerning relevant aspects of the technology. These conclusions would be the result of the analyses conducted.

Fourth, it requires the MAKING OF RECOMMENDATIONS concerning relevant aspects.

2. Relevant Aspects

By relevant aspects is meant those aspects of a technology that would be pertainent to formulation, evaluation, and implementation of development projects. Relevant aspects include the following.

Technical aspects. This includes description, analysis, conclusions, and recommendations concerning technology. It is based primarily on the work of technical experts [e.g., agricultural engineers, experts in plastics transformation].

Management and administrative aspects. This includes [in the case of the present TA] description, analysis, conclusions, and recommendations concerning management and administration of programs/projects to foster applications of plastics [e.g., extention services, demonstration projects, educational programs], management and admininistration of farms [e.g. assessment of farmers capacity and willingness to adopt plastics technology], and management and administration of transforming firms [e.g., assessment of transforming firms' willingness and ability to integrate necessary production and distribution operations into their businesses].

Organizational aspects. Organizational aspects are closely related to management and administrative aspects. The focus however is on the description, analysis, conclusions, and recommendations concerning alternative organizational structures for promoting innovation and diffusion of the technology.

Commercial aspects. Commercial aspects includes description, analysis, conclusions, and recommendations concerning distribution of inputs and outputs related to the use of the technology. Included in the case of PAZA would be provision of plastics inputs and complementary inputs [e.g., fertilizers, etc] to farmers, and provision for distribution of any surplus agricultural production generated.

Financial aspects. Financial apects includes description, analysis, conclusions, and recommendations concerning alternatives for financing innovation and diffusion of the technology. Included in financial aspects would be consideration of such things as alternative financing arrangements and the effects of these on financial viability of the technology as viewed by commercial farmers, semi-subsistence farmers, subsistence farmers, plastics transformers, the financing entity [under alternatives that would provide special financing facilities].

Economic aspects. Economic aspects differ from financial aspects in that financial aspects view the technology from the point of view of the individual economic entities [i.e., farms, businesses, consumers] that would be involved with it. Economic aspects attempt to view the technology from the perspective of the social costs and benefits associated with it. Not all such social costs and benefits can be quantified, but there are reasonably satisfactory ways to deal with such costs as foreign exchange, distortions in technology brought about by artificially low costs of capital in relation to labor, and distortions between true production cost and value of output produced brought about by price controls, taxes, and other policies.

Social aspects. Social aspects includes description, analysis, conclusions, and recommendations concerning possible social effects associated with a technology and measures for their mitigation or amplification. Included in PAZA might be such effects as changed migration, changed patterns of agriculture and consequent effects on farm families, effects on income distribution, availability of social services, and so forth.

Policy aspects. Policy aspects includes description, analysis, conclusions, and recommendations concerning possible policies for managing innovation and diffusion. Included in PAZA would be policies with respect to import of necessary plastic inputs, pricing of plastic inputs, output purchase, etc.

Environmental aspects. Environmental aspects include description, analysis, conclusions, and recommendations concerning possible environmental effects of import/manufacture of agricultural plastics and their use.

3. Products

The main products of PAZA, if it is successful, will be serious development project proposals for manufacture and use of agricultural plastics, thorough evaluations of those project proposals, and informed decisions concerning the implementation of these proposals. Subsidiary, but nonetheless important products will be publications documenting the formulation and evaluation of project proposals.

Not all audiences will be interested in all of the stages and aspects discussed in C.1 and C.2 above. The most important audience, those involved in the decision-making process, will be interested primarily in a very general summary description of information and of the analyses conducted. They will be somewhat more interested in conclusions and recommendations.

Presentation, therefore, should be at two levels. For decision-makers, presentations should be of the form of executive reports. These are relatively short, and make good use of graphics. Conclusions and recommendations should be clearly stated, along with a summary justification for each.

Executive reports should be backed up by technical reports on each aspect of the assessment. This reports should be prepared with the assistance of experts when required, and should be subjected to peer review. They should be prepared and revised during the course of the project. They should be prepared in sufficient detail [e.g., including data utilized, description of methods, tests, etc.] to permit reviewers to evaluate the data used, analysis conducted, and conclusions reached.

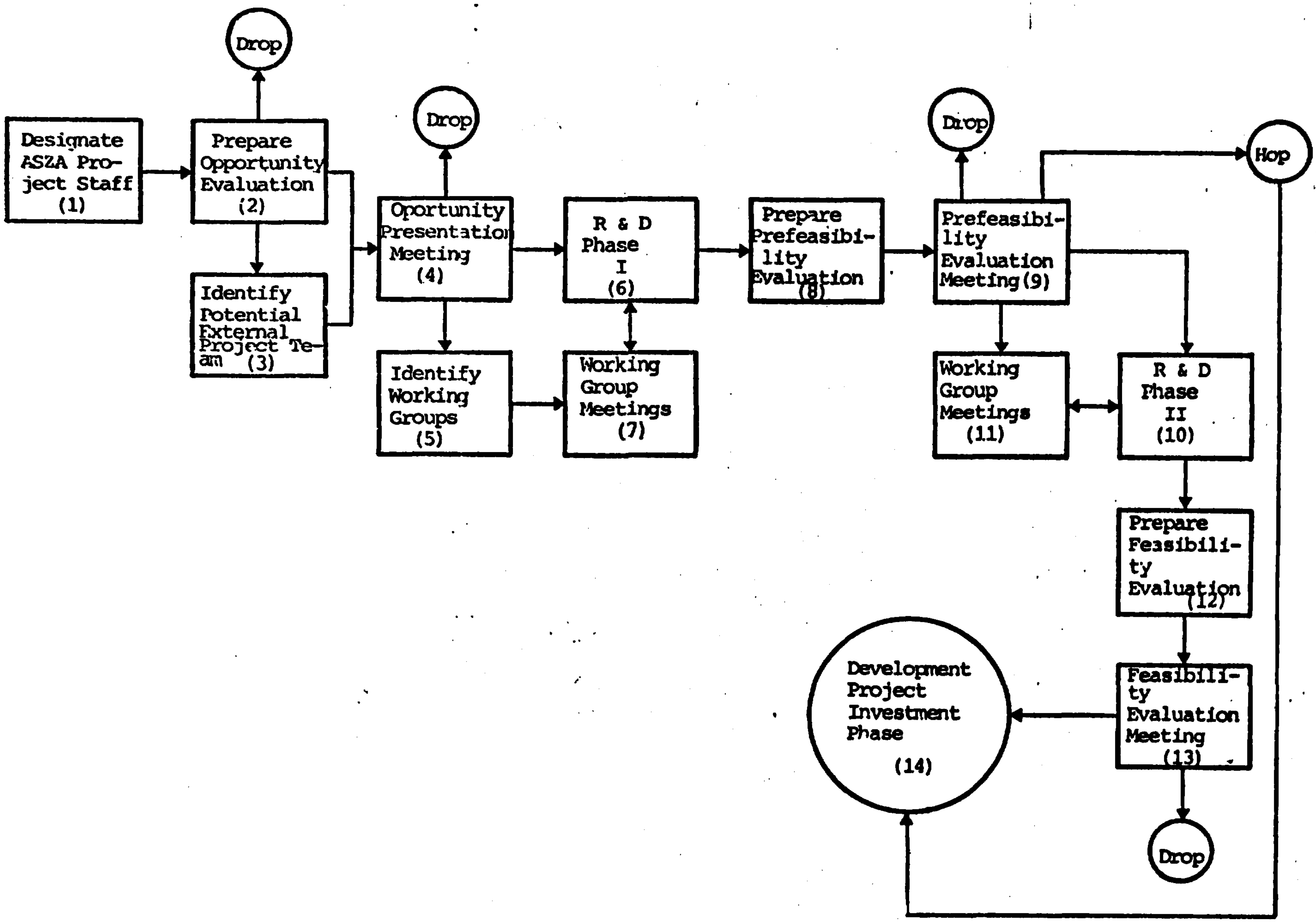
D. Conducting the TA

I propose that PAZA be conducted according to an approach described by C.S. Holling and his colleagues in a book entitled ADAPTIVE ENVIRONMENTAL ASSESSMENT AND MANAGEMENT. The essence of this approach is the explicit embedding of of the assessment in a decision-making process. The particular decision-making process I would like to embed PAZA in is frequently called the "project development cycle" by development agencies (i.e. FAO, IDB, UNDP, IBRD, UNIDO, etc). This is a decision-process designed to formulate and evaluate development project proposals, leading to a decision to implement or to reject proposed projects.

1. A Step-by-Step Description of the Process

A step-by-step overview of the proposed approach to conducting this sort of TA is shown in Figure 1. Each of the boxes in the figure represents a step. Numbers in boxes refer to numbered paragraphs below which explain briefly the intended content of each step. The text and example outlines cover both the manufacture and use of plastics technologies.

STEPS OF A TECHNOLOGY ASSESSMENT



(1)

DESIGNATE PROJECT STAFF. This step establishes a 'core' project staff for the duration of the project. It does not include personnel who may be associated with the project only at certain stages [e.g., laboratory personnel conducting experiments, engineers designing a production facility]. The make-up of the core staff depends upon the nature of the project, but might include an economist [with appropriate sectoral specialties], one or more technical specialists, a policy analyst, and a specialist in project organization/management. The core staff is responsible for organization of all meetings, preparation of all documents, and for management and integration of the results of R&D and/or meetings.

(2)

PREPARE OPPORTUNITY EVALUATION STUDY. The core staff prepares an Opportunity Evaluation Study. This study introduces a project idea and evaluates its technical, economic, social, and policy aspects using available data. If the idea [which in fact would embrace a wide range of alternative projects] appears potentially attractive, a plan for formulating project alternatives and for completion of prefeasibility and feasibility evalautions of them is prepared, and included in the opportunity evaluation study. .

A rough table of contents for the Opportunity Evaluation Study of opportunities in the transformation industry is as follows:

I Part I Project Summary-Manufacture of Plastics for Agricultural Use
- A Commercial aspects
  - 1 Products
  - 2 Markets
  - 3 Marketing strategy
- B Technical aspects
  - 1 Products
  - 2 Production technologies
  - 3 Inputs
  - 4 Quality control
- C Administrative/managerial aspects
  - 1 Baseline description of transformation industry
  - 2 Compatibility of agroplastics with industrial str
  - 3 Alternatives for technology transfer
- D Organizational aspects
  - 1 Organizational options
  - 2 Roles of public and private sector
- E Financial aspects
  - 1 Transformers

2 Project
3 Government

F Economic aspects
1 At efficiency prices
2 At equity prices

G Environmental aspects
1 Effects on air
2 Effects on water
3 Solid wastes
4 Hazardous and toxic substances

H Social aspects
1 Effects on social services
2 Effects on employment
3 Training
4 Effects on population dynamics

I Policy aspects
1 Relationship to development objectives
2 Adequacy of present policy framework

II Part II Plan for Evaluation

A Functional Study Specifications
1 Input Studies
  a Critical questions
  b Plan
  c Cost and time of completion of the study
2 Technology development
3 Market and marketing strategy
4 Siting and transportation
5 Enterprise organization
6 Finance
7 Impact assessment
8 Policy analysis

B Plan for preparation of evaluation
1 Criteria
2 Incorporation of functional studies
3 Decision strategy

C Overall preliminary evaluation of opportunity

If the evaluations conducted in Part I of the Opportunity Evaluation Study show the project idea to have little potential merit, the project is dropped and Part II of the Opportunity Evaluation Study is not prepared. If the evaluations in Part I show the project idea to be meritorious, Part II is prepared. If the evaluation in Part II shows the idea to have little merit [becuase of the likely expense and/or difficulty of successful execution of the of a satisfactory evaluation phase], then the project idea may be dropped.

The outline for the Opportunity Evaluation Study of opportunities for use of plastics in agriculture is similar:

Part I Project Summary-Use of Plastics in Agriculture

- A Technical aspects
  - 1 Technology description
  - 2 Input requirements
  - 3 Input costs and use costs
  - 4 Yield increments
  - 5 Production functions
- B Managerial and administrative aspects
  - 1 Technology transfer
    - a Demonstration
    - b Extension
    - c Training
    - d Provision of inputs
    - e Distribution of outputs
    - f Credit
  - 2 Technology adoption
    - a Model farms
    - b Farm plans
    - c Attitudes and perceptions
- C Organizational aspects
  - 1 Relevant authorities
  - 2 Organizational options
- D Commercial aspects
  - 1 Provision of inputs
  - 2 Distribution of outputs
- E Financial aspects
  - 1 Farm
  - 2 Credit-granting authority
  - 3 Project
  - 4 Government
- F Economic aspects
  - 1 At efficiency shadow-prices
  - 2 At equity shadow-prices
  - 3 At merit good shadow prices
- G Environmental aspects
  - 1 Effects on soil resources
  - 2 Effects on water resources
  - 3 Desertification
- H Social aspects
  - 1 Effects on social services
  - 2 Effects on rural-urban land conversion
  - 3 Effects on employment
  - 4 Effects on population dynamics
- I Policy aspects
  - 1 Relationship to national and regional developm objectives
  - 2 Adequacy of present policy framework

Part II Plan for Evaluation [as above]

(3) IDENTIFY POTENTIAL EXTERNAL PROJECT TEAM. Fundamental to the success of the approach outlined here is the involvement from the beginning of people who can solve the practical problems of project formulation and can make the decisions necessary to formulate, evaluate, and if warranted, implement a development project. The objective of this step is to identify those people and begin the process of persuading them to become involved in the effort.

The completion of the necessary functional support studies may require incremental funding. For example, in projects dependent upon the availability of natural resources whose quality and/or quantity are uncertain [e.g., a project to mine a particular mineral in a region], a resource assessment would have to be undertaken. It is hoped that one or more of the agencies represented in the External Project Team would provide resources, either in the form of funding or in kind, for the conduct of any functional support studies requiring incremental funding.

(4) OPPORTUNITY PRESENTATION MEETING. This meeting is the vehicle for encouraging the External Project Team identified in Step (3) to participate, and for organizing that participation. The meeting would consist of a very well organized presentation of the Opportunity Evaluation Study, complemented when necessary by a field trip, laboratory demonstration, distribution of sample products [e.g., laminates made from natural fibre composites, guayule rubber], and so-forth. The meeting lasts about one-and-one-half days. It is fast-paced and hard-hitting. If it fails to generate interest, the project idea may be dropped at this point no matter how promising the Opportunity Evaluation Study shows the idea to be.

Two Opportunity Presentation meetings are planned during PAZA. The first, currently scheduled for the end of June, 1982, will deal with opportunities for the use of plastics in agriculture. The second, scheduled for August, 1982, will deal with the manufacture of plastics for agricultural uses.

(5)

IDENTIFY WORKING GROUPS. The Project Team [core and external] is organized into working groups according to specific functional studies that must be accomplished to complete the evaluation. For example, representatives from BANRURAL, SEPAFIN, and SPyP might be asked to serve on a Finance Working Group. The working groups would both contribute expertise in working out potential formulations for various aspects of a project and [hopefully] would be prepared to assist with these aspects in implementation of a project should the evaluation result in a decision to implement a project.

(6)

R&D PHASE I. In this step, the functional studies that support preparation of the prefeasibility evaluation are carried out. This would include laboratory and bench-scale experimentation, resource assessments, analysis of relevant policy frameworks, analysis of financing options, analysis of organizational alternatives, etc., as needed.

(7)

WORKING GROUP MEETINGS. Working group meetings take place to assist with the conduct of functional studies. During the meetings, group members work with project core staff and expert staff to complete functional studies.

(8)

PREPARE PREFEASIBILITY EVALUATION. The project core staff prepares a Prefeasibility Study Report based on the preliminary results of functional studies. This report is intended to report and provide supporting evidence for preliminary conclusions concerning the various relevant aspects of the project.

The outline for this report is basically the same as that for the Opportunity Evaluation Study [see above]. More detail is provided, however. The report includes such things as preliminary plant layouts, consideration of location options, and summarizes the results of functional studies in progress or completed.

(9)

PREFEASIBILITY EVALUATION MEETING. The results of the Prefeasibility Evaluation will be examined in a meeting involving all external study participants. If the results are unfavorable, the project may be dropped. If the results are extremely favorable, participating agencies may decide to skip the Feasibility Evaluation and proceed directly with project implementation.

More probably, meeting participants may decide to procede with the Feasibility Evaluation. The meeting will identify project aspects requiring particular attention in the preparation of the Feasibility Evaluation.

(10)

R&D PHASE II. Functional studies are completed at this step, taking into account any additional study requirements identified at the Prefeasibility Evaluation Meeting.

(11)

WORKING GROUP MEETINGS. Functionally organized working groups meet with project staff to assist and advise in the completion of functional studies.

(12)

FEASIBILITY EVALUATION STUDY. The project core staff prepares a Feasibility Evaluation Study. The outline of this study is roughly the same as that for the Prefeasibility Evaluation Study.

(13)

FEASIBILITY EVALUATION MEETING. The results of the Feasibility Evaluation Study are presented for consideration of all project participants. If favorable, it is hoped that the appropriate external participants will take the necessary steps to move the project into the next step...

(14)

DECISION AND PROJECT IMPLEMENTATION.

2. Discussion of the approach

There are three points concerning the approach suggested above that merit stress. First, the use of terms used by development agencies to describe various parts of the project development cycles is intentional. The approach is intended to stimulate the initiation of a project development cycle for manufacture and use of agricultural plastics. The terminology used is intended to keep this objective firmly in view.

Second, the process outlined above is designed to produce results and tentative conclusions at each step of the study. This helps to keep the study oriented toward its objective, to identify unresolved questions and issues requiring resolution, and to facilitate an adaptive approach to decision-making.

Third, it is important to remember that CIQA is not per se responsible for development project formulation. It can only be successful if it can secure the cooperation of agencies that have this responsibility.

In implementing the above approach, therefore, CIQA should seek the sponsorship of an agency that has this responsibility.

CIOA's role would be to execute, and provide the supporting organizational and analytical technology necessary to do so. Ideally, the sponsoring agency would be one that would not provoke jealousy or suspicion among other agencies. The prerequisites for this probably are that either (1) the sponsoring agency have unquestioned primacy with respect to the project in question [so that others have nothing to lose and perhaps something to gain by participating], and/or (2) the sponsoring agency has no direct interest in the project that would in any way conflict with the interests of the other agencies but has the political influence to compel the participation of others. An example of the latter might be the Office of the Governor of a state that might benefit from the project.

CHAPTER 4: REMARKS CONCERNING THE EVALUATION OF COSTS AND BENEFITS OF PLASTIC MULCHES

A. Introduction

This chapter examines qualitatively some of the costs and benefits that are frequently mentioned in discussions of the possible costs and benefits of use of plastic mulches. Its purpose is to recommend the categories of costs and benefits that merit priority in evaluation of mulch applications of plastics technology.

B. Benefits and Costs of Plastic Mulches

1. Benefits

Several benefits have been claimed for the use of mulches. Each of these is described and discussed briefly below.

a. Increased yields

Increased yields with mulches have been reported under both experimental and field conditions. These yield increases are thought to derive primarily from control of evapotranspiration, which results in meeting a greater portion of crops' water needs. Several experts have stated that where water is available to meet the full needs of an unmulched crop, its yield would be equal to that of a mulched crop. Observed yield differences, according to these experts, are due primarily to deficiencies in water available to unmulched crops.

Inasmuch as the yield increments obtained through use of mulches are frequently substantial, associated benefits may be substantial. Benefits of this type are measured approximately by the value of the increased production obtained.

b. Conservation of water inputs

The discussion above raises the possibility that mulch may be substituted for water input. Two situations may be distinguished here. In the first, sufficient water is available to maintain the rate of evapotranspiration at the maximum potential rate for soil-crop-climate conditions. In this case, use of plastic mulches enables the reduction of water inputs with no sacrifice in yields.

In the second case, available water inputs are insufficient to maintain the maximum potential rate of evapotranspiration. Use of mulches may mean that water inputs become sufficient (or perhaps even more than sufficient) to maintain this rate. In this case too, it may be possible (and economically desirable) to reduce water inputs, with little or no consequent sacrifice in yield.

In valuing water savings, it is particularly important to value water at its opportunity cost. The nominal value of water (reported by several individuals to be about $0.50 MN per cubic meter--primarily pumping and set-up costs) is probably well below its opportunity cost in most situations.

c. Conservation of fertilizers/nutrients

Use of plastic mulches reduces the leaching of nutrients from the root zone. It may thus be possible to reduce fertilizer inputs needed to maintain any given nutrient level.

In the case of conservation of fertilizers, it is also important to value the benefit at the opportunity cost of fertilizer. Fertilizer is in short supply relative to demand at current nominal costs, and is rationed. The opportunity cost of fertilizer is therefore likely to be somewhat above its nominal cost.

d. Conservation of cultivation inputs

Mulch may also contribute to the control of weeds. Herbicide use and/or hand weeding may thus be reduced. In the case of a reduction of the demand for hand labor, the extent to which such is to be counted as a benefit may be debateable. Another point to bear in mind is that, due to minimum wage provisions, the nominal cost of labor may be somewhat above its opportunity cost.

e. Improved crop quality

Improved quality of crops (e.g. improved melon quality through reduction of direct contact with the soil) sometimes results from use of mulch. The value of this benefit is approximately the increase in the market value of the crop due to higher quality.

f. Earliness

Experiments and field experience indicate that use of mulches results in a reduction in the time required for crops to attain harvest maturity. There are three aspects to the earliness benefit, each of which merits separate mention and discussion.

First, earliness makes a crop available at precisely the time at which its supply from alternative sources (e.g. storage, other grow regions) may be most costly. That is, earlieness makes a crop available at a time at which it is generally more scarce than it is at the normal time of harvest. This is clearly a benefit, and is reflected in the higher price received by the farmer who is early to the market with his crops.

One must, however, be a bit careful in the interpretation and measurement of this aspect of the earliness benefit. To see why this is so, let us suppose that all farmers used mulch, and hence, the date at which all brought their crops to market was correspondingly earlier. The effect would be that the relatively low price that characterizes the usual period of heavy marketing would be shifted forward in time, and no farmer would receive a higher price.

If the peak marketing period occurs earlier, does this mean that there is no earliness benefit? The answer is no. The availability of mulch technology means that it is possible to prolong the period during which fresh crop matures and is brought to the market. By a coordinated use of mulch and conventional technology, it may be possible to secure a sustained period of availability of fresh crop, and thus to reduce costs of storage and/or costs of transport of the crop from other growing regions. As noted above, this may require some kind of a coordinating mechanism (a futures market, for example, could provide this function) insuring the proper balance between technologies, production regions, and storage capacities.

A second aspect of the earliness benefit is in the reduction of working capital costs associated with a crop. The nature of this benefit is clear: capital is tied-up in a crop under cultivation for a shorter period of time. Under the conditions of capital shortage and capital rationing that seem to characterize the current agricultural capital market in Mexico, this could be an important benefit.

A third aspect of earliness is that it may be possible to crop a given parcel of land more intensively. Shortened growing periods of crops may make possible multiple cropping.

g. Social benefits not elsewhere classified

A variety of potential benefits in addition to those directly connected with crop production have been ascribed to the use of plastic mulches. Since these benefits may have considerable political appeal, it is important to be clear on their nature and the extent to which they may reasonably be expected to derive from expanded plastics usage. Accordingly, those that are frequently mentioned in discussion of the outlook for agricultural plastics applications in Mexico are discussed and evaluated briefly below.

(i) stem the flow of rural-urban migration

By raising productivity and incomes in commercial and semi-subsistence agriculture, use of plastics would increase the attractiveness of agricultural occupations. By raising productivity in subsistence agriculture, the 'carrying capacity' of the land would be increased.

There is some empirical evidence to support the contention that improvements in agricultural productivity result in a slight decrease in urban-rural migration. The study which shows this (a study by A. Silvers and P. Crosson, published by Resources for the Future), however, shows that the effect is small. Also, the investments considered in the Silvers-Crosson study were primarily investments targeted toward commercial agriculture.

I am not awsare of any evidence concerning the effect of productivity improvements on subsistence agriculture on migration rates. The argument, however, is that some migration occurs because of crop failure. In all-too-frequent bad years, people are forced to migrate from subsistence rural areas. If plastic mulches increased yields in years that otherwise would be disasterous (through conservation of soil moisure), forced outmigration would be reduced.

(ii) improved nutrition in subsistence agriculture

This benefit is closely related to that described above. The argument goes that by increasing average yields and reducing the likelihood of disasterously low yields, nutritional needs of the poorest segments of the rural population would be met more adequately.

(iii) reduced degradation of the soil resource

Use of mulches could reduce soil erosion, nutrient leaching, and compaction. These benefits are soil conservation benefits.

2. Costs

The most important issues with respect to evaluation of the costs of mulch technology relate to the evaluation of the costs of the film and its application, and disposal. Costs should be evaluated both at nominal costs and at opportunity costs. The two may diverse in the case of film due to PEMEX subsidies, and in the case of application and disposal due to distortions in labor and capital costs. In the case of disposal, the possible environmental problems associated with disposal of film after use should also be considered.

CHAPTER 5: ANALYZING AGRICULTURAL DEMANDS FOR PLASTICS

A. Introduction

This chapter presents and illustrates two models developed by the author for analyzing the effects of use of plastic mulches on agricultural production and income. Computer source listings, instructions for use, and examples of input and output files are contained in the appendices to the chapter.

The plan of the chapter is as follows. In Section B, the specification of an economic model for analyzing the effects of usage of mulch on agricultural production and income is presented. The model presented is a simple but powerful linear programming model of regional agricultural production.

Section C presents some preliminary results that were obtained when this model was used to estimate potential effects of plastics usage on production and income in the La Laguna region of Mexico. The results also show how the model can be used to analyze the demand for plastic mulches.

Section D presents and illustrates an agro-climatic model that can be used to estimate the effect of use of mulching on crop yield and/or water usage. This model is intended to complement the model contained in Section B as a tool for analyzing the effects of mulch usage on income and production.

B. A Linear Programming Model of Production and Income

1. Introduction

This section describes a possible framework for evaluating the application of alternative plastics technologies to agriculture in Mexico. Available experimental evidence suggests that applications of selected technologies can result in substantial increases in the yields of important crops. The framework proposed is designed to appraise the consequences of alternative policies with respect to the diffusion of this technology into field applications.

It is useful in developing such a framework to consider briefly the nature of the relationship between technologies employed in Mexican agriculture and economic and social development. The main direct effect of plastic technologies [or other agricultural technologies for that matter] is on the productivity of land. Better technology, if successfully applied, results in one or more of the following effects: higher yields; better crop quality; lower costs; conservation [which results in higher yields, better crop quality, and/or lower costs on a sustained basis]. This, in turn, effects the well-being of the farmer. In commercial and semi-subsistence agriculture, better technology results in increased production and farm income. In subsistence agriculture, better technology may result in improved nutrition, liberation of family labor for other undertakings, reduced risk of crop failure, conservation, and/or in promotion of the transition from subsistence agriculture to semi-subsistence agriculture.

The indirect effects of improved agricultural technology extend well beyond the confines of the agricultural sector. Backward linkages may be created to industry to supply inputs associated with the use of the new technology. In the case of the opportunities for using plastics in agriculture, the potential opportunities that could be created through backward linkage to the plastics transformation industry are important considerations.

Similarly, the additional agricultural output anticipated from commercial and semi-subsistence agriculturalists may offer opportunities for the creation of forward linkages. Additional opportunities in the processing and distribution of agricultural products could be expected.

The extent to which these effects [both direct and indirect] occur depends upon decisions taken by agriculturalists, industry, and government. This paper focuses primarily on the decisions of agricult ralists to adopt or not to adopt agricultural plastics technologies. The paper describes a method that can be applied to analyze the effect of alternative technologies on agricultural production and farm income. It is important to recognize that these factors [i.e., production and farm income] are not the only factors that bear upon agriculturalists' decisions to use or not to use a given technology. Other motivations such as effects on family nutrition, conservation, effects on social status, perceived risks associated with use of the new technology, education, age, land tenure form, parcel size, and a host of other factors have been found to be relevant factors influencing agricultural technology adoption decisions.

Nonetheless, it is useful to focus on production and income in an initial analysis as a first step for two reasons. First, these factors relate importantly to national and regional development objectives, and thus have some bearing on decisions to undertake projects and or or programs to facilitate the use of agricultural plastics. Second, agriculturalists are quite responsive to these stimuli.

2. The model

As noted above, the model developed here assumes that agriculturalists are motivated by economic considerations. In the case of commercial and semi-subsistance agriculturalists, this translates into maximizing farm income, subject to resource constraints. In the case of subsistence agriculturalists, this translates into minimizing production costs subject to producing the necessary amount of food required to meet family needs, again given some constraints [e.g., amount of family labor available for agricultural activities].

The basic idea behind the model developed below is quite simple. The givens of the model are a set of parcels of land, each distinguished by yields that could be achieved in a variety of crops using a variety of alternative cultivation technologies, and by costs of cultivation of each of these crops on each of the parcels under alternative technologies. Given crop prices, the model finds the cropping pattern that maximizes agricultural income, subject to certain constraints. This is an approximation of the pattern of land allocation that would emerge if agriculturalists made their decisions primarily on the basis of economic considerations.

a. Notation

To begin, let us adopt the following notation.

i = 1,...,Nc; index of crops

j = 1,...,Np; index of land parcels

k = 1,...,Nt; index of technologies

Y(ijk) = yield of ith crop on jth parcel using kth technology

C(ijk) = production cost of ith crop on jth parcel using kth technology

P(i) = farm price of ith crop

A(ijk) = fraction of jth parcel current planted in ith crop using kth technology

M(ijk) = maximum potential fraction of jth parcel in ith crop using kth technology

I(ijk) = indicator variable, fraction of jth parcel in ith crop using kth technology

R(ijk) = plastics requirement on jth parcel for ith crop using kth technology

b. Intermediate expressions

It will facilitate subsequent discussion of the model if certain intermediate expressions are first developed. To this end, note the following expressions.

P(i)Y(ijk)-C(ijk) = profit if jth parcel is planted in ith crop using technology k

D(ijk){P(i)Y(ijk)-C(ijk)}= profit if fraction D(ijk) of parcel j is planted in crop i using technology k

A(ijk) = A(ij.), current fraction of parcel j in crop i

A(ijk){P(i)Y(ijk)-C(ijk)} = farm income under current cropping pattern

D(ijk){P(i)Y(ijk)-C(ijk)} = farm income under cropping pattern D(ijk)

D(ijk) = 1, for all j; i.e., at most 100 percent of any parcel may be allocated

D(ijk)R(ijk) = plastics requirement

With the notation and intermediate expressions developed above, and some assumptions to discussed, it is relatively straightforward to complete the specification of the model.

c. Formulation of the model

As noted above, the basic formulation of the model calculates the allocation of land and choice of technology that would result in maximum farm income. Alternative formulations that reflect other objectives are discussed briefly below.

In terms of the notation developed above, total farm income for a region resulting from selection of a cropping pattern and technology may be found by solving the following problem for the D(ijk):

Maximize: D(ijk){P(i)Y(ijk) - C(ijk)}

(1)

Subject to: D(ijk) = 1
D(ijk) = 0 for all i, j, and k.

This problem has the form of the well-known Assignment Problem. The computer programs for finding the solution of this problem are discussed in an appendix to this chapter.

d. Alternative formulations

It is a relatively easy matter to see how the above formulation in Equation (1) could be extended to encompass other objectives. For example, the choices of subsistence agriculturalists might be modeled by assuming that their objective is minimizing costs subject to achieving a level of food production sufficient to meet family needs. In like manner, other objectives and/or constraints could be accomodated. For example, one might also wish to explore the effect of crop and technology choices on the variability of farm income or farm production, and hence the risk associated with agricultural activity.

The above formulation of the model can also be easily modified to incorporate multiple cropping of the same area during a single crop year, and crop rotations over several years. In such a reformulation, each alternative cropping pattern constitutes a 'crop' in the formulation presented in B.2.c above.

Another modification that is relatively easy to make is to constrain the amount of land area planted in any given crop. This might be done, for example, to reflect constraints on the capacity of the distribution system to handle farm output, or as a crude adjustment to reflect farmers' efforts to mitigate risks. The computer program developed to implement this model (see appendix) provide for the easy inclusion of constraints on crop area.

C. An Analysis of La Laguna

1. Introduction

To illustrate the application of the model described above, an example analysis of the La Laguna region has been carried out. Using maps prepared by DIGETENAL at a scale of 1:1,000,000, the region was divided into cells of 2,500 hectares. Data were collected for each cell on soil type, texture, conductivity, and presence or absence of irrigation. These data showed that there are 26 different types of parcels of land in the La Laguna region when distinguished according to the above-mentioned characteristics.

Sixteen (16) different crops were included in the analysis, including both major and minor crops (in terms of land area) in the region. Cost and price conditions roughly representative of July 31, 1982, were assumed in the analysis. In the results reported here, the area planted in each crop was constrained to be approximately the same as the corresponding area planted during the 1980/81 crop year.

Estimates were made by CIAA's agronomists of production cost and yield of each crop on each type of parcel. These estimates were supplied as input to the model, in a form described in the Appendix.

Tables 1-6 below illustrate the output obtained from the model. In the particular analysis reported in Tables 1-6, it is postulated that a mulch technology exists which costs $ 25,000 MN per hectare to apply irrespective of the type of crop or land on which applied, requires 400 kilograms of plastic per hectare, and results in a yield increment of 50% for all of the crops considered in the analysis.

Table 1

la lasuna, tecnolosia presente y acol $25000/ha, rendimiento=1.5x ,acol=.4t/ha

cultivo	costo promedio* ($/ha)	rendimiento** (t/ha)	precio rural ($/t)	area maxima (%)	area minima (%)
alpiste	9199.00	1.00	7300.00	0.04	0.02
avena(forr)	17128.90	38.01	350.00	5.30	3.30
cartamo	10131.90	1.87	5450.00	6.00	4.00
frijol	17653.30	1.75	17000.00	3.80	1.80
maiz	13336.10	2.73	5500.00	11.40	9.40
maiz(forr)	14696.20	37.15	380.00	6.00	4.00
melon	19810.30	24.33	3000.00	3.30	1.30
sandia	18508.10	27.79	2900.00	2.10	0.10
sorgo	15333.30	3.56	3650.00	4.00	2.00
sorgo(forr)	15326.30	32.60	450.00	1.90	0.90
tomate	26716.00	24.25	7500.00	1.10	0.10
algodon	26667.50	2.50	15800.00	42.10	40.10
trigo	17171.70	2.56	3750.00	2.30	0.30
alfalfa	47167.00	68.23	400.00	13.20	11.20
nogal	25883.40	1.08	60000.00	3.90	1.90
vid	41855.20	10.71	3550.00	7.00	5.00

*no incluye costo de la tierra

**promedio

Table 2

la laguna, tecnologia presente y acol $25000/ha, rendimiento=1.5% ,acol=.4t/ha

resultados sumarizados

produccion (mil toneladas)

alpiste	0.02
avena(forr)	87.92
cartamo	5.46
frijol	4.73
maiz	18.19
maiz(forr)	69.87
melon	147.62
sandia	107.27
sorgo	3.35
sorgo(forr)	12.95
tomate	47.24
algodon	123.77
trigo	0.18
alfalfa	1007.88
nogal	7.47
vid	65.57

Table 3

la laguna, tecnologia presente y acol $25000/ha, rendimiento=1.5x ,acol=.4t/ha

ingreso total (mil pesos)

alpiste	10.70
avena(forr)	-121.83
cartamo	2889.11
frijol	40495.09
maiz	-17924.02
maiz(forr)	-28724.97
melon	303416.34
sandia	224968.75
sorgo	-16623.97
sorgo(forr)	-6074.51
tomate	300549.63
algodon	897575.81
trigo	-1642.75
alfalfa	-94549.77
nogal	26103[illegible].22
vid	35620.15

ingreso total = 1900896.13

Table 4

la laguna, tecnologia presente y acol $25000/ha, rendimiento=1.5x ,acol=.4t/ha

superficie total (mil hectareas)

alpiste	0.02
avena(forr)	3.10
cartamo	3.77
frijol	2.26
maiz	8.84
maiz(forr)	3.76
melon	3.11
sandia	1.98
sorgo	1.88
sorgo(forr)	0.85
tomate	1.04
algodon	39.67
trigo	0.28
alfalfa	10.55
nogal	3.68
vid	4.71

superficie total = 89.50

Table 5

la laguna, tecnologia presente y acol $25000/ha, rendimiento=1.5x ,acol=.4t/ha

consumo de los plasticos (mil toneladas)

alpiste	0.
avena(forr)	0.
cartamo	0.
frijol	0.
maiz	0.
maiz(forr)	0.
melon	1.24
sandia	0.79
sorgo	0.
sorgo(forr)	0.
tomate	0.42
algodon	0.
trigo	0.
alfalfa	0.
nogal	1.47
vid	0.

consumo total = 3.92

Table 6

la laguna, tecnologia presente y acol $25000/ha, rendimiento=1.5x ,acol=.4t/ha

resultados para parcelas de tipo 1

tipo de suelo = xerosol haplico   agua = riego
fase quimica = ausente   textura = media

cultivo	tecnologia	costo de produccion ($/ha)	margen ($/ha)	superficie (mil ha)	rendimiento (t/ha)	produccion (mil ton)	ingreso (mil $)	uso de plasticos (mil ton)
alpiste	presente	9199.00	-804.00	0.	1.15	0.	0.	0.
alpiste	acolchad	34199.00	-21606.50	0.	1.73	0.	0.	0.
avena(forr)	presente	17128.90	-1829.47	0.	43.71	0.	0.	0.
avena(forr)	acolchad	42128.90	-19179.76	0.	65.57	0.	0.	0.
cartamo	presente	10131.90	1817.66	0.	2.19	0.	0.	0.
cartamo	acolchad	35131.90	-17207.56	0.	3.29	0.	0.	0.
frijol	presente	17653.30	17944.70	2.26	2.09	4.73	40495.09	0.
frijol	acolchad	42653.30	10743.70	0.	3.14	0.	0.	0.
maiz	presente	13336.10	6212.00	0.	3.55	0.	0.	0.
maiz	acolchad	38336.10	-9013.95	0.	5.33	0.	0.	0.
maiz(forr)	presente	14696.20	3657.38	0.	48.30	0.	0.	0.
maiz(forr)	acolchad	39696.20	-12165.83	0.	72.45	0.	0.	0.
melon	presente	19810.30	75061.10	0.	31.62	0.	0.	0.
melon	acolchad	44810.30	97496.80	2.45	47.44	116.26	238959.94	0.98
sandia	presente	18508.10	86260.20	0.	36.13	0.	0.	0.
sandia	acolchad	43508.10	113644.34	1.98	54.19	107.27	224968.75	0.79
sorgo	presente	15333.30	900.08	0.	4.45	0.	0.	0.
sorgo	acolchad	40333.30	-15983.24	0.	6.67	0.	0.	0.
sorgo(forr)	presente	15326.30	3008.95	0.	40.75	0.	0.	0.
sorgo(forr)	acolchad	40326.30	-12823.42	0.	61.12	0.	0.	0.
tomate	presente	26716.00	191534.00	0.	29.10	0.	0.	0.
tomate	acolchad	51716.00	275659.00	0.	43.65	0.	0.	0.
algodon	presente	26667.50	22707.50	18.47	3.13	57.73	419455.31	0.
algodon	acolchad	51667.50	22395.00	0.	4.69	0.	0.	0.
trigo	presente	17171.70	-5647.20	0.	3.07	0.	0.	0.
trigo	acolchad	42171.70	-24834.95	0.	4.61	0.	0.	0.
alfalfa	presente	47167.00	-8960.44	8.35	95.52	797.74	-74836.80	0.
alfalfa	acolchad	72167.00	-14857.16	0.	143.27	0.	0.	0.
nogal	presente	25883.40	55341.60	0.	1.35	0.	0.	0.
nogal	acolchad	50883.40	70954.11	0.68	2.03	1.38	48169.89	0.27
vid	presente	41855.20	7562.22	3.61	13.92	50.26	27301.71	0.
vid	acolchad	66855.20	7270.93	0.	20.88	0.	0.	0.

Table 1 reports in summary form the main inputs of the model. The inputs reported in this table are average production cost (exclusive of the cost of land), average yield, the average farm price, and the maximum and minimum fractions of the cultivable land area of the region that may be planted in each crop.

Table 2 reports the total production of each crop in thousands of metric tons. For example, in the analysis reported in Table 2, the production of beans is 4730 tons when land is allocated and technology is chosen so as to maximize the contribution to farm income.

Table 3 reports the estimated contribution to farm income obtained from each crop. Note that in the results reported in Table 3, several of the crops are estimated to produce a negative contribution to farm income. This reflects the assumed production costs, yields, prices and restrictions of crop areas. A total contribution to farm income of approximately $ 1.9 billion MN is estimated.

Table 4 reports the allocation of land area to crops. As can be seen, the cropped area occupies a total of approximately 90 thousand hectares.

Table 5 reports estimated usage of plastics by crop. In the case of the analysis reported, it is estimated that approximately 3920 tons of plastic would be used in the La Laguna Region. Most of this would be used in the production of nogal.

Table 6 illustrates the detailed output produced by the model for each parcel type included in the analysis. This table reports the characteristics of the parcel, the cost of production of each crop (exclusive of the cost of land) on each type of parcel using each of the available technologies, the contribution margin that would be earned with each crop-parcel-technology combination, the crop area devoted to each crop-technology combination, yield of each crop-technology combination, production, income, and plastics consumption.

2. Parameter ranges

Using the basic agronomic data and estimates supplied by CIGA's agronomists, the model described above can be used to study the demand for mulch, production, and farm income as a function of yield increment and the cost of mulch. This section presents the results of an analysis in which yield increments in the range of from 10 percent to 50 percent, and costs of mulch of between $7300 MN and $25000 MN were explored. In this analysis, crop areas were constrained to lie between the upper and lower bounds reported in Table 1 above. The analysis thus reflects the demand for plastics that might be anticipated under roughly the present cropping pattern.

3. Analysis

Tables 7 through 9 report estimated demand for mulch in La Laguna at three different levels of assumed yield increment and cost of mulch. Table 7 reports estimated demand assuming a yield increment of 50 percent at three different levels of cost per hectare of mulch, $7500 MN, $15000 MN, and $25000 MN. As can be seen, demand is greatest at a cost of $7500 MN (i.e. approximately 27328 tons) and is least at a cost of $25000 MN (i.e. approximately 3920 tons).

A comparison of the results reported in Tables 8 and 9 with those in Table 7 reveals that demand is lower at lower levels of assumed yield increments. This is precisely what one would expect. Table 9 shows that at the lowest assumed yield increment and highest mulch cost (i.e. a 10 percent yield increment and cost per hectare of mulch of $25000 MN), no mulch would be used according to the model.

Table 7

Demand for Mulch in La Laguna
by Crop
(tons/yr)
(Assumed Yield Increment=50%)

Crop	Cost of Mulch per Hectare		
	$ 7500 MN	$15000 MN	$25000 MN
Alpiste	0.0	0.0	0.0
Avena (forr)	0.0	0.0	0.0
Cartamo	0.0	0.0	0.0
Frijol	1440.0	896.0	0.0
Maiz	0.0	0.0	0.0
Maiz (forr)	0.0	0.0	0.0
Melon	1248.0	1248.0	1248.0
Sandia	784.0	784.0	784.0
Sorgo	0.0	0.0	0.0
Sorgo (forr)	0.0	0.0	0.0
Tomate	416.0	416.0	416.0
Algodon	15872.0	15872.0	0.0
Trigo	0.0	0.0	0.0
Alfalfa	4224.0	4224.0	0.0
Nogal	1472.0	1472.0	1472.0
Vid	1888.0	1888.0	0.0
TOTAL	27328.0	26800.0	3920.0

Assumes mulch = 0.4 tons/ha-yr.

Table 8

Demand for Mulch in La Laguna
by Crop
(tons/yr)
(Assumed Yield Increment=30%)

Crop	Cost of Mulch per Hectare		
	$ 7500 MN	$15000 MN	$25000 MN
Alpiste	0.0	0.0	0.0
Avena (forr)	0.0	0.0	0.0
Cartamo	0.0	0.0	0.0
Frijol	896.0	0.0	0.0
Maiz	0.	0.0	0.0
Maiz (forr)	0.0	0.0	0.0
Melon	1248.0	1248.0	1248.0
Sandia	784.0	784.0	784.0
Sorgo	0.0	0.0	0.0
Sorgo (forr)	0.0	0.0	0.0
Tomate	416.0	416.0	416.0
Algodon	15872.0	0.0	0.0
Trigo	0.0	0.0	0.0
Alfalfa	4224.0	0.0	0.0
Nogal	1472.0	1472.0	0.0
Vid	1888.0	0.0	0.0
TOTAL	26800.0	3920.0	2448.0

Assumes mulch = 0.4 tons/ha-yr.

Alpiste	0.0	0.0	0.0
Avena (forr)	0.0	0.0	0.0
Cartamo	0.0	0.0	0.0
Frijol	0.0	0.0	0.0
Maiz	0.0	0.0	0.0
Maiz (forr)	0.0	0.0	0.0
Melon	1248.0	0.0	0.0
Sandia	784.0	0.0	0.0
Sorgo	0.0	0.0	0.0
Sorgo (forr)	0.0	0.0	0.0
Tomate	416.0	416.0	0.0
Algodon	0.0	0.0	0.0
Trigo	0.0	0.0	0.0
Alfalfa	4224.0	0.0	0.0
Nogal	1472.0	0.0	0.0
Vid	0.0	0.0	0.0
TOTAL	3920.0	416.0	0.0

==

Assumes mulch = 0.4 tons/ha-yr.

Table 9

Demand for Mulch in La Laguna
by Crop
(tons/yr)
(Assumed Yield Increment=10%)

Crop	Cost of Mulch per Hectare		
	$ 7500 MN	$15000 MN	$25000 MN

4. Discussion

As of July 31, 1982, the price in Mexico of black polyethylene film suitable for mulch was approximately $60 MN per kilogram. At an assumed rate of application of 400 kilograms per hectare per year, this translates into an annual cost per hectare under mulch of $24000. The estimated cost of $25000 MN per hectare thus probably most nearly approximates the cost of mulch prior to the most recent devaluation. Costs significanly lower than this level (for example, costs of between $7500 MN and $15000 MN could be anticipated only if plastics usage were rather heavily subsidized or if there were some dramatic reduction in the cost of mulch per hectare due to technological improvements).

It is somewhat more difficult to say which of the alternative yield increments most nearly approximates the productivity increase that would be acheived via application of mulches in La Laguna under field conditions. Experimental results in Mexico, particularly those reported by CIGA's agronomists (see Chapter 6 of this report) indicate yield increases of more than 100 percent in some cases. Nonetheless, there is no experimental evidence for many of the crops considered in the analysis, and there is relatively little experimental evidence obtained from large plots under the range of soil and climate conditions that characterize Mexican agriculture.

While the matter most certainly warrants further study, experience indicates that yield increments achieved under normal field conditions are but a fraction of those achieved under experimental conditions. Pending further study, it is prudent to assume that increases might be on the order of 10 percent to 30 percent.

If one accepts these arguments, one would be inclined to the view that the demand for mulches in La Laguna would fall toward the lower end of the range spanned by the estimates presented in Tables 7 through 9. One would probably also be inclined to the view that mulches would be used primarily in the production of high-valued crops such as melon, sandia, and tomate. This view would probably be strengthened by the observation that, in countries in which mulches are currently in widespread use, the predominant use is in the production of high-valued crops like those mentioned above.

Inspection of the back-up tables for individual types of land parcels (like Table 6 above) shows that under the range of assumptions explored in this analysis, plastic mulches are never used under rainfed conditions. Even assuming yield increments of 50 percent for all crops on rainfed parcels and a cost of mulch of $ 7500 per hectare per year, it is not economical to use mulch on rainfed parcels for any of the crops in the model.

D. A Water Stress - Crop Yield Model

1. Introduction

The yield increments used in the linear programming analysis discussed in Sections B and C above are based on judgemental extrapolation from experimental results and field experience in other countries. The author decided to develop an agro-climatic model to enable the scientific calculation of yield increments and/or reduced water requirements (see the discussion in Chapter 4). These calculated values can then be used as a source of input information for the linear programming model. In addition, the agro-climatic model can be used in a Monte Carlo simulation mode using data on the probability distribution of effective precipitation to study the effect of the use of mulches on the probability distribution of crop yields, and hence the probability of crop failure (see the discussion in Chapter 4 on the importance of preventing crop failure).

To use the model presented in this section to evaluate the effect of mulch on crop yield and/or water requirement, measurements are required of the effect of mulch on potential and actual evapotranspiration. The author understands that such measurements are now being made by CIQA's agronomists.

The model developed by the author is a computerized version of the calculations explained in 'Efectos del Agua Sobre El Rendimiento de los Cultivos', by J. Doorenbos and A.H. Kassam, FAO Study: Irrigation and Drainage Number 33, FAO 1979. Due to a computer malfunction during the period the model was developed, inadequate time was available to document the model. The model is interactive, however, and a diligent individual should be able to use it after reading the Doorenbos and Kassam publication, perhaps with occasional consultation of the source program listing. To aid in the use of the model, an example model use session is reproduced and commented upon in the following section.

2. An example session

The session begins with the analyst invoking the object code of the model. In the author's current file, the object code of the model is named 'a.out'. After typing 'a.out' at the terminal the model prompts the user to input a series of parameters characterizing the climate, the soil, and the crop. The prompts, illustrative responses, and results of the model run are shown in Figure 2.

Figure 2

```
crop numbers


------------------------------------------------------------
1.0   banana                    9.0   guisante, fresco
1.1    subtropical             10.0   pimentero, fresca
1.2    tropical                11.0   patata
2.0   frijol                   12.0   arroz
2.1    verde                   13.0   cartamo
2.2    seca                    14.0   sorgo
3.0   col                      15.0   soja
4.0   algodon                  16.0   remolcha azucar
5.0   vid                      17.0   cana de azucar
6.0   cacahuete                18.0   girasol
7.0   maiz                     19.0   tabaco
7.1    dulce                   20.0   tomate
7.2    grano                   21.0   sandia
8.0   cebolla                  22.0   trigo
8.1    seca                    23.0   alfalfa
8.2    verde
------------------------------------------------------------

  enter crop number,
2.1
  entry correct? enter '1 return' if so, '0 return' if not
1
  enter altitude of site,m
500
  entry correct? enter '1 return' if so, '0 return' if not
1
  enter latitude of site, degrees
25
  entry correct? enter '1 return' if so, '0 return' if not
1
  enter mean monthly temperatures, degrees celsius
15
16
17
20
25
30
35
30
20
18
15
15
  entry correct? enter '1 return' if so, '0 return' if not
1
```

Figure 2 (cont'd)

```
  enter mean daytime windspeed, m/sec, by month
2
3
4
4
3
3
2
2
2
2
2
2
  entry correct? enter '1 return' if so, '0 return' if not
1
  enter mean nighttime windspeed, m/sec, by month
1
1
1
1
1
1
1
1
1
1
1
1
  entry correct? enter '1 return' if so, '0 return' if not
1
  enter maximum yield of this crop on this site, kg
500
  entry correct? enter '1 return' if so, '0 return' if not
1
  enter monthly effective precipitation, mm
30
40
50
50
40
30
30
30
20
20
20
20
  entry correct? enter '1 return' if so, '0 return' if not
1
```

Figure 2 (cont'd)

```
 enter depth of root zone, m
.5
 entry correct? enter '1 return' if so, '0 return' if not
1
 enter available soil moisture at this site, mm/m
200
 entry correct? enter '1 return' if so, '0 return' if not
1
 enter initial depth of available water, mm
100
 entry correct? enter '1 return' if so, '0 return' if not
1
 enter monthly relative humidity, percent
50
50
50
50
50
50
50
50
50
50
50
50
 entry correct? enter '1 return' if so, '0 return' if not
1
 enter monthly relative humidity maxima, percent
65
65
65
65
65
65
65
65
65
65
65
65
 entry correct? enter '1 return' if so, '0 return' if not
1
 enter monthly actual hours of sunshine
8
8
8
8
8
8
8
8
```

Figure 2 (cont'd)

```
0
3
3
3
  entry correct? enter '1 return' if so, '0 return' if not
1
  enter 5 crop factors for maximum evapotranspiration (kc)
.3,.4,.5,.4,.3
  entry correct? enter '1 return' if so, '0 return' if not
1
  enter 5 crop factors for yield (ky)
.5,1.1,.5,.5,.5
  entry correct? enter '1 return' if so, '0 return' if not
1
  enter matrix of days in 5 crop stages by month
0.,0.,0.,0.,0.,
0.,0.,0.,0.,0.,
15.,0.,0.,0.,0.,
0.,30.,0.,0.,0.,
0.,0.,52.,0.,0.,
0.,0.,0.,30.,0.,
0.,0.,0.,0.,15.,
0.,0.,0.,0.,0.,
0.,0.,0.,0.,0.,
0.,0.,0.,0.,0.,
0.,0.,0.,0.,0.,
0.,0.,0.,0.,0.,
  entry correct? enter '1 return' if so, '0 return' if not
1
              9.01e+01        1.61e+01
              2.13e+02        5.00e+01
              2.22e+02        4.00e+01
              2.48e+02        3.00e+01
              1.98e+02        1.50e+01
              4.10e-01        5.00e-01        1.61e+01        9.01e+01
              8.42e-01        1.10e+00        5.00e+01        2.13e+02
              4.10e-01        5.00e-01        4.00e+01        2.22e+02
              4.40e-01        5.00e-01        3.00e+01        2.48e+02
              4.62e-01        5.00e-01        1.50e+01        1.98e+02
              5.90e-01
              4.10e-01
              9.33e-02
              8.42e-01
              5.51e-02
              8.42e-01
              3.09e-02
              8.42e-01
              1.66e-02
              8.42e-01
```

Figure 2 (cont'd)

input data summary

crop = 2.10 maximum yield (kg/ha) = 500.00 latitude (degrees) = 25.0
altitude (meters) = 500.00 root zone (meters) = .50 available soil moisture (mm/m) =200.0
initial available moisture (mm) = 100.0

monthly data (mean)/

temperature (celsius)	precipitation (mm)	max. humidity (%)	humidity (%)	daytime wind (m/sec)	nightime wind (m/sec)	sunshine (hr/day)
15.00	30.00	65.00	50.00	2.00	1.00	8.00
16.00	40.00	65.00	50.00	3.00	1.00	8.00
17.00	50.00	65.00	50.00	4.00	1.00	8.00
20.00	50.00	65.00	50.00	4.00	1.00	8.00
25.00	40.00	65.00	50.00	3.00	1.00	8.00
30.00	30.00	65.00	50.00	3.00	1.00	8.00
35.00	30.00	65.00	50.00	2.00	1.00	8.00
30.00	30.00	65.00	50.00	2.00	1.00	8.00
20.00	20.00	65.00	50.00	2.00	1.00	8.00
18.00	20.00	65.00	50.00	2.00	1.00	8.00
15.00	20.00	65.00	50.00	2.00	1.00	8.00
15.00	20.00	65.00	50.00	2.00	1.00	8.00

crop stages, by month (duration of stage in days)

	month											
stage	1	2	3	4	5	6	7	8	9	10	11	12
1	0.	0.	15.00	0.	0.	0.	0.	0.	0.	0.	0.	0.
2	0.	0.	0.	30.00	0.	0.	0.	0.	0.	0.	0.	0.
3	0.	0.	0.	0.	30.00	0.	0.	0.	0.	0.	0.	0.
4	0.	0.	0.	0.	0.	30.00	0.	0.	0.	0.	0.	0.
5	0.	0.	0.	0.	0.	0.	15.00	0.	0.	0.	0.	0.

Figure 2 (cont'd)

results of the analysis

maximum yield (kg/ha) = 500.00
maximum actual yield (kg/ha) = 79.13
minimum actual yield (kg/ha) = 8.30

maximum evapotranspiration	actual evapotranspiration/
9.81e+01	9.79e+01
1.33e+02	8.98e+01
1.80e+02	3.23e+01
2.13e+02	5.00e+01
2.22e+02	4.00e+01
2.46e+02	3.00e+01
3.96e+02	3.00e+01
2.09e+02	3.00e+01
1.57e+02	2.00e+01
1.31e+02	2.00e+01
1.03e+02	2.00e+01
9.32e+01	2.00e+01

Figure 2 (cont'd)

intermediate results

ea(k)	ha(k)	n(k)	ed(k)	fed(k	fann
1.700000e+01	1.000000e+01	1.070000e+01	8.500000e+00	2.117191e-01	7.728972e-01
1.820000e+01	1.170000e+01	1.130000e+01	9.100000e+00	2.072687e-01	7.371681e-01
1.940000e+01	1.380000e+01	1.200000e+01	9.700000e+00	2.029628e-01	7.000000e-01
2.340000e+01	1.535000e+01	1.270000e+01	1.170000e+01	1.894968e-01	6.669291e-01
3.170000e+01	1.640000e+01	1.330000e+01	1.585000e+01	1.648269e-01	6.413534e-01
4.240000e+01	1.665000e+01	1.370000e+01	2.120000e+01	1.374088e-01	6.255475e-01
5.670000e+01	1.660000e+01	1.350000e+01	2.835000e+01	1.057232e-01	6.333333e-01
4.240000e+01	1.575000e+01	1.300000e+01	2.120000e+01	1.374088e-01	6.538461e-01
2.340000e+01	1.440000e+01	1.230000e+01	1.170000e+01	1.894968e-01	6.853659e-01
2.060000e+01	1.245000e+01	1.160000e+01	1.030000e+01	1.987681e-01	7.206897e-01
1.700000e+01	1.050000e+01	1.090000e+01	8.500000e+00	2.117191e-01	7.605505e-01
1.700000e+01	9.500000e+00	1.060000e+01	8.500000e+00	2.117191e-01	7.792453e-01

Figure 2 (cont'd)

intermediate results

tfta(	w(k)	fu(k)	rs(k)	rnl(k	rn(k)
6.250000e-01	6.350000e-01	6.072841e-01	6.238318e+00	2.233646e+00	2.445092e+00
6.400000e-01	6.500000e-01	7.229520e-01	7.066593e+00	2.109528e+00	3.191417e+00
6.500000e-01	6.600000e-01	8.532001e-01	8.050000e+00	1.989035e+00	4.040465e+00
6.900000e-01	7.000000e-01	8.736120e-01	8.672147e+00	1.845162e+00	4.658948e+00
7.400000e-01	7.500000e-01	7.618321e-01	9.032331e+00	1.654378e+00	5.119851e+00
7.900000e-01	7.900000e-01	7.696080e-01	9.023315e+00	1.418269e+00	5.349592e+00
8.250000e-01	8.250000e-01	6.345001e-01	9.068519e+00	1.168418e+00	5.632973e+00
7.800000e-01	7.900000e-01	6.296400e-01	8.783654e+00	1.432430e+00	5.105311e+00
6.900000e-01	7.000000e-01	6.228360e-01	8.282927e+00	1.896170e+00	4.316025e+00
6.600000e-01	6.700000e-01	6.160320e-01	7.405604e+00	2.034356e+00	3.519847e+00
6.250000e-01	6.350000e-01	6.092281e-01	6.478211e+00	2.197965e+00	2.660674e+00
6.250000e-01	1.000000e+02	6.063120e-01	5.959906e+00	2.251992e+00	2.217937e+00

Figure 2 (cont'd)

intermediate results

ru(k)	c(k)	eto(k	p(k)	wa(k)	esi(k
2.000000e+00	9.518666e-01	6.023247e+00	6.728629e-01	3.211994e+01	9.913141e-01
3.000000e+00	1.011257e+00	1.824865e+00	5.573707e-01	-1.770261e+01	2.097843e-01
4.000000e+00	1.094769e+00	3.349730e+00	4.498568e-01	0. e+00	-1.260848e-01
4.000000e+00	1.121843e+00	4.624326e+00	4.200698e-01	0. e+00	-3.753365e-02
3.000000e+00	1.030718e+00	5.698922e+00	4.043867e-01	0. e+00	-8.796831e-02
3.000000e+00	1.000529e+00	6.673517e+00	3.692820e-01	0. e+00	-1.337240e-01
2.000000e+00	1.025863e+00	7.996718e+00	2.451354e-01	0. e+00	-1.149120e-01
2.000000e+00	1.019271e+00	6.968096e+00	4.257976e-01	0. e+00	-1.311704e-01
2.000000e+00	1.006011e+00	5.238672e+00	4.880664e-01	0. e+00	-1.984814e-01
2.000000e+00	9.827780e-01	4.375515e+00	5.624484e-01	0. e+00	-1.609704e-01
2.000000e+00	9.582193e-01	3.430110e+00	6.569890e-01	0. e+00	-1.389761e-01
2.000000e+00	9.447240e-01	3.107645e+00	6.892355e-01	0. e+00	-1.158086e-01

%

After the user has answered all of the queries (the last query calls for the user to specify the number of days by month that the crop spends in each of the five developmental stages- each row of the response corresponds to a month, and each entry with a row to a stage), the computer takes over and prints out the results of the analysis. The numbers printed out immediately after the last query are numbers printed out for diagnostic purposes and will be removed from the next version of the program.

The first page of model output summarizes the input data supplied by the user. The next page of the output reports estimated yield and calculated maximum potential and actual evapotranspiration. Two estimated actual yields are reported. The first (labelled 'maximum actual yield') calculates actual yield assuming that the yield loss due to water stress is equal to the maximum of the yield losses at any of the 5 stages of crop development. The second (labelled 'minimum actual yield') calculates actual yield assuming that the yield loss due to water stress is equal to the product of the yield losses at the 5 stages of crop development. For example, if the yield loss during the first stage is 20 percent and during the fifth stage is 20 percent, then calculated minimum actual yield is 64 percent of maximum yield (i.e. .8 x .8 x 100).

The remaining pages of output print out intermediate results. These are included for diagnostic purposes and will be deleted from the final version of the program. The names of most of the columns correspond roughly to variable names in the publication by Doorenbos and Kassam. Each row corresponds to the value of the corresponding for a month.

3. Comments on the program

The source program for the model is available in the author's directory and is named 'try2.f'. This program involves looking up data in tables and interpolating as an element of the calculations. It may happen that some of the data input into the model falls out of the range of the tables included. When this happens, the program terminates and prints out 'OUT OF BOUNDS AT NDCG = n'. The user may find the problem by examining the source listing in the appendix and finding the place at which the branching occurred.

Due to a computer malfunction, it was not possible to conduct all of the tests of the program that would be desirable and to 'clean it up'. The program is therefore best viewed as experimental and results from its use should be subjected to thorough inspection and manual verification.

APPENDIX: INSTRUCTIONS FOR THE USE OF AGMOD, SHOPT, AND SHOUT2

A.1 INTRODUCTION

AGMOD prepares data in a form suitable for ASZITA's LP package, OPTIMIZ. For ease in merging the output files of the programs, OPTIMIZ has been changed slightly to produce only the output needed for subsequent analysis. The changed version of OPTIMIZ is called SHOPT.

AGMOD prepares data for the solution of the assignment problem stated in Section 3.0 of the body of this paper. SHOUT2 takes a concatenated file composed of the AGMOD input file and a shortened version of the SHOPT output file and prepares summary tables for the region under study and for each type of land parcel in the region.

A.2 INPUTS TO AGMOD

The input file required to operate AGMOD is as follows:

LINE	FORMAT	CONTENT
1	20A4	Any identification desired
2	4I5	Options: nopt(1)=1 if technology costs independent of parcel type, 0 otherwise; nopt(2)=1 if there is an upper bound on fraction of region that may be planted in one or more crop, 0 otherwise; nopt(3)=1 if there is a lower bound on fraction of region that may be planted in one or more crop, 0 otherwise; nopt(4)=1 if yield increment is independent of parcel type
3	3I3	Np = # of parcels, Nc = # of crops, Nt = # of technologies
4,4+np	4(4a4)	Parcel characteristics, in fields of 16;

		suelo=soil type; agua=source of water; fase=chemical phase; text=texture
5,5+nt	2a4	Names of technologies
6,6+nt	10F7.0	If nopt(1)=1, costec(k,i)=cost of technology for each crop [Rows correspond to technologies; columns correspond to crops]; each record contains costs for all crops for a given technology
7,7+nt	10F7.0	If nopt(1)=1, pran(k,i)=plastics requirement for technology and crop [Rows correspond to technologies, columns to crops]; each record contains plastics requirements for all crops for a given technology.
8	16F5.0	Area [1000 hectares] of each plot
9	16F5.0	If nopt(2)=1, maximum fraction of total area in each crop
10	16F5.0	If nopt(3)=1, minimum fraction of total area in each crop
11	10F7.0	Farm prices of crops
12	10F7.0	Mean yield of crops, tons/ha.
14,14+nt	10F7.0	If nopt(4)=1, atec(k,i)=yield of ith crop using kth technology relative to mean yield of ith crop [Rows correspond to technologies, columns to crops]; each record contains yield factors for all for a given technology
15, 15+np+nt	3a4;10F7.0	Name of crop; relative yield factors for that crop [Rows correspond to parcels; columns correspond to technologies]

REPEAT ABOVE SET OF LINES FOR EACH CROP

16	10F7.0	Average production cost for each crop
17, 17+np+nt	3a4;16F5.0	Name of crop;relative production cost for that crop [Rows correspond to parcels; columns correspond to technologies]

REPEAT ABOVE SET OF LINES FOR EACH CROP

==

Of the inputs, only the relative yield factors and relative cost factors may require explanation. These factors relate the yield for a specific crop, using a specific technology on a specific type of land parcel, to the mean yield for the crop. For example, let us suppose that the yield of maiz on parcel type 1 using plastic mulch technology is 60 percent higher than the mean yield. Then the relative yield factor for parcel type 1 with mulch technology would be '1.6'. Or, suppose that yields on parcel type 8 with current technology are estimated to be only 70 percent of average yields. Then the relative yield factor for parcel type 8 with current technology would be '0.7'.

Relative cost factors are defined similarly. Suppose, for example, that production cost exclusive of land costs (per hectare) of maiz on parcels of type 6 with current technology were 60 percent of average production costs. Then the relative cost factor for this crop, technology, and parcel type would be '0.6'. An examination of the example input listing presented in Section A.4 should help to clarify the usage of these factors.

A.3 USAGE

A source code for AGMOD is available in the directory /usr/asza/em/itec/randers. The filename of the code is 'agmod.f'. The user compiles agmod.f, uses the file constructed as instructed in Section A.2 above as input, and obtains an output file suitable for use as an input file for executing SHOPT. The user then concatenates the AGMOD input file and the SHOPT output file and inputs the concatenated file to SHOUT2. Source codes for SHOPT and SHOUT2 (named respectively shopt.f and shout2.f) are also available in the above-mentioned directory.

A.4 LISTINGS AND EXAMPLE

A complete set of listings for AGMOD, SHOPT, and SHOUT2, as well as the input file used to compute the results reported in Chapter 5 of the report are presented below. The instructions given below explain step by step how the models may be used on ASZA's computer system--ASZITA.

The use of the model is initiated by preparing an input file for AGMOD. An example input file, named 'laguna', is presented below. This file corresponds to the results reported in Section C.1, Tables 1-6, of Chapter 5.

The session is initiated by instructing the computer to process the input file into a form suitable for linear programming analysis. This is done by invoking the AGMOD object program (here named 'agmod.o) as follows:

```
agmod.o<laguna>output
```

The file output is in a form suitable for linear programming analysis using the program SHOPT. The appropriate command when the file "output" has been created by AGMOD is

```
shopt.o<output>result
```

When SHOPT has created result, the user concatenates the AGMOD input file and the SHOPT output file to create a new file. The relevant command is

```
cat laguna result>test
```

This command creates a file named "test" which is then used by SHOUT2 to construct tables reporting the results of the analysis. The relevant command to invoke SHOUT2 and produce tables of results is

```
shout2.o<test>testout
```

The results of the analysis are then contained in a file named "testout", which may be printed on a line printer using the command

```
lpr testout
```

APPENDIX: SOURCE LISTING FOR AGMOD

```
c     AGMOD Version 1
c     this program sets up the constraints
c     and objective function and other data
c     to assign agricultural land optimally.
c     output provides input to the lp package
c     optimize.
      dimension label(20),p(20),y(20),c(20),yr(30,6,20)
      dimension cr(30,6,20),a(70,1200),aw(30,6,20),ar(30)
      dimension ac(30,6,20),fi(30,6,20),fiv(3600),b(70)
      dimension armax(20),armin(20),arel(30)
      dimension crop(20,3),tech(20,2),costec(6,20),nopt(4)
      dimension atec(6,20),preq(6,20)
      dimension suelo(30,4),agua(30,4),fase(30,4),text(30,4)
c **********************************
c     read label
c **********************************
      read(5,1) label
    1 format(20a4)
c **********************************
      read(5,20) (nopt(l),l=1,4)
   20 format(4i5)
c **********************************
c     read np=no of parcels, nc=no of crops,
c     nt=no of technologies
c **********************************
      read(5,2) np,nc,nt
    2 format(3i5)
c **********************************
c     read parcel characteristics
c **********************************
      do 699 j=1,np
  699 read(5,69) (suelo(j,l),l=1,4),(agua(j,l),l=1,4),(fase(j,l),l
     .(text(j,l),l=1,4)
   69 format(4a4,4a4,4a4,4a4)
c **********************************
c     read technology names
c **********************************
```

```
      do 1600 k=1,nt
 1600 read(5,1601) (tech(k,j),j=1,2)
 1601 format(2a4)
c ***********************************
c read technology costs if cost independent of parcel type and crop
c ***********************************
      if(nopt(1).ne.1) go to 900
      do 9000 k=1,nt
 9000 read(5,3) (costec(k,i),i=1,nc)
c **********************************
c     read plastics requirements per hectare
c ***********************************
      do 9001 k=1,nt
 9001 read(5,3) (preq(k,i),i=1,nc)
c ***********************************
  900 continue
c *************************************
c     read areas [in hectares] of each parcel
c *************************************
      read(5,104) (ar(j), j=1,np)
  104 format(16f5.0)
      if (nopt(2).ne.1) go to 901
      do 8000 i=1,nc
      armax(i)=1.0
 8000 armin(i)=0.0
c **************************************
c     read restrictions on maximum area of each crop
c **************************************
      read(5,104) (armax(i), i=1,nc)
  901 continue
      if(nopt(3).ne.1) go to 902
c ***************************************
c read restrictions on minimum acreage of crops
c ***************************************
      read(5,104) (armin(i),i=1,nc)
  902 continue
c ***************************************
c     determine coefficients for area restrictions
c ***************************************
      sum=0.0
      do 1040 j=1,np
 1040 sum=sum+ar(j)
      do 1041 j=1,np
 1041 arel(j)=ar(j)/sum
c *******************************
c     read farm prices of crops
c **********************************
      read(5,3) (p(i),i=1,nc)
    3 format(10f7.0)
c ***********************************
c     read mean yields
c ***********************************
      read(5,3) (y(i),i=1,nc)
```

```
      if(nopt(4).ne.1) go to 4000
      do 4001 k=1,nt
 4001 read(5,30) (atec(k,i),i=1,nc)
 4000 continue
c ************************************
c     read relative yield factors
c *************************************
      nt1=nt
      if(nopt(4).eq.1) nt1=1
      do 4 i=1,nc
      read(5,1602) (crop(i,l),l=1,3)
 1602 format(3a4)
      do 4 j=1,np
    4 read(5,30) (yr(j,k,i), k=1,nt1)
   30 format(16f5.0)
c ************************************
c     read average production costs
c **************************************
      read(5,3) (c(i), i=1,nc)
c *************************************
c     read relative production cost factors
c ****************************************
      nt1=nt
      if(nopt(1).eq.1) nt1=1
      do 5 i=1,nc
      read(5,1602) (crop(i,l),l=1,3)
      do 5 j=1,np
    5 read(5,30) (cr(j,k,i), k=1,nt1)
c *********************************
c     compute A matrix and B vector
c *********************************
      nrow=np
      ncol=np*nt*nc
      nset=nt*nc
      do 6 i=1,nrow
      b(i)=1.0
      do 6 j=1,ncol
    6 a(i,j)=0.0
      iter=0
      do 70 i=1,nrow
      nbeg=iter*nset+1
      nend=nbeg+nset-1
      do 7 j=nbeg,nend
    7 a(i,j)=1.0
   70 iter=iter+1
      nct2=0
      if(nopt(2).ne.1) go to 710
      nbeg=nrow+1
      nend=nbeg+nc-1
      iter1=0
      do 700 i=nbeg,nend
      iter=0
      nd=(i-nrow)+(nt-1)*iter1
```

```
      nd1=(i-nrow)
      if(armax(nd1).eq.1.0) go to 702
      nct2=nct2+1
      ii=nrow+nct2
      do 702 j=nd,ncol,nset
      jk=iter+1
      mend=j+nt-1
      do 701 k=j,mend
  701 a(ii,k)=arel(jk)
      b(ii)=armax(nd1)
  702 iter=iter+1
      iter1=iter1+1
  700 continue
  715 continue
      nct3=0
      if(nopt(3).ne.1) go to 7001
      iter1=0
      nbeg=nrow+nct2+1
      nend=nbeg+nc-1
      nrow2=nrow+nct2
      do 7000 i=nbeg,nend
      iter=0
      nd=(i-nrow2)+(nt-1)*iter1
      nd1=(i-nrow2)
      if(armin(nd1).eq.0.0) go to 7020
      nct3=nct3+1
      ii=nrow2+nct3
      do 7020 j=nd,ncol,nset
      jk=iter+1
      mend=j+nt-1
      do 7010 k=j,mend
 7010 a(ii,k)=arel(jk)
      b(ii)=armin(nd1)
 7020 iter=iter+1
      iter1=iter1+1
 7000 continue
 7001 continue
c ******************************
c compute objective function terms
c ******************************
      do 7 i=1,nc
      do 9 j=1,np
      do 9 k=1,nt
      if(nopt(4).eq.1) go to 9030
      aw(j,k,i)=w(i)*wr(j,k,i)
      go to 9031
 9030 aw(j,k,i)=w(i)*wr(j,1,i)*atec(k,i)
 9031 continue
      if(nopt(1).eq.1)go to 903
      ac(j,k,i)=c(i)*cr(j,k,i)
      go to 9
  903 ac(j,k,i)=c(i)*cr(j,1,i)+costec(k,i)
    9 continue
```

```
      do 10 i=1,nc
      do 10 j=1,np
      do 10 k=1,nt
   10 fi(j,k,i)=(p(i)*ag(j,k,i)-ac(j,k,i))*ar(j)
c ********************************
c     write out files
c ********************************
      nend1=nrow+nct2+nct3
      nend2=nrow+nct2
      ndum1=1
      write(6,1) label
      write(6,100) ncol,nend1,nend2,nct3,ndum1,ndum1,ndum1
  100 format(4i3,6x,3i3)
      do 11 i=1,nend1
      write(6,103) (a(i,j), j=1,ncol)
      write(6,103) b(i)
   11 continue
      iter=0
      do 12 j=1,np
      do 12 i=1,nc
      do 12 k=1,nt
      j1=iter+1
      fiv(j1)=-fi(j,k,i)
      iter=iter+1
   12 continue
      write(6,103) (fiv(j), j=1,ncol)
  103 format(1p8e10.2)
      ndum=0
      write(6,105) ndum
  105 format(I1)
      stop
      end
```

APPENDIX: SOURCE LISTING FOR SHOPT

```
c
c     ******************************************************************
c
c     this routine is used to calculate the array dimensions and
c     then allocate space in blank common for these arrays.
c
c     using this routine does not change the the input to optimize as
c     previously used.
c
c     ******************************************************************
c
      common/a/ label(20),n,m,m1,m2,m3,m4,inter,kkk,job,datout
      common//d(100000)
      integer datout
   10 continue
      read(5,1) label
      read(5,2)n,m,m1,m2,m3,m4,inter,kkk,datout
      mm = m + 2
      na=n+m
      nb1 = mm * na + 1
      nb2 =  nb1 + mm + 1
      nb3 = nb2 + mm + 1
      nb4 = nb3 + na + 1
      nb5 = nb4 + na + 1
      nb6 = nb5 + mm + 1
      nb7=nb6+mm+1
      lwa=nb7+mm+100
      call main(d,d(nb1),d(nb2),d(nb3),d(nb4),d(nb5),d(nb6),d(nb7),mm)
      if(job.ne.0)go to 10
      stop
    1 format(20a4)
    2 format(9i3)
      end
      subroutine main(a,b,tz,z,x,basis,aa,bb,ma1)
c
c     ******************************************************************
c
```

```
c
c
c     this program was adapted for agricultural analysis
c                             by
c                       Robert Anderson
c                        25 June 1982
c
c
c     this program does the following..
c        1. zeroes storage arrays.
c        2. reads optimization data.
c        3. calls the simple  algorithm.
c        4. writes
c          (a) the minimum value of the objective function.
c          (b) the optimizing variable vector
c     *****instructions for entering data*****
c     1. the first data card is for problem title. punch any desired
c        title information in columns 1 through 80.
c     2. the second card of the input contains 9 integer constants,
c        right adjusted , in fields of three columns each, in the
c        following order..
c        a) n = number of original variables
c        b) m = number of original equations (rows) in the a matrix.
c        c) m1 = subset of m. it is the number of less-that-or-equal
c           inequalities.
c        d) m2 = subset of m. it is the number of greater-than-or-equal
c           inequalities.
c        e) m3 = subset of m. it is the number of equalities with
c           positive b(i).
c        f) m4 = subset of m. it is the number of equalities with
c           negative b(i).
c     **note** m1+m2+m3+m4 must equal m.
c        g) inter = signal. punch with any non-zero number if
c           intermediate results are not wanted.
c        h) nsk punch any non-zero number if sensitivity not wanted.
c        i) datout  punch any nonzero number if data not to be
c           printed out by rows.
c     3. the a matrix should be initially constructed with
c        subsets listed in order m1, m2, m3, m4.
c     4. the a matrix is punced by rows, 8 coefficients to a card, in
c        fields of 10 columns per coefficient.  as many cards as are
c        necessary may be used for a given row. data is punched with a
c        decimal.
c     5. following a given row of the a matrix, a single card lists the
c        corresponding b coefficient. the b element is listed in column
c        1 through 10. a decimal punch is required.
c     6. as many groups of a matrix rows and b coefficients are listed
c        as may be required.
c     7. following the a and b listings, the cost function is listed
c        according the the same format as for a row of the a matrix.
c     8. the last card reads zero (or blank) if only one problem is to
c        be solved or if this is the last problem in a set.  punch any
c        non-zero integer for any but the last problem in a set. punch
```

```
c         appropriate code in column 1, as an integer.
c
c       ***********************************************************************
c
        dimension a(maa,1),b(1),tz(1),z(1),x(1),basis(1),aa(1),bb(1)
        common/a/ label(20),n,m,m1,m2,m3,m4,inter,kkk,job,datout
        integer datout
        ma2=n+m1+m2
        do 2 i=1,ma1
        b(i)=0.0
        do 2 j=1,ma2
        a(i,j)=0.0
      2 continue
        do 3 j=1,ma2
        z(j)=0.0
        x(j)=0.0
      3 continue
        nn=n
        do 5 i=1,m
        read (5,11) (a(i,j),j=1,n)
        read(5,11)b(i)
        do 4 j=1,n
        a(i,j)=a(i,j)+0.
      4 continue
        b(i)=b(i)+0.
        tz(i)=b(i)
      5 continue
        read(5,11)(z(j),j=1,n)
        do 6 j=1,n
        z(j)=z(j)+0.
      6 continue
        read (5,14) job
        if(datout.ne.0) go to 750
        write (6,15)
        write (6,24) label
        write (6,16)
        if(n.le.10) go to 74
c        if(datout.ne.0)go to 75
     74 continue
        do 7 i=1,m
        write (6,17) ( a(i,j),j ,j=1,n)
      7 write (6,18) b(i)
        write (6,19) ( z(j),j ,j=1,n)
        go to 78
     75 continue
        naa=n/10+1
        do 97 jaa=1,naa
        write(6,23)
        ja=jaa*10-9
        na=ja+9
        if(naa.le.jaa)go to 80
        write(6,27)( j ,j=ja,na)
        go to 81
```

```
 80 write(6,27)( j ,j=ja,n)
    write(6,23)
 81 continue
    do 77 i=1,m
    if(naa.le.jaa)go to 76
    write(6,26)i,(a(i,j),j=ja,na)
    go to 77
 76 continue
    write(6,26)i,(a(i,j),j=ja,n )
 77 continue
    if(naa.le.jaa)go to 82
    write(6,29)(z(j),j=ja,na)
    go to 97
 82 write(6,29)(z(j),j=ja,n)
 97 continue
    write(6,15)
    do 79 i=1,m
    write(6,28) b(i)
 79 continue
 78 continue
    write(6,15)
    ierror=0
750 continue
    call simple  (a,b,m,n,m1,m2,m3,m4,z,cost,x,inter,ierror,ma1,basis
    if (ierror.eq.1) go to 9
    if(datout.ne.0) go to 751
    write (6,20)
    write (6,21) cost
751 continue
    do 8 j=1,n
  8 write (6,22) j,x(j)
    if (kkk.gt.0) go to 9
    l=m1+m2
    call sence(l,n,a,b,x,z,nn,tz,ma1,aa,bb)
  9 return

 11 format (8f10.0)
 14 format (i1)
 15 format (1h1)
 16 format (3x,10hinput data,/)
 17 format (3x,5(3x,f10.2,1hx,i2,2x))
 18 f--mat (110x,1h=,f10.2,//3x,)
 19 fo mat (3x, 18hobjective function,//,(3x,5(3x,f10.2,1hx,i2,2x)))
 20 format (1h0,[illegible] , 36h  solution to the objective function,//)
 21 format (3x, 20hobjective function =,f20.2)
 22 format (15x,1hx,i3,1h=,f20.5)
 23 format(/)
 24 format (20x,20a4)
 25 format(//)
 26 format(5x,i3,2x,10(f10.2,2x))
 27 format(1h1,10x,10(4x,1hx,i3,4x)/)
 28 format(110x,1h=,f10.2)
 29 format(//10x,10(f10.2,2x))
```

```
      end
      subroutine simple  (a,b,m,n,m1,m2,m3,m4,z,cost,x,inter,ierror,mai,
     1basis)
c
c     ****************************************************************
c
c     debugging instructions and print commands lack simple  id
c     and are numbered beginning with 1000.
c     variable list*****
c     1. m = number of original equations
c     2. n = number of original variables
c     3. a = variable coefficient matrix. dimension for m+2 x novar
c        elements.
c     4. b = constant column vector. dimension for m+2 elements.
c     5. m1 = number of less-than-or-equal inequalities.
c     6. m2 = number of greater-than-or-equal inequalities.
c     7. m3 = number of equality statements with positive b(i).
c     8. m4 = number of equality statements with negative b(i).
c     9. novar = total number of variables in revised standard
c        cannonical form.
c     10. basis = array containing j indices of basis for any iteration.
c           dimension for m elements. elements are integers.
c     11. r = pivot row number for any iteration. must be an integer.
c     12. s = pivot column number for any iteration. must be an integer.
c     13. inter = signal, to delete intermediate printouts. if inter
c        is zero, intermediate cycles will be printed. if inter is not
c        zero (for example, punch 1) intermediate cycles will not be
c        printed.
c
c     ****************************************************************
c
      dimension a(mai,1),b(1),basis(1),z(1),x(1)
      integer r,s,basis
      m1234=m1+m2+m3+m4
      if (m1234.ne.m) go to 42
      novar=n+m1+m2
      mplus2=m+2
      do 1 i=1,mai
      basis(i)=0
    1 continue
      if (inter.ne.0) go to 2
      write (6,43)
c     conversion of matrix a to standard cannonical form
    2 nplus1=n+1
      if (m1.eq.0) go to 5
c     first, addition of slack variables to m1 submatrix
      do 4 i=1,m1
      k=i
      nplusk=n+k
      a(i,nplusk)=1.0
      do 3 j=nplus1,novar
      if (j.eq.nplusk) go to 3
      a(i,j)=0.0
```

```
    3 continue
      if (b(i).lt.0.0) go to 40
    4 continue
c     next, convert m2 submatrix
    5 if (m2.eq.0) go to 8
      m1plu1 =m1+1
      m1m2=m1+m2
      do 7 i=m1plu1 ,m1m2
      k=i
      nplusk=n+k
      a(i,nplusk)=-1.0
      do 6 j=nplus1,novar
      if (j.eq.nplusk) go to 6
      a(i,j)=0.0
    6 continue
      if (b(i).lt.0.0) go to 40
    7 continue
c     submatrix m3 needs no conversion or artificial variables
    8 if (m4.eq.0) go to 11
c     finally, convert m4
      m123p1=m1+m2+m3+1
      do 10 i=m123p1,m
      do 9 j=1,n
    9 a(i,j)=-a(i,j)
      if (b(i).gt.0.0) go to 41
      b(i)=-b(i)
   10 continue
c     construction of infeasibility equation
   11 mplus2=m+2
      do 12 j=1,novar
      a(mplus2,j)=0.0
      do 12 i=1,m
      a(mplus2,j)=-a(i,j)+a(mplus2,j)
   12 continue
      b(mplus2)=0.0
      do 13 i=1,m
      b(mplus2)=-b(i)+b(mplus2)
   13 continue
c     insertion of cost function coefficients into matrix a
      mplus1=m+1
      do 14 j=1,n
      a(mplus1,j)=z(j)
   14 continue
      do 15 j=nplus1,novar
      a(mplus1,j)=0.0
   15 continue
      b(mplus1)=0.0
c     problem should now be in the standard infeasibility form and read
c     for phase one operations
      k=1
      do 16 i=1,m
      basis(i)=novar+k
      k=k+1
```

```
   16 continue
      if (inter.ne.0) go to 18
      do 17 i=1,mplus2
      write (6,49) (a(i,j),j=1,novar)
   17 write (6,50) b(i)
c     begin main iteration procedure *** phase one ***
c     location of most negative realtive price.
   18 mp=m+2
      n=novar
      kount=1
   19 if (inter.ne.0.) go to 20
      write (6,53) kount
   20 test=0.0
      do 21 j=1,n
      if (a(mp,j).ge.test) go to 21
      abvala=abs(a(mp,j))
      if (abvala.le.0.001) go to 21
      trap=abs(a(mp,j))-abs(test)
      abtrap=abs(trap)
      if (abtrap.le.0.00001) go to 21
      test=a(mp,j)
      s=j
c     s is the pivot column number
   21 continue
      if (test.eq.0.0) go to 33
c     determination of pivot row number
c     r is the pivot row number
      denom=10.0e8
      dum=0.0
      do 23 i=1,m
      if (a(i,s).le.0.0) go to 23
      epsilo =abs(b(i))
      if (epsilo .lt.0.00001) go to 22
      test=b(i)/a(i,s)
      if (test.ge.denom) go to 23
      denom=test
      k=i
      go to 23
   22 if (a(i,s).le.dum) go to 23
      dum=a(i,s)
      kk=i
   23 continue
      if (dum.eq.0.0) go to 24
      abdum=abs(dum)
      epsilo =0.0001
      if (abdum.lt.epsilo ) go to 24
      r=kk
      go to 25
   24 if (denom.eq.10.0e8) go to 43
      r=k
   25 pivot=a(r,s)
      if (inter.ne.0) go to 26
      write (6,52) r,s
```

```
      write (6,54)
      write (6,55) (basis(i),i=1,m)
   26 do 27 j=1,novar
   27 a(r,j)=a(r,j)/pivot
      b(r)=b(r)/pivot
      basis(r)=s
      do 29 i=1,mp
      if (i.eq.r) go to 29
      do 28 j=1,n
      if (j.eq.s) go to 28
      a(i,j)=a(i,j)-a(i,s)*a(r,j)
   28 continue
      b(i)=b(i)-a(i,s)*b(r)
   29 continue
      do 30 i=1,mp
      if (i.eq.r) go to 30
      a(i,s)=0.0
   30 continue
      a(r,s)=1.0
      k=0
      kk=0
      if (inter.ne.0) go to 32
      write (6,51) kount
      do 31 i=1,mp
      write (6,49) (a(i,j),j=1,novar)
   31 write (6,50) b(i)
c     start new cycle
   32 kount=kount+1
      go to 19
   33 if (mp.eq.mplus1) go to 34
      go to 37
   34 if (b(mp).ge.0.0) go to 35
      tol=0.001
      b(mp)=abs(b(mp))
      if (b(mp).gt.tol) go to 36
c     begin phase two
   35 mp=m+1
      if (inter.ne.0) go to 20
      write (6,56)
      go to 20
   36 write (6,46)
      go to 44
   37 cost=b(mp)
      do 38 j=1,n
   38 x(j)=0.0
      do 39 i=1,m
      j=basis(i)
   39 x(j)=b(i)
      go to 45
   40 write (6,57) i
      go to 44
   41 write (6,58) i
      go to 44
```

```
   42 write (6,39)
      go to 44
   43 write (6,47)
   44 ierror=1
   45 return
c
   46 format (3x,42hthere is no feasible solution to phase one)
   47 format (3x,31hobjective function is unbounded)
   48 format (1h1,3x,20hdebug printout*****,//)
   49 format (3x,10f10.3)
   50 format (110x,1h=,f10.3)
   51 format (3x,16hend of cycle no.,i3,//)
   52 format (3x,22hpivot location***row  ,i3,1h,,5x,8hcolumn  ,i3)
   53 format (3x,15hbegin cycle no.,i3)
   54 format (3x,11h***basis***)
   55 format (6x,1hx,i3)
   56 format (3x,21h***start phase two***)
   57 format (3x,39himproper problem formulation. equation ,i3,26hhas ne
     1gative b coefficient)
   58 format (3x,39himproper problem formulation. equation ,i3,26hhas po
     1sitive b coefficient)
   59 format (3x,60himproper problem formulation. m1 +m2 +m3 +m4 not equ
     1al to m.)
      end
      subroutine lowup (k,aa,bb,low,up,ifl)
c
c     ****************************************************************
c
c     this subroutine finds the upper and lower value of set of numbers
c
c     ****************************************************************
c
      dimension aa(1),bb(1)
      real low
      iflag=0
      iiflag=0
      gnum=1.e-13
      low=-1.0e+30
      up=  1.0e+30
      do 6 j=1,k
      absa=abs(aa(j))
      absb=abs(bb(j))
      if(absa.lt.gnum.or.absb.lt.gnum) go to 6
      delt=-bb(j)/aa(j)
      if (aa(j).lt.0.0) go to 4
      if (delt.ge.low) go to 3
      go to 6
    3 low=delt
      iflag=1
      go to 6
    4 if (delt.le.up) go to 5
      go to 6
    5 up=delt
```

```
      iiflag=2
    6 continue
      ifl=iflag+iiflag
      return
      end
      subroutine sence (m,novar,a,b,x,z,n,tz,mal,aa,bb,ml)
      real low,lo
c
c     ****************************************************************
c
c     this subroutine determines which variables and constraints are
c     within a ten percent tolerance range of changing the solution
c
c     ****************************************************************
c
      dimension a(mal,1),b(1),tz(1),z(1),x(1)
      dimension aa(1),bb(1)
      write (6,22)
      write (6,23)
      mk=n+1
      nov=n+m
      mkl=mk+ml
      do 6 i=mk,nov
      do 1 j=1,m
      aa(j)=a(j,i)
      if(i.ge.mkl)aa(j)=-aa(j)
      bb(j)=b(j)
    1 continue
      call lowup (m ,aa,bb,low,up,iflag)
      jx=i-n
      l=jx
      mm=mal-1
      iflag=iflag+1
      low=tz(l)+low
      if(low.le.0.0)low=0.0
      up=tz(l)+up
      go to (4,3,2,5), iflag
    2 write (6,25) jx,tz(l),up,a(mm,i)
      go to 6
    3 write (6,26) jx,tz(l),low,a(mm,i)
      go to 6
    4 write (6,27) jx,tz(l),a(mm,i)
      go to 6
    5 write (6,24) jx,tz(l),low,up,a(mm,i)
    6 continue
      write (6,28)
      do 21 i=1,n
      ll=0
      if (x(i).ne.0.0) go to 8
      ban=z(i)-a(mm,i)
      if (z(i).ge.0.) go to 7
      z(i)=-z(i)
      ban=-ban
```

```
      write (6,29) i,z(i),ban
      go to 21
    7 write (6,30) i,z(i),ban
      go to 21
    8 k=1
    9 if (a(k,i).ne.0.0) go to 10
      k=k+1
      go to 9
   10 do 11 kk=1,novar
      if (kk.eq.i) go to 11
      if (a(k,kk).eq.0.0) go to 11
      ll=ll+1
      bb(ll)=a(mm,kk)
      aa(ll)=a(k,kk)
   11 continue
      call lowup (ll,aa,bb,low,up,iflag)
      low=z(i)-low
      up=z(i)-up
      iflag=iflag+1
      if (z(i).gt.0.) go to 16
      z(i)=-z(i)
      low=-low
      up=-up
      if (low .le. 0.0) low = 0.0
      go to (12,13,14,15), iflag
   12 write (6,31) i,z(i)
      go to 21
   13 write (6,35) i,z(i),low
      go to 21
   14 write (6,33) i,z(i),up
      go to 21
   15 write (6,37) i,z(i),low,up
      go to 21
   16 lo=up
      upp=low
      low=lo
      up=upp
      if (low .le. 0.0) low = 0.0
      go to (17,19,18,20), iflag
   17 write (6,32) i,z(i)
      go to 21
   18 write (6,36) i,z(i),low
      go to 21
   19 write (6,34) i,z(i),up
      go to 21
   20 write (6,38) i,z(i),low,up
   21 continue
      return

   22 format (//10x, 21hsensitivity analysis ,//)
   23 format (//10x, 11h constraint,5x,  5h rhs ,10x, 13h lower limit ,
     10x, 12hupper limit ,5x, 24hshadow price/oppro. cost)
   24 format (/15x,i3,5x,f10.2,3(10x,f10.2))
```

```
25 format (/15x,i3,5x,f10.2,8x, 14hno lower limit,8x,f10.2,10x,f10.2
26 format (/15x,i3,5x,f10.2,10x,f10.2,10x, 14hno upper limit,6x,f10.
  1)
27 format (/15x,i3,5x,f10.2,8x, 14hno lower limit,8x, 14hno upper li
  1it,6x,f10.2)
28 format (//10x,  8hvariable,5x,  8hcost/rev,10x, 10hvar.status,10x
  1 13hinitial value,6x, 11hlower limit,8x, 11hupper limit)
29 format (/10x,  2hx(,i3,  1h),10x,  7hrevenue,10x,  9hnon basic,10
  1,f10.2,16x,  3hn/a,11x,f10.2)
30 format (/10x,  2hx(,i3,  1h),10x,  7h cost  ,10x,  9hnon basic,10
  1,f10.2,10x,f10.2,16x,  3hn/a)
31 format (/10x,  2hx(,i3,  1h),10x,  7hrevenue,12x,  5hbasic,12x,f1
  1.2,10x, 14hno lower limit,5x, 14hno upper limit)
32 format (/10x,  2hx(,i3,  1h),10x,  7h cost  ,12x,  5hbasic,12x,f1
  1.2,10x, 14hno lower limit,5x, 14hno upper limit)
33 format (/10x,  2hx(,i3,  1h),10x,  7hrevenue,12x,  5hbasic,12x,f1
  1.2,10x, 14hno lower limit,6x,f10.2)
34 format (/10x,  2hx(,i3,  1h),10x,  7h cost  ,12x,  5hbasic,12x,f1
  1.2,10x, 14hno lower limit,6x,f10.2)
35 format (/10x,  2hx(,i3,  1h),10x,  7hrevenue,12x,  5hbasic,12x,f1
  1.2,10x,f10.2,8x, 14hno upper limit)
36 format (/10x,  2hx(,i3,  1h),10x,  7h cost  ,12x,  5hbasic,12x,f1
  1.2,10x,f10.2,8x, 14hno upper limit)
37 format (/10x,  2hx(,i3,  1h),10x,  7hrevenue,12x,  5hbasic,12x,f1
  1.2,10x,f10.2,10x,f10.2)
38 format (/10x,  2hx(,i3,  1h),10x,  7h cost  ,12x,  5hbasic,12x,f1
  1.2,10x,f10.2,10x,f10.2)
   end
```

APPENDIX: SOURCE LISTING FOR SHOUT2

```
c       SHOUT Version 2
c       this program takes the asmod input file and
c       the output file of SHOPT and
c       constructs summary output tables
        dimension label(20),p(20),y(20),c(20),yr(30,6,20)
        dimension cr(30,6,20),a(70,1200),ay(30,6,20),ar(30)
        dimension ac(30,6,20),fi(30,6,20),fiv(3600),b(70)
        dimension armax(20),armin(20),arel(30)
        dimension crop(20,3),tech(20,2),costec(6,20),nopt(4)
        dimension totout(20),totinc(20),totare(20),x(3600)
        dimension atec(6,20),preq(6,20),totpla(20)
        dimension suelo(30,4),adua(30,4),fase(30,4),text(30,4)
        data iff/o'14'/
c ********************************
c       read label
c ********************************
        read(5,1) label
    1   format(20a4)
c *********************************
        read(5,20) (nopt(l),l=1,4)
   20   format(4i5)
c **********************************
c       read np=no of parcels, nc=no of crops,
c       nt=no of technologies
c **********************************
        read(5,2) np,nc,nt
    2   format(3i5)
c **********************************
c       read parcel characteristics
c **********************************
        do 699 j=1,np
  699   read(5,69) (suelo(j,l),l=1,4),(adua(j,l),l=1,4),(fase(j,l),l=1,4),
       1(text(j,l),l=1,4)
   69   format(4a4,4a4,4a4,4a4)
c **********************************
c       read technology names
c ***********************************
```

```
      do 1600 k=1,nt
 1600 read(5,1601) (tech(k,j),j=1,2)
 1601 format(2a4)
c ************************************
c read technology costs if cost independent of parcel type and crop
c ************************************
      if(nopt(1).ne.1) go to 900
      do 9000 k=1,nt
 9000 read(5,3) (costec(k,i),i=1,nc)
c ***********************************
c     read plastics requirements
c ***********************************
      do 9001 k=1,nt
 9001 read(5,3) (prea(k,i),i=1,nc)
c ************************************
  900 continue
c *************************************
c     read areas [in hectares] of each parcel
c **************************************
      read(5,104) (ar(j), j=1,np)
  104 format(16f5.0)
      do 8000 i=1,nc
      armax(i)=1.0
 8000 armin(i)=0.0
      if (nopt(2).ne.1) go to 901
c ***************************************
c     read restrictions on maximum area of each crop
c ****************************************
      read(5,104) (armax(i), i=1,nc)
  901 continue
      if(nopt(3).ne.1) go to 902
c *****************************************
c read restrictions on minimum acreage of crops
c ****************************************
      read(5,104) (armin(i),i=1,nc)
  902 continue
c ***********************************
c     read farm prices of crops
c *************************************
      read(5,3) (p(i),i=1,nc)
    3 format(10f7.0)
c *************************************
c     read mean yields
c *************************************
      read(5,3) (y(i),i=1,nc)
      if(nopt(4).ne.1) go to 4000
      do 4001 k=1,nt
 4001 read(5,30) (atec(k,i),i=1,nc)
 4000 continue
c *************************************
c     read relative yield factors
c **************************************
      nt1=nt
```

```
      if(nopt(4).eq.1) nt1=1
      do 4 i=1,nc
      read(5,1602) (crop(i,l),l=1,3)
 1602 format(3a4)
      do 4 j=1,np
    4 read(5,30) (yr(j,k,i), k=1,nt1)
   30 format(16f5.0)
c ****************************************
c     read average production costs
c ******************************************
      read(5,3) (c(i), i=1,nc)
c *****************************************
c     read relative production cost factors
c ********************************************
      nt1=nt
      if(nopt(1).eq.1) nt1=1
      do 5 i=1,nc
      read(5,1602) (crop(i,l),l=1,3)
      do 5 j=1,np
    5 read(5,30) (cr(j,k,i), k=1,nt1)
c **************************************
c     read in solution values from SHOPT
c ***************************************
      ncol=np*nt*nc
      do 7 l=1,ncol
    7 read(5,100) x(l)
  100 format(20x,f20.5)
c ******************************
c compute objective function terms
c ******************************
      do 9 i=1,nc
      do 9 j=1,np
      do 9 k=1,nt
      if(nopt(4).eq.1) go to 9030
      ay(j,k,i)=y(i)*yr(j,k,i)
      go to 9031
 9030 ay(j,k,i)=y(i)*yr(j,1,i)*atec(k,i)
 9031 continue
      if(nopt(1).eq.1)go to 903
      ac(j,k,i)=c(i)*cr(j,k,i)
      go to 9
  903 ac(j,k,i)=c(i)*cr(j,1,i)+costec(k,i)
    9 continue
      do 10 i=1,nc
      do 10 j=1,np
      do 10 k=1,nt
   10 fi(j,k,i)=(p(i)*ay(j,k,i)-ac(j,k,i))*ar(j)
c **********************************
      iter=0
      do 12 j=1,np
      do 12 i=1,nc
      do 12 k=1,nt
      j1=iter+1
```

```
      fiv(j1)=fi(j,k,i)
      iter=iter+1
   12 continue
      do 13 i=1,nc
      totpla(i)=0.0
      totout(i)=0.0
      totare(i)=0.0
   13 totinc(i)=0.0
      iter=1
      do 14 j=1,np
      do 14 i=1,nc
      do 14 k=1,nt
      totpla(i)=totpla(i)+preq(k,i)*ar(j)*x(iter)
      totout(i)=totout(i)+ay(j,k,i)*ar(j)*x(iter)
      totinc(i)=totinc(i)+fi(j,k,i)*x(iter)
      totare(i)=totare(i)+ar(j)*x(iter)
   14 iter=iter+1
      sumpla=0.0
      suminc=0.0
      sumare=0.0
      do 15 i=1,nc
      sumpla=sumpla+totpla(i)
      sumare=sumare+totare(i)
   15 suminc=suminc+totinc(i)
      write(6,499) iff,label
  499 format(a1,//1x,20a4)
      write(6,600)
  600 format(//1x,7hcultivo,5x,15hcosto promedio*,5x,13hrendimiento**,
     15x,12hprecio rural,5x,11harea maxima,5x,11harea minima/17x,
     26h($/ha),13x,6h(t/ha),12x,5h($/t),13x,3h(%),13x,3h(%)//)
      do 160 i=1,nc
      armax(i)=100.*armax(i)
      armin(i)=100.*armin(i)
  160 write(6,601) (crop(i,j),j=1,3),c(i),y(i),p(i),armax(i),armin(i)
  601 format(1x,3a4,2x,f10.2,6x,f10.2,10x,f10.2,5x,f10.2,6x,f10.2)
      write(6,602)
  602 format(//1x,30h*no incluye costo de la tierra//1x,10h**promedio)
      write(6,499) iff,label
      write(6,500)
  500 format(//1x,22hresultados sumarizados//1x,
     126hproduccion (mil toneladas)//)
      do 16 i=1,nc
   16 write(6,501) (crop(i,j), j=1,3),totout(i)
  501 format(1x,3a4,5x,f20.2)
      write(6,499) iff,label
      write(6,502)
  502 format(//1x,25hingreso total (mil pesos)//)
      do 17 i=1,nc
   17 write(6,501) (crop(i,j), j=1,3),totinc(i)
      write(6,5010) suminc
 5010 format(1x,//5x,16hingreso total = ,f20.2)
      write(6,499) iff,label
      write(6,503)
```

```
503 format(//1x,32hsuperficie total (mil hectareas)//)
    do 18 i=1,nc
 18 write(6,501) (crop(i,j),j=1,3),totare(i)
    write(6,5011) sumare
5011 format(1x,//5x,19hsuperficie total = ,f20.2)
    write(6,499) iff,label
    write(6,701)
701 format(//1x,40hconsumo de los plasticos (mil toneladas)//)
    do 702 i=1,nc
702 write(6,501) (crop(i,j),j=1,3),totpla(i)
    write(6,703) sumpla
703 format(//5x,16hconsumo total = ,f20.2)
    iter=1
    do 19 j=1,np
    write(6,504) iff,label,j,(suelo(j,l),l=1,4),(agua(j,l),l=1,4),
   1(fase(j,l),l=1,4),(text(j,l),l=1,4)
504 format(a1,//1x,20a4//1x,32hresultados para parcelas de tipo,2x,
   1i3//1x,16htipo de suelo = ,4a4,4x,7hagua = ,4a4/1x,
   215hfase quimica = ,4a4,4x,10htextura = ,4a4//)
    write(6,505)
505 format(1x,7hcultivo,5x,10htecnologia,3x,19hcosto de produccion,3x,
   16hmargen,3x,10hsuperficie,3x,
   211hrendimiento,3x,10hproduccion,2x,7hingreso, x,
   316huso de plasticos/
   432x,6h($/ha),10x,6h($/ha),4x,8h(mil ha),7x,
   56h(t/ha),5x,9h(mil ton),4x,7h(mil $),7x,9h(mil ton)//)
    do 19 i=1,nc
    do 19 k=1,nt
    aa=ar(j)*x(iter)
    pp=aa*preq(k,i)
    yy=ay(j,k,i)
    cc=ac(j,k,i)
    gm=ay(j,k,i)*p(i)-ac(j,k,i)
    o=aa*yy
    f=fi(j,k,i)*x(iter)
    write(6,506) (crop(i,l),l=1,3),(tech(k,l),l=1,2),cc,gm,aa,yy,o,f,
   1pp
506 format(1x,3a4,2x,2a4,6x,f10.2,6x,f10.2,
   1f10.2,3x,f10.2,4x,f10.2,1x,f12.2,3x,f10.2)
 19 iter=iter+1
    stop
    end
```

APPENDIX: EXAMPLE INPUT DATA FOR AGMOD

```
la laguna, tecnologia presente y acol $25000/ha, rendimiento=1.5x ,acol·
    1     1     1     1
   26    16     2
xerosol haplico riego           ausente         media
xerosol haplico riego           salina          media
xerosol haplico riego           sodica          media
xerosol haplico riego           salina-sodica   media
xerosol haplico riego           ausente         fina
xerosol haplico riego           salina-sodica   fina
xerosol calcico riego           salina          media
yermosol haplicoriego           ausente         media
yermosol haplicoriego           salina          media
yermosol haplicoriego           sodica          media
yermosol haplicoriego           ausente         fina
yermosol haplicoriego           salina          fina
yermosol calcicoriego           ausente         media
litosol          riego          ausente         media
regosol calcaricriego           salina          media
regosol eutrico riego           ausente         gruesa
vertisol cromicoriego           ausente         media
solonchak orticoriego           ausente         media
solonchak orticoriego           sodica          media
solonchak takiririego           ausente         media
xerosol haplico temporal        ausente         media
xerosol haplico temporal        salina          media
xerosol luvico  temporal        salina-sodica   fina
yermosol haplicotemporal        ausente         fina
regosol calcarictemporal        salina          media
solonchak orticotemporal        sodica          media
presente
acolchad

25000. 25000. 25000. 25000. 25000. 25000. 25000. 25000. 25000. 25000.
25000. 25000. 25000. 25000. 25000. 25000.
```

```
0.400  0.400  0.400  0.400  0.400  0.400  0.400  0.400  0.400  0.400
0.400  0.400  0.400  0.400  0.400  0.400
 37.8   8.6 12.6   1.1   1.1   1.7   2.9   1.1   1.1   1.1     3  0.6   1.1   0.6
  4.6   3.4   1.1   1.1   1.1   1.1   1.1   0.6   1.1   2.3
4.e-4.0530.0600.0380.1140.0600.0330.0210.0400.0190.0110.4210.0230.1320.
2.e-4.0330.0400.0180.0940.0400.0130.0010.0200.0090.0010.4010.0030.1120.
   7300     350   5450  17000   5500     380   3000   2900   3650     450
   7500   15800   3750    400  60000    3550
    1.0 38.011  1.874  1.745  2.734 37.153 24.326 27.790  3.558 32.596
 24.250  2.500  2.561 68.226  1.083 10.708
1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.
1.50 1.50 1.50 1.50 1.50 1.50 1.50 1.50 1.50 1.50 1.50 1.50 1.50 1.50 1.
alpiste
1.1501.450
1.0001.300
0.5000.800
1.0001.300
1.1501.450
1.0001.300
1.0001.300
1.1501.450
1.0001.300
0.5000.800
1.1501.450
1.0001.300
1.1501.450
0.7001.000
1.0001.300
1.0001.300
1.1501.450
0.9001.200
0.9001.200
0.9001.200
0.8001.100
0.8001.100
0.8001.100
0.8001.100
0.7501.050
0.7001.000
avena(forr)
1.1501.450
0.9001.200
0.5000.800
0.9001.200
1.1501.450
0.9001.200
0.9001.200
1.1501.450
0.9001.200
0.5000.800
1.1501.450
0.9001.200
1.1501.450
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0.9501.250
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1.3001.600
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0.5000.800
1.2501.550
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1.2501.550
1.3001.600
1.2501.550
0.5000.800
1.3001.600
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0.7501.050
0.5000.800

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sorso(forr)
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1.2501.550
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1.2501.550
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1.2001.500

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1.2001.500
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0.9001.200
1.2501.550
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tomate
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0.1300.450
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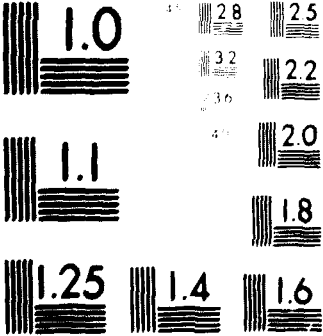

MICROCOPY RESOLUTION TEST CHART

NATIONAL BUREAU OF STANDARDS-1963-A

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APPENDIX: SOURCE LISTING OF AGRO-CLIMATIC MODEL

```
c          main program of trs2.f
c          common statement goes here
       common / s / t9(40,2),t10(13,11),t11(13,5),t12(19,2),t15(21,2
      *t16304(5,5),t16604(5,5),t16904(5,5),t16303(5,5),t16603(5,5),
      *t16903(5,5),t16302(5,5),t16602(5,5),t16902(5,5),t16301(5,5),
      *t16601(5,5),t16901(5,5),t19(10,4),t20(10,5),t2283(6,6),
      *t2267(6,6),t2250(6,6),t2233(6,6),t2217(6,6),t2200(6,6),
      *t13(7,27)
       common / t / temp(12),ea(12),ra(12),n(12),ftc(12),fed(12),
      *ed(12),fann(12),an(12),tfta(12),w(12),wa(13),fu(12),rs(12),
      *rnl(12),rn(12),ru(12),udia(12),unoche(12),rhmax(12),tab(5,5
      *eto(12),c(12),rh(12),winit,etm(12),p(12),resid(12),asi(12),
      *teta(12),eta(12),pe(12),etac(5),etoc(5),stage(5,12),
      *ratio(5),ky(5),ym,samax,samin,kc(5),crop,xlat,alt,d,sa,ndom
       real n(12),kc(5),ky(5)
       print 100
  100  format (///'crop numbers'///
      1'-----------------------------------------------------------------
      1'1.0    banana                    9.0    guisante, fresco
      1'1.1     subtropical             10.0    pimentero, fresca
      1'1.2     tropical                11.0    patata
      1'2.0    frijol                   12.0    arroz
      1'2.1     verde                   13.0    cartamo
      1'2.2     seco                    14.0    sorgo
      1'3.0    col                      15.0    soja
      1'4.0    algodon                  16.0    remolacha azucar
      1'5.0    vid                      17.0    cana de azucar
      1'6.0    cacahuate                18.0    girasol
      1'7.0    maiz                     19.0    tabaco
      1'7.1     dulce                   20.0    tomate
      1'7.2     grano                   21.0    sandia
      1'8.0    cebolla                  22.0    trigo
      1'8.1     seco                    23.0    alfalfa
      1'8.2     verde
      1'-----------------------------------------------------------------
    1 print*,'enter crop number'
       read*, crop
```

```
      print*,'entry correct? enter '1 return' if so, '0 return' if not'
      read*, err
      if(err.eq.0) go to 1
    2 print*,'enter altitude of site,m'
      read*, alt
      print*,'entry correct? enter '1 return' if so, '0 return' if not'
      read*,err
      if(err.eq.0) go to 2
    3 print*,'enter latitude of site, degrees'
      read*, xlat
      print*,'entry correct? enter '1 return' if so, '0 return' if not'
      read*, err
      if(err.eq.0) go to 3
    4 print*,'enter mean monthly temperatures, degrees celsius'
      read*, temp
      print*,'entry correct? enter '1 return' if so, '0 return' if not'
      read*, err
      if(err.eq.0) go to 4
    5 print*,'enter mean daytime windspeed, m/sec, by month'
      read*, udia
      print*,'entry correct? enter '1 return' if so, '0 return' if not'
      read*, err
      if(err.eq.0) go to 5
    6 print*,'enter mean nighttime windspeed, m/sec, by month'
      read*, unoche
      print*,'entry correct? enter '1 return' if so, '0 return' if not'
      read*, err
      if(err.eq.0) go to 6
    7 print*,'enter maximum yield of this crop on this site, kg'
      read*, ym
      print*,'entry correct? enter '1 return' if so, '0 return' if not'
      read*, err
      if(err.eq.0) go to 7
c
c
c        the following statements are to be replaced to read
c         an effective precipitation data set generated
c         by a random variable generator when data from
c         probability investigations of precipitation
c         become available.
c
c
    8 print*,'enter monthly effective precipitation, mm'
      read*, pe
      print*,'entry correct? enter '1 return' if so, '0 return' if not'
      read*, err
      if(err.eq.0) go to 8
c
c
    9 print*, 'enter depth of root zone, m'
      read*, d
      print*,'entry correct? enter '1 return' if so, '0 return' if not'
      read*, err
```

```
      if(err.eq.0) go to 9
   10 print*,'enter available soil moisture at this site, mm/m'
      read*, sa
      print*,'entry correct? enter '1 return' if so, '0 return' if not'
      read*, err
      if(err.eq.0) go to 10
   11 print*,'enter initial depth of available water, mm'
      read*, winit
      print*, 'entry correct? enter '1 return' if so, '0 return' if not
      read*, err
      if(err.eq.0) go to 11
   12 print*,'enter monthly relative humidity, percent'
      read*, rh
      print*,'entry correct? enter '1 return' if so, '0 return' if not'
      read*, err
      if(err.eq.0) go to 12
   13 print*, 'enter monthly relative humidity maxima, percent'
      read*, rhmax
      print*,'entry correct? enter '1 return' if so, '0 return' if not'
      read*, err
      if(err.eq.0) go to 13
   14 print*,'enter monthly actual hours of sunshine'
      read*,en
      print*,'entry correct? enter '1 return' if so, '0 return' if not'
      read*, err
      if(err.eq.0) go to 14
   15 print*,'enter 5 crop factors for maximum evapotranspiration (kc)'
      read*,kc
      print*,'entry correct? enter '1 return' if so, '0 return' if not'
      read*, err
      if(err.eq.0) go to 15
   16 print*,'enter 5 crop factors for yield (ky)'
      read*,ky
      print*,'entry correct? enter '1 return' if so, '0 return' if not'
      read*, err
      if(err.eq.0) go to 16
   17 print*,'enter matrix of days in 5 crop stages by month'
      read*,stage
      print*,'entry correct? enter '1 return' if so, '0 return' if not'
      read*, err
      if(err.eq.0) go to 17
      ndos=0
      call evapp
      if(ndos.ne.0) go to 699
      call evapa
      if(ndos.ne.0) go to 699
      call adjust
      if(ndos.ne.0) go to 699
      call yielda
      if(ndos.ne.0.) go to 699
      call output
      go to 700
  699 call dos
```

```
  700 continue
      end
c ************************
c      this part of the program sets up the tables for the analysis
      block data
      common / s / t9(40,2),t10(13,11),t11(13,5),t12(19,2),t15(21,6),
     *t16304(5,5),t16604(5,5),t16904(5,5),t16303(5,5),t16603(5,5),
     *t16903(5,5),t16302(5,5),t16602(5,5),t16902(5,5),t16301(5,5),
     *t16601(5,5),t16901(5,5),t19(10,4),t20(10,5),t2283(6,6),
     *t2267(6,6),t2250(6,6),t2233(6,6),t2217(6,6),t2200(6,6),
     *t18(7,27)
      common / d / temp(12),ea(12),ra(12),n(12),ftc(12),fed(12),
     *ed(12),fann(12),an(12),tfta(12),w(12),wa(13),fu(12),rs(12),
     *rnl(12),rn(12),ru(12),udia(12),unoche(12),rhmax(12),tat(5,5),
     *eto(12),c(12),rh(12),winit,etm(12),p(12),resid(12),asi(12),
     *teta(12),eta(12),pe(12),etac(5),etmc(5),stage(5,12),
     *ratio(5),ky(5),ym,yamax,yamin,kc(5),crop,xlat,alt,d,sa,ndos
      real n(12),kc(5),ky(5)
c
c
c  Table 9, D&K.  Column 1 is temperature. Column 2 is ea.
c
c
      data t9/0.,1.,2.,3.,4.,5.,6.,7.,8.,9.,10.,11.,12.,13.,
     *14.,15.,16.,17.,18.,19.,20.,21.,22.,23.,24.,25.,26.,27.,28.,29.,
     *30.,31.,32.,33.,34.,35.,36.,37.,38.,39.,6.1,6.6,7.1,7.6,8.1,8.7,
     *9.3,10.0,10.7,11.5,12.3,13.1,14.0,15.0,16.1,17.0,18.2,19.4,20.6,
     *22.0,23.4,24.9,26.4,28.1,29.8,31.7,33.6,35.7,37.8,40.1,42.4,44.9,
     *47.6,50.3,53.2,56.7,59.4,62.8,66.3,69.9/
c
c
c  Table 10, D&K.  Columns are ra by latitude.  Rows 1-12 are months.
c   Row 13 is latitude.
c
c
      data t10/7.4,9.4,12.1,14.7,16.4,17.2,16.7,15.4,13.1,10.6,8.0,6.6,
     *36.,7.9,9.8,12.4,14.8,16.5,17.1,16.8,15.5,13.4,10.8,8.5,7.2,34.,
     *8.3,10.2,12.8,15.0,16.5,17.0,16.8,15.6,13.6,11.2,9.0,7.8,32.,
     *8.8,10.7,13.1,15.2,16.5,17.0,16.8,15.7,13.9,11.6,9.5,8.3,30.,
     *9.3,11.1,13.4,15.3,16.5,16.8,16.7,15.7,14.1,12.0,9.9,8.8,28.,
     *9.8,11.5,13.7,15.3,16.4,16.7,16.7,15.7,14.3,12.3,10.3,9.3,26.,
     *10.2,11.9,13.9,15.4,16.4,16.6,16.5,15.8,14.5,12.6,10.7,9.7,24.,
     *10.7,12.3,14.2,15.5,16.3,16.4,16.4,15.8,14.6,13.0,11.1,10.2,22.,
     *11.2,12.7,14.4,15.6,16.3,16.4,16.3,15.9,14.8,13.3,11.6,10.7,20.,
     *11.6,13.0,14.6,15.6,16.1,16.1,16.1,15.8,14.9,13.6,12.0,11.1,18.,
     *12.0,13.3,14.7,15.6,16.0,15.9,15.9,15.7,15.0,13.9,12.4,11.6,16./
c
c
c  Table 11, D&K.  Columns are N for each latitude.  Rows 1-12 are mont
c   Row 13 is latitude.
c
c
```

```
      data t11/10.1,11.0,11.9,13.1,14.0,14.5,14.3,13.5,12.4,11.3,
     *10.3,9.8,35.,10.4,11.1,12.0,12.9,13.6,14.0,13.9,13.2,12.4,11.3,
     *10.6,10.2,30.,10.7,11.3,12.0,12.7,13.3,13.7,13.5,13.0,12.3,11.6,
     *10.9,10.6,25.,11.0,11.5,12.0,12.6,13.1,13.3,13.2,12.8,12.3,11.7,
     *11.2,10.9,20.,11.2,11.6,12.0,12.5,12.8,13.0,12.9,12.6,12.2,11.8,
     *11.4,11.2,15./
c
c
c   Table 12, D&K.  Column 1 is temperature.  Column 2 is corresponding
c     factor.
c
c
      data t12/0.,2.,4.,6.,8.,10.,12.,14.,16.,18.,20.,22.,24.,26.,28.,
     *32.,34.,36.,38.,11.0,11.4,11.7,12.0,12.4,12.7,13.1,13.5,13.8,
     *14.2,14.6,15.0,15.4,15.9,16.3,16.7,17.2,17.7,18.1/
c
c
c   Table 15, D&K.  Column 1 is temperature.  Row 1 is altitude.  Elemen
c    are factors corresponding to altitude/temperature combinations.
c
c
      data t15/0.,2.,4.,6.,8.,10.,12.,14.,16.,18.,20.,22.,24.,26.,28.,
     *30.,32.,34.,36.,38.,40.,0.,0.43,.46,.49,.52,.55,.58,.61,.64,.66,
     *.69,.71,.73,.75,.77,.78,.80,.82,.83,.84,.85,500.,,.45,.48,.51,.54,
     *.57,.60,.62,.65,.67,.70,.72,.74,.76,.78,.79,.81,.82,.84,.85,.86,
     *1000.,,.46,.49,.52,.55,.58,.61,.64,.66,.69,.71,.73,.75,.77,.79,
     *.80,.82,.83,.85,.86,.87,2000.,,.49,.52,.55,.58,.61,.64,.66,.69,
     *.71,.73,.75,.77,.79,.81,.82,.84,.85,.86,.87,.88,3000.,,.52,.55,
     *.58,.61,.64,.66,.69,.71,.73,.75,.77,.79,.81,.83,.84,.85,.86,.88,
     *.88,.89/
c
c
c   Table 19.  Columns correspond to crop groups as per D&K Table 19.
c    Not more that 10 crops in a group.  Crop numbers corresponding to
c    crop listing given below place each crop in a group.
c
c     banana               1.0
c      tropical            1.1
c      subtropical         1.2
c     frijol               2.0
c      verde               2.1
c      seco                2.2
c     col                  3.0
c     algodon              4.0
c     vid                  5.0
c     cacahuete            6.0
c     maiz                 7.0
c      dulce               7.1
c      grano               7.2
c     cebolla              8.0
c      seca                8.1
c      verde               8.2
c     guisante fresco      9.0
```

```
c    pimentero,fresco   10.0
c    patata             11.0
c    arroz              12.0
c    cartamo            13.0
c    sorgo              14.0
c    soja               15.0
c    remolacha azucar   16.0
c    cana de azucar     17.0
c    girasol            18.0
c    tabaco             19.0
c    tomate             20.0
c    sandia             21.0
c    trigo              22.0
c    alfalfa            23.0
c
c
      data t19/8.1,8.2,10.0,11.0,0.,0.,0.,0.,0.,0.,
     %1.1,1.2,3.0,5.0,9.0,20.0,0.,0.,0.,0.,
     %23.0,2.1,2.2,6.0,18.0,21.0,22.0,0.,0.,0.,
     %4.0,7.1,7.2,13.0,14.0,15.0,16.0,17.0,19.0,0./
c
c
c  Table 20, D&K. Column 1 is etm.  Row 1 is crop group.  Elements
c   correspond to factors for etm and crop group.
c
c
      data t20/0.,2.,3.,4.,5.,6.,7.,8.,9.,10.,1.,.50,.425,.35,.30,.25,
     %.225,.20,.20,.175,2.,.675,.575,.475,.40,.35,.325,.275,.25,.225,
     %3.,.80,.70,.60,.50,.45,.425,.375,.35,.30,4.,.875,.80,.70,.60,
     %.55,.50,.45,.425,.40/
c
c
c  Table 22, D&K.  Last two digits correspond to asi.  Column 1 is etm.
c   Row 1 is remaining water (1-p)SaD.
c
c
      data t2283/0.,2.,4.,6.,8.,10.,25.,1.9,3.8,5.6,7.3,9.1,
     %50.,2.0,3.9,5.7,7.6,9.4,
     %100.,2.0,3.9,5.9,7.8,9.6,
     %150.,2.0,4.0,5.9,7.8,9.7,
     %200.,2.0,4.0,5.9,7.9,9.8/
      data t2267/0.,2.,4.,6.,8.,10.,
     %25.,1.8,3.3,4.8,6.1,7.5,
     %50.,1.9,3.6,5.2,6.7,8.1,
     %100.,1.9,3.8,5.5,7.2,8.8,
     %150.,2.0,3.8,5.7,7.4,9.1,
     %200.,2.0,3.9,5.7,7.5,9.3/
      data t2250/0.,2.,4.,6.,8.,10.,
     %25.,1.6,2.8,3.8,4.8,5.8,
     %50.,1.7,3.2,4.4,5.5,6.5,
     %100.,1.9,3.5,5.0,6.3,7.6,
     %150.,1.9,3.7,5.3,6.7,8.1,
     %200.,1.9,3.7,5.4,7.0,8.3/
```

```
      data t2233/0.,2.,4.,6.,8.,10.,
     *25.,1.3,2.1,2.8,3.5,4.2,
     *50.,1.6,2.7,3.5,4.3,5.0,
     *100.,1.9,3.2,4.3,5.3,6.2,
     *150.,1.8,3.4,4.7,5.9,7.0,
     *200.,1.9,3.5,5.0,6.3,7.5/
      data t2217/0.,2.,4.,6.,8.,10.,
     *25.,1.1,1.5,1.8,2.2,2.5,
     *50.,1.4,2.1,2.8,3.0,3.3,
     *100.,1.7,2.8,3.6,4.2,4.7,
     *150.,1.7,3.1,4.2,5.0,5.7,
     *200.,1.8,3.3,4.5,5.5,6.4/
      data t2200/0.,2.,4.,6.,8.,10.,
     *25.,0.8,0.8,0.8,0.8,0.8,
     *50.,1.2,1.5,1.6,1.7,1.7,
     *100.,1.5,2.3,2.8,3.0,3.2,
     *150.,1.7,2.7,3.5,4.0,4.3,
     *200.,1.7,3.0,4.0,4.7,5.1/
c
c
c  Table 16, DAX.  Second two digits are relative humidity maximum.
c   Last digit is ratio of daytime windspeed to nighttime windspeed.
c   Column 1 is rs.  Row 1 is udis.
c
c
      data t16304/0.,3.,6.,9.,12.,0.,.86,.90,1.00,1.00,3.,.79,.84,.92,
     *.97,6.,.68,.77,.87,.93,9.,.55,.65,.79,.90/
      data t16604/0.,3.,6.,9.,12.,0.,.96,.98,1.05,1.05,3.,.92,1.00,1.11
     *1.19,6.,.85,.96,1.11,1.19,9.,.76,.88,1.02,1.14/
      data t16904/0.,3.,6.,9.,12.,0.,1.02,1.06,1.10,1.10,3.,.99,1.10,
     *1.27,1.32,6.,.94,1.10,1.26,1.33,9.,.88,1.01,1.16,1.27/
      data t16303/0.,3.,6.,9.,12.,0.,.86,.90,1.00,1.00,3.,.76,.81,.88,
     *.94,6.,.61,.68,.81,.88,9.,.46,.56,.72,.82/
      data t16603/0.,3.,6.,9.,12.,0.,.96,.98,1.05,1.05,3.,.87,.96,1.06,
     *1.12,6.,.77,.88,1.02,1.10,9.,.67,.79,.88,1.05/
      data t16903/0.,3.,6.,9.,12.,0.,1.02,1.06,1.10,1.10,3.,.94,1.04,
     *1.18,1.28,6.,.86,1.01,1.15,1.22,9.,.78,.92,1.06,1.18/
      data t16302/0.,3.,6.,9.,12.,0.,.86,.90,1.00,1.00,3.,.69,.76,.85,
     *.92,6.,.53,.61,.74,.84,9.,.37,.48,.65,.76/
      data t16602/0.,3.,6.,9.,12.,0.,.96,.98,1.05,1.05,3.,.83,.91,.99,
     *1.05,6.,.70,.80,.94,1.02,9.,.59,.70,.84,.95/
      data t16902/0.,3.,6.,9.,12.,0.,1.02,1.06,1.10,1.10,3.,.89,.98,
     *1.10,1.14,6.,.79,.92,1.05,1.12,9.,.71,.81,.96,1.06/
      data t16301/0.,3.,6.,9.,12.,0.,.86,.90,1.00,1.00,3.,.64,.71,
     *.82,.89,6.,.43,.53,.68,.79,9.,.27,.41,.59,.70/
      data t16601/0.,3.,6.,9.,12.,0.,.96,.98,1.05,1.05,3.,.78,.86,.94,
     *.99,6.,.62,.70,.84,.93,9.,.5,.6,.75,.87/
      data t16901/0.,3.,6.,9.,12.,0.,1.02,1.06,1.10,1.10,3.,.85,.92,
     *1.01,1.05,6.,.72,.82,.95,1.00,9.,.62,.72,.87,.96/
c
c
c  Table 18, DAX.  Row 1 is crop number.  Columns correspond to
c   kc factors for each crop
```

```
c
c
      data t18/1.,1.,0.45,0.775,1.05,0.95,0.80,0.75,1.2,.575,.85,
     *1.1,1.075,1.075,.8,2.1,.35,.7,1.,.925,.9,.875,2.2,.35,.75,
     *1.125,.7,.275,.075,3.,.45,.75,1.025,.95,.875,.75,4.,.45,
     *.75,1.15,.85,.675,.85,5.,.45,.7,.8,.7,.625,.65,6.,.45,.75,
     *1.025,.8,.575,.775,7.1,.4,.8,1.125,1.075,1.025,.875,
     *7.2,.4,.775,1.125,.875,.575,.825,8.1,.5,.75,1.025,.875,.8,.85,
     *8.2,.5,.675,1.,1.,1.,.725,9.,.45,.775,1.125,1.075,1.025,.875,
     *10.,.35,.675,1.025,.925,.85,.75,11.,.45,.75,1.125,.9,.775,.825,
     *12.,1.175,1.3,1.2,1.,1.,1.125,13.,.35,.75,1.125,.675,.225,.675,
     *14.,.35,.725,1.075,.775,.525,.8,15.,.35,.75,1.125,.75,.45,.925,
     *16.,.45,.8,1.125,.95,.65,.85,17.,.45,.85,1.15,.775,.55,.95,
     *18.,.35,.75,1.125,.75,.4,.8,19.,.35,.75,1.1,1.,.8,.9,
     *20.,.45,.75,1.15,.875,.625,.825,21.,.45,.75,1.,.85,.7,.8,
     *22.,.35,.75,1.125,.7,.225,.85,
     *23.,0.95,0.95,0.95,0.95,0.95,0.95/
      end
      subroutine evapp
c ***************************
c     this subroutine calculates maximum potential evapotranspiration
c      for a reference crop based upon the method of penman.
c ***************************
      common / s / t9(40,2),t10(13,11),t11(13,5),t12(19,2),t15(21,6),
     *t16304(5,5),t16604(5,5),t16904(5,5),t16303(5,5),t16603(5,5),
     *t16903(5,5),t16302(5,5),t16602(5,5),t16902(5,5),t16301(5,5),
     *t16601(5,5),t16901(5,5),t19(10,4),t20(10,5),t2283(6,6),
     *t2267(6,6),t2250(6,6),t2233(6,6),t2217(6,6),t2200(6,6),
     *t18(7,27)
      common / d / temp(12),ea(12),ra(12),n(12),ftt(12),fed(12),
     *ed(12),fann(12),an(12),tfta(12),w(12),wa(13),fu(12),rs(12),
     *rnl(12),rn(12),ru(12),udia(12),unoche(12),rhmax(12),tab(5,5),
     *eto(12),c(12),rh(12),winit,etm(12),p(12),resid(12),asi(12),
     *teta(12),eta(12),pe(12),etac(5),etoc(5),staga(5,12),
     *ratio(5),ky(5),ym,yamax,yamin,kc(5),crop,xlat,alt,d,sa,ndos
      real n(12),kc(5),ky(5)
      dimension atem(12)
c ***************************
      do 1000 k=1,12
c
c
c       calculate saturation vapor pressure
c
c
      do 1 j=2,40
    1 if(temp(k).le.t9(j,1).and.temp(k).gt.t9(j-1,1)) nrow=j
      if(nrow.eq.0) ndos=1
      if(nrow.eq.0) return
      nrow1=nrow-1
      test=t9(nrow,1)-t9(nrow-1,1)
      if(test.eq.0.) ndos=11
      if(test.eq.0.) return
      ea(k)=(temp(k)-t9(nrow-1,1))/(t9(nrow,1)-t9(nrow-1,1))*
```

```
     1(t9(nrow,2)-t9(nrow-1,2))+t9(nrow-1,2)
c
c
c     calculate extraterrestrial radiation
c
c
      ncol=0
      do 2 j=1,10
    2 if(xlat.lt.t10(13,j).and.xlat.ge.t10(13,j+1)) ncol=j
      if(ncol.eq.0) ndos=2
      if(ncol.eq.0) return
      test=t10(13,ncol+1)-t10(13,ncol)
      if(test.eq.0.) ndos=21
      if(test.eq.0.) return
      ra(k)=(xlat-t10(13,ncol))/(t10(13,ncol+1)-t10(13,ncol))*
     1(t10(k,ncol+1)-t10(k,ncol))+t10(k,ncol)
c
c
c     calculate maximum possible hours of radiation
c
c
      ncol=0
      do 3 j=1,4
    3 if(xlat.lt.t11(13,j).and.xlat.ge.t11(13,j+1)) ncol=j
      if(ncol.eq.0) ndos=3
      if(ncol.eq.0) return
      test=t11(13,ncol+1)-t11(13,ncol)
      if(test.eq.0.) ndos=31
      if(test.eq.0.) return
      n(k)=(xlat-t11(13,ncol))/(t11(13,ncol+1)-t11(13,ncol))*
     1(t11(k,ncol+1)-t11(k,ncol))+t11(k,ncol)
c
c
c     calculate actual vapor pressure
c
c
      ed(k)=ea(k)*rh(k)/100.
c
c
c       calculate temperature attenuation effect
c
c
      nrow=0
      do 4 j=2,19
    4 if(temp(k).gt.t12(j-1,1).and.temp(k).le.t12(j,1)) nrow=j-1
      if(nrow.eq.0) ndos=4
      if(nrow.eq.0) return
      test=t12(nrow+1,1)-t12(nrow,1)
      if(test.eq.0.) ndos=41
      if(test.eq.0.) return
      ftc(k)=(temp(k)-t12(nrow,1))/(t12(nrow+1,1)-t12(nrow,1))*
     1(t12(nrow+1,2)-t12(nrow,2))+t12(nrow,2)
c
```

```
c
c        calculate vapor pressure attentuation factor
c
c
      fed(k)=0.34-0.044*sqrt(ed(k))
c
c
c         calculate adjustment for actual radiation
c
c
      funn(k)=0.1+0.9*an(k)/n(k)
c
c
c         evaluation of temperature/altitude adjustment factor
c
c
      nrow=0
      do 55 i=3,21
   55 if(temp(k).gt.t15(i-1,1).and.temp(k).le.t15(i,1)) nrow=i-1
      if(nrow.eq.0) ndos=5
      if(nrow.eq.0) return
      ncol=0
      do 5 j=3,6
    5 if(alt.gt.t15(1,j-1).and.alt.le.t15(1,j)) ncol=j-1
      if(ncol.eq.0) ndos=6
      if(ncol.eq.0) return
      test1=t15(nrow+1,1)-t15(nrow,1)
      test2=t15(1,ncol+1)-t15(1,ncol)
      if(test1.eq.0.) ndos=51
      if(test2.eq.0.) ndos=61
      if(test1.eq.0.or.test2.eq.0.) return
c
c
c         calculate temperature/altitude factor
c
c
      tfta(k)=(temp(k)-t15(nrow,1))/(t15(nrow+1,1)-t15(nrow,1))*
     1(t15(nrow+1,ncol)-t15(nrow,ncol))+t15(nrow,ncol)
      w(k)=(alt-t15(1,ncol))/(t15(1,ncol+1)-t15(1,ncol))*
     1(t15(nrow,ncol+1)-t15(nrow,ncol))+tfta(k)
c
c
c         calculate wind factor
c
c
      u=(n(k)*60.**2*udia(k)+(24.-n(k))*60.**2*unoche(k))/1000.
      fu(k)=0.27*(1.+u/100.)
c
c
c         calculate more radiation factors
c
c
      rs(k)=(0.25+0.50*an(k)/n(k))*ra(k)
```

```
      rnl(k)=ftc(k)*fann(k)*fad(k)
      rn(k)=0.75*rs(k)-rnl(k)
c
c
c           calculate c factor
      ru(k)=udia(k)/unoche(k)
      do 6 i=2,3
      do 6 j=2,5
      if(rhmax(k).ge.30.and.rhmax(k).lt.60.) go to 60
      go to 69
   60 if(ru(k).le.4.and.ru(k).gt.3.)
     1tab(i,j)=-(ru(k)-4.0)*((rhmax(k)-30.)/30.*
     2(t16603(i,j)-t16303(i,j))+t16303(i,j)-((rhmax(k)-30.)/30.*
     3(t16604(i,j)-t16304(i,j))+t16304(i,j)))
     4+(rhmax(k)-30.)/30.*(t16604(i,j)-t16304(i,j))+t16304(i,j)
      if(ru(k).le.3.and.ru(k).gt.2.)
     1tab(i,j)=-(ru(k)-3.0)*((rhmax(k)-30.)/30.*
     2(t16602(i,j)-t16302(i,j))+t16302(i,j)-((rhmax(k)-30.)/30.*
     3(t16603(i,j)-t16303(i,j))+t16303(i,j)))
     4+(rhmax(k)-30.)/30.*(t16603(i,j)-t16303(i,j))+t16303(i,j)
      if(ru(k).le.2.and.ru(k).ge.1.)
     1tab(i,j)=-(ru(k)-2.0)*((rhmax(k)-30.)/30.*
     2(t16601(i,j)-t16301(i,j))+t16301(i,j)-((rhmax(k)-30.)/30.*
     3(t16602(i,j)-t16302(i,j))+t16302(i,j)))
     4+(rhmax(k)-30.)/30.*(t16602(i,j)-t16302(i,j))+t16302(i,j)
      go to 79
   69 continue
      if(ru(k).le.4.and.ru(k).gt.3.)
     1tab(i,j)=-(ru(k)-4.0)*((rhmax(k)-60.)/30.*
     2(t16903(i,j)-t16603(i,j))+t16603(i,j)-((rhmax(k)-60.)/30.*
     3(t16904(i,j)-t16604(i,j))+t16604(i,j)))
     4+(rhmax(k)-60.)/30.*(t16904(i,j)-t16604(i,j)      604(i,j)
      if(ru(k).le.3.and.ru(k).gt.2.)
     1tab(i,j)=-(ru(k)-3.0)*((rhmax(k)-60.)/30.*
     2(t16902(i,j)-t16602(i,j))+t16602(i,j)-((rh.   .)-60.)/30.*
     3(t16903(i,j)-t16603(i,j))+t16603(i,j)))
     4+(rhmax(k)-60.)/30.*(t16903(i,j)-t16603(i,j))+t16603(i,j)
      if(ru(k).le.2.and.ru(k).ge.1.)
     1tab(i,j)=-(ru(k)-2.0)*((rhmax(k)-60.)/30.*
     2(t16901(i,j)-t16601(i,j))+t16601(i,j)-((rhmax(k)-60.)/30.*
     3(t16902(i,j)-t16602(i,j))+t16602(i,j)))
     4+(rhmax(k)-60.)/30.*(t16902(i,j)-t16602(i,j))+t16602(i,j)
   79 continue
    6 continue
      ncol=0
      nrow=0
      do 7 i=2,4
      if(udia(k).gt.t16304(1,i).and.udia(k).le.t16304(1,i+1)) ncol
    7 if(rs(k).gt.t16304(i,1).and.rs(k).le.t16304(i+1,1)) nrow=i
      if(ncol.eq.0.or.nrow.eq.0) ndod=8
      if(ncol.eq.0.or.nrow.eq.0) return
      xnrow=nrow
      xncol=ncol
```

```
      c(k)=(udia(k)-(xncol*3.-6.))/3.*((rs(k)-(xnrow*3.-3.))/3.*
     1(tab(nrow+1,ncol+1)-tab(nrow,ncol+1))+tab(nrow,ncol+1)-
     2((rs(k)-(xnrow*3.-3.))/3.*(tab(nrow+1,ncol)-tab(nrow,ncol))
     3+tab(nrow,ncol)))
     4+(rs(k)-(xnrow*3.-3.))/3.*(tab(nrow+1,ncol)-tab(nrow,ncol))
     5+tab(nrow,ncol)
c
c
c         calculate reference evapotranspiration
c
c
      eto(k)=c(k)*(w(k)*rn(k)+(1.-w(k))*fu(k)*(ea(k)-ed(k)))
c
c
 1000 continue
c
c
c        calculate monthly maximum evapatranspiration
c
c
      do 101 k=1,12
  101 etem(k)=0.0
      do 100 k=1,12
      do 100 i=1,5
      if(stage(i,k).eq.30.) etem(k)=etem(k)+kc(i)*stage(i,k)*eto(k)
      if(stage(i,k).gt.0.and.stage(i,k).lt.30.) etem(k)=etem(k)+kc(i)*
     *stage(i,k)*eto(k)+(30.-stage(i,k))*eto(k)
      if(stage(i,k).eq.0.) etem(k)=eto(k)*30.
  100 continue
      do 102 k=1,12
  102 etm(k)=etem(k)
      return
      end
      subroutine evapa
      common / s / t9(40,2),t10(13,11),t11(13,5),t12(19,2),t15(21,6),
     *t16304(5,5),t16604(5,5),t16704(5,5),t16303(5,5),t16603(5,5),
     *t16903(5,5),t16302(5,5),t16602(5,5),t16902(5,5),t16301(5,5),
     *t16601(5,5),t16901(5,5),t19(10,4),t20(10,5),t2283(6,6),
     *t2267(6,6),t2250(6,6),t2233(6,6),t2217(6,6),t2200(6,6),
     *t18(7,27)
      common / d / temp(12),ea(12),ra(12),n(12),ftc(12),fed(12),
     *ed(12),fann(12),an(12),tfta(12),w(12),wa(13),fu(12),rs(12),
     *rnl(12),rn(12),u(12),udia(12),unoche(12),rhmax(12),tab(5,5),
     *eto(12),c(12),rh(12),winit,etm(12),p(12),resid(12),asi(12),
     *teta(12),eta(12),pe(12),etac(5),etoc(5),stage(5,12),
     *ratio(5),ky(5),ym,ymax,ymin,kc(5),crop,xlat,alt,d,sa,ndog
      real n(12),kc(5),ky(5)
      dimension tetm(12)
c
c
c         find crop group
c
c
```

```
      do 1 i=1,4
      do 1 j=1,10
    1 if(t19(j,i).eq.crop) ngroup=i
c
c
      ws(0)=max(0.0,winit)
      do 1001 k=1,12
c
c
c        find exhaustion fraction
c
c
      tetm(k)=etm(k)/30.
      ncol=ngroup+1
      do 2 i=3,10
    2 if(tetm(k).gt.t20(i-1,1).and.tetm(k).le.t20(i,1)) nrow=i
      if(nrow.eq.0) nrow=3
      test=t20(nrow,1)-t20(nrow-1,1)
      if(test.eq.0.) ndos=69
      if(test.eq.0.) return
      p(k)=(tetm(k)-t20(nrow-1,1))/(t20(nrow,1)-t20(nrow-1,1))*
     1(t20(nrow,ncol)-t20(nrow-1,ncol))+t20(nrow-1,ncol)
      resid(k)=(1.0-p(k))*d*sa
c
c
c          calculate asi and eta
c
c
      if(etm(k).eq.0.) ndos=79
      if(etm(k).eq.0.) return
      asi(k)=(pe(k)+ws(k-1)-resid(k))/etm(k)
      if(asi(k).lt.0.0) eta(k)=pe(k)+ws(k-1)
      if(asi(k).ge.1.0) eta(k)=etm(k)
      if(asi(k).ge.1.0.or.asi(k).lt.0.0) go to 600
      do 3 i=2,6
      do 3 j=2,6
      if(asi(k).lt.1.0.and.asi(k).ge.0.83) tab(i,j)=(asi(k)-0.83)/
     1(1.0-0.83)*(tetm(k)-t2283(i,j))+t2283(i,j)
      if(asi(k).lt.0.83.and.asi(k).ge.0.67) tab(i,j)=(asi(k)-0.67)/
     1(0.83-0.67)*(t2283(i,j)-t2267(i,j))+t2267(i,j)
      if(asi(k).lt.0.67.and.asi(k).ge.0.50) tab(i,j)=(asi(k)-0.50)/
     1(0.67-0.50)*(t2267(i,j)-t2250(i,j))+t2250(i,j)
      if(asi(k).lt.0.50.and.asi(k).ge.0.33) tab(i,j)=(asi(k)-0.33)/
     1(0.50-0.330)*(t2250(i,j)-t2233(i,j))+t2233(i,j)
      if(asi(k).lt.0.33.and.asi(k).ge.0.17) tab(i,j)=(asi(k)-0.17)/
     1(0.33-0.17)*(t2233(i,j)-t2217(i,j))+t2217(i,j)
      if(asi(k).lt.0.17.and.asi(k).ge.0.00) tab(i,j)=(asi(k)-0.00)/
     1(0.17-0.00)*(t2217(i,j)-t2200(i,j))+t2200(i,j)
    3 continue
      nrow=0
      ncol=0
      do 4 i=2,6
      if(tetm(k).le.t2283(i,1).and.tetm(k).gt.t2283(i-1,1)) nrow=i
```

```
    4 if(resid(k).le.t2283(1,i).and.teta(k).gt.t2283(1,i-1)) ncol=i
      if(nrow.eq.0.or.ncol.eq.0) nrow=4
      if(nrow.eq.0.or.ncol.eq.0) ncol=4
c      if(nrow.eq.0.or.ncol.eq.0) ndos=10
c      if(nrow.eq.0.or.ncol.eq.0) return
      test1=t2283(nrow,1)-t2283(nrow-1,1)
      test2=t2283(1,ncol)-t2283(1,ncol-1)
      if(test1.eq.0.) ndos=100
      if(test2.eq.0.) ndos=101
      if(test1.eq.0.or.test2.eq.0.) return
      teta(k)=(tetm(k)-t2283(nrow-1,1))/(t2283(nrow,1)-t2283(nrow-1,1))*
     1(tab(nrow,ncol)-tab(nrow-1,ncol))+tab(nrow-1,ncol)
      eta(k)=((resid(k)-t2283(1,ncol-1))/(t2283(1,ncol)-t2283(1,ncol-1))
     1*(tab(nrow,ncol)-tab(nrow,ncol-1))+teta(k))*30.
  600 continue
c
c
c      investigate the above interpolation
c
c
      wa(k)=pe(k)+wa(k-1)-eta(k)
 1001 continue
      return
      end
      subroutine adjust
c ***************************************
c          this subroutine calculates the maximum potential
c           evapotranspiration and actual evapotranspiration
c           for each stage of the crop development cycle.
      common / s / t9(40,2),t10(13,11),t11(13,5),t12(19,2),t15(21,6),
     *t16304(5,5),t16604(5,5),t16904(5,5),t16303(5,5),t16603(5,5),
     *t16903(5,5),t16302(5,5),t16602(5,5),t16902(5,5),t16301(5,5),
     *t16601(5,5),t16901(5,5),t19(10,4),t20(10,5),t2283(6,6),
     *t2267(6,6),t2250(6,6),t2233(6,6),t2217(6,6),t2200(6,6),
     *t18(7,27)
      common / d / temp(12),ea(12),ra(12),n(12),ftc(12),fed(12),
     *ed(12),fann(12),an(12),tfta(12),w(12),wa(13),fu(12),rs(12),
     *rnl(12),rn(12),ru(12),udia(12),unoche(12),rhmax(12),tab(5,5),
     *eto(12),c(12),rh(12),winit,etm(12),p(12),resid(12),asi(12),
     *teta(12),eta(12),pe(12),etac(5),etoc(5),stage(5,12),
     *ratio(5),ky(5),wm,wamax,wamin,kc(5),crop,xlat,alt,d,sa,ndos
      real n(12),kc(5),ky(5)
c ***************************************
      do 1 i=1,5
      etac(i)=0.0
    1 etoc(i)=0.0
      do 2 i=1,5
      do 2 k=1,12
      if(stage(i,k).gt.0.) etoc(i)=etoc(i)+stage(i,k)*etm(k)/30.
      if(stage(i,k).gt.0.) etac(i)=etac(i)+stage(i,k)*eta(k)/30.
    2 continue
      do 22 i=1,5
   22 write(6,5000) etoc(i), etac(i)
```

```
 5000 format(3x,1p2e20.2)
      return
      end
      subroutine yielda
c ***********************************
c        this subroutine calculates actual yield as a function of
c          actual and potential evapotranspiration at each stage
c          of crop development
c ***********************************
      common / s / t9(40,2),t10(13,11),t11(13,5),t12(19,2),t15(21,6),
     *t16304(5,5),t16604(5,5),t16904(5,5),t16303(5,5),t16603(5,5),
     *t16903(5,5),t16302(5,5),t16602(5,5),t16902(5,5),t16301(5,5),
     *t16601(5,5),t16901(5,5),t19(10,4),t20(10,5),t2283(6,6),
     *t2267(6,6),t2250(6,6),t2233(6,6),t2217(6,6),t2200(6,6),
     *t18(7,27)
      common / d / temp(12),ea(12),ra(12),n(12),ftc(12),fed(12),
     *ed(12),fann(12),an(12),tfta(12),w(12),wa(13),fu(12),rs(12),
     *rnl(12),rn(12),ru(12),udia(12),unoche(12),rhmax(12),tab(5,5),
     *eto(12),c(12),rh(12),winit,etm(12),p(12),resid(12),asi(12),
     *teta(12),eta(12),pe(12),etac(5),etoc(5),stage(5,12),
     *ratio(5),ky(5),ym,yamax,yamin,kc(5),crop,xlat,alt,d,sa,ndos
      real n(12),kc(5),ky(5)
c ***********************************
      do 1 i=1,5
      if(etac(i).eq.0.) ndos=200
      if(etoc(i).eq.0) return
      ratio(i)=(1.0-etac(i)/etoc(i))*ky(i)
    1 if(ratio(i).gt.1.0) ratio(i)=1.0
      do 10 i=1,5
   10 write(6,5000) ratio(i),ky(i),etac(i),etoc(i)
 5000 format(3x,1p4e20.2)
      ymin=1.0
      ymax=0.0
      do 2 i=1,5
      ymin=ymin*(1.0-ratio(i))
      ymax=max(ymax,ratio(i))
      write(6,5000) ymin
      write(6,5000) ymax
    2 continue
      yamin=ymin*ym
      yamax=(1.0-ymax)*ym
      return
      end
      subroutine output
      common / s / t9(40,2),t10(13,11),t11(13,5),t12(19,2),t15(21,6),
     *t16304(5,5),t16604(5,5),t16904(5,5),t16303(5,5),t16603(5,5),
     *t16903(5,5),t16302(5,5),t16602(5,5),t16902(5,5),t16301(5,5),
     *t16601(5,5),t16901(5,5),t19(10,4),t20(10,5),t2283(6,6),
     *t2267(6,6),t2250(6,6),t2233(6,6),t2217(6,6),t2200(6,6),
     *t18(7,27)
      common / d / temp(12),ea(12),ra(12),n(12),ftc(12),fed(12),
     *ed(12),fann(12),an(12),tfta(12),w(12),wa(13),fu(12),rs(12),
     *rnl(12),rn(12),ru(12),udia(12),unoche(12),rhmax(12),tab(5,5),
```

```
     *eto(12),c(12),rh(12),winit,etm(12),p(12),resid(12),asi(12),
     *teta(12),eta(12),pe(12),etac(5),etoc(5),stage(5,12),
     *ratio(5),ky(5),ym,yamax,yamin,kc(5),crop,xlat,alt,d,sa,ndos
      real n(12),kc(5),ky(5)
      data iff/o '14'/
      write(6,499) iff
  499 format(a1,////3x,18hinput data summary//)
      write(6,501) crop,ym,xlat,alt,d,sa,winit
  501 format(3x,7hcrop = ,f12.2,13x,24hmaximum yield (kg/ha) = ,
     *f10.2,4x,21hlatitude (degrees) = ,f4.1/
     *3x,20haltitude (meters) = ,f6.2,6x,21hroot zone (meters) = ,
     *f3.2,14x,32havailable soil moisture (mm/m) = ,f5.1/
     *3x,34hinitial available moisture (mm) = ,f5.1////)
      write(6,502)
  502 format(3x,20hmonthly data (mean)//)
      write(6,503)
  503 format(3x,11htemperature,4x,13hprecipitation,2x,
     *13hmax. humidity,2x,3x,8hhumidity,4x,12hdaytime wind,3x,
     *13hnightime wind,5x,8hsunshine/4x,9h(celsius),10x,4h(mm),
     *11x,3h(%),12x,3h(%),10x7h(m/sec),8x,7h(m/sec),
     *8x,8h(hr/day)//)
      do 1 k=1,12
    1 write(6,504)temp(k),pe(k),rhmax(k),rh(k),udia(k),unoche(k),an(k)
  504 format(3x,7(f10.2,5x))
      write(6,505)
  505 format(////3x,49hcrop stages, by month (duration of stage in days
     *//63x,5hmonth/3x,5hstage,4x,1h1,5x,1h2,5x,1h3,5x,1h4,5x,
     *1h5,5x,1h6,5x,1h7,5x,1h8,5x,1h9,5x,2h10,4x,2h11,4x,2h12//)
      do 2 i=1,5
    2 write(6,506)i,(stage(i,k),k=1,12)
  506 format(5x,i1,3x,12f6.2)
      write(6,507) iff
  507 format(a1,////3x,23hresults of the analysis////)
      write(6,508) ym,yamax,yamin
  508 format(3x,24hmaximum yield (kg/ha) = ,f10.2/
     *3x,31hmaximum actual yield (kg/ha) = ,f10.2/
     *3x,31hminimum actual yield (kg/ha) = ,f10.2////)
      write(6,509)
  509 format(3x,26hmaximum evapotranspiration,5x,
     *25hactual evapotranpiration//)
      do 3 k=1,12
    3 write(6,510) etm(k),eta(k)
  510 format(6x,1pe20.2,10x,1pe20.2)
      write(6,511) iff
  511 format(a1////3x,20hintermediate results//11x,5hea(k),15x,5hra(k),
     *15x,5h n(k),15x,5hed(k),15x,5hfed(k,15x,5h fann//)
      do 4 k=1,12
    4 write(6,512) ea(k),ra(k),n(k),ed(k),fed(k),fann(k)
  512 format(1x,1p6e20.6)
      write(6,513) iff
  513 format(a1////3x,20hintermediate results//11x,5htfta(,15x,5h w(k),
     *15x,5hfu(k),15x,5hrs(k),15x,5hrnl(k,15x,5hrn(k)//)
      do 5 k=1,12
```

```
  5 write(6,512) tfta(k),w(k),fu(k),rs(k),rnl(k),rn(k)
    write(6,514) iff
514 format(a1////3x,20hintermediate results//11x,5h u(k),15x,5h c(k),
   *15x,5heto(k,15x,5h p(k),15x,5hwa(k),15x,5hasi(k//)
    do 6 k=1,12
  6 write(6,512) ru(k),c(k),eto(k),p(k),wa(k),asi(k)
    return
    end
    subroutine dos
    common / s / t9(40,2),t10(13,11),t11(13,5),t12(19,2),t15(21,6),
   *t16304(5,5),t16604(5,5),t16904(5,5),t16303(5,5),t16603(5,5),
   *t16903(5,5),t16302(5,5),t16602(5,5),t16902(5,5),t16301(5,5),
   *t16601(5,5),t16901(5,5),t19(10,4),t20(10,5),t2283(6,6),
   *t2267(6,6),t2250(6,6),t2233(6,6),t2217(6,6),t2200(6,6),
   *t18(7,27)
    common / d / temp(12),ea(12),ra(12),n(12),ftc(12),fed(12),
   *ed(12),fann(12),an(12),tfta(12),w(12),wa(13),fu(12),rs(12),
   *rnl(12),rn(12),ru(12),udia(12),unoche(12),rhmax(12),tah(5,5),
   *eto(12),c(12),rh(12),winit,atm(12),p(12),resid(12),asi(12),
   *teta(12),ata(12),pe(12),etac(5),etoc(5),stage(5,12),
   *ratio(5),ky(5),ym,yamax,yamin,kc(5),crop,xlat,alt,d,sa,ndos
    real n(12),kc(5),ky(5)
    write(6,501) ndos
501 format(///3x,24hout of bounds at ndos = ,i3)
    return
    end
```

CHAPTER 6: OPPORTUNITY STUDY

INTRODUCCION

Cada vez más y más la evidencia demuestra que el uso agrícola de Plásticos especiales puede conducir a incrementos substanciales en la productividad por área. Experiencias previas de ésta y otras instituciones han demostrado que el uso de agroplásticos puede aumentar el rendimiento de las cosechas, disminuir los costos de producción, al mismo tiempo que permite obtener cosechas fuera de las temporadas usuales. Tomando en cuenta los objetivos de desarrollo nacional, los plásticos agrícolas podrían contribuir substancialmente a lograr las metas de producción alimentaria que se han fijado y coadyuvar a reducir las marcadas diferencias de desarrollo que actualmente existen entre las áreas urbanas y rurales. El empleo de plásticos podría también ayudar a fortalecer los nexos entre los sectores petroquímico y agrícola.

1.- Este reporte presenta el potencial que podría tener el empleo de plásticos especiales en la agricultura nacional para lograr los objetivos de desarrollo económico y social basados en esta actividad económica. Un reporte adicional, en etapa de preparación, examina la posible relación que este desarrollo podría tener con la industria petroquímica nacional y la posible contribución adicional que esta interrelación podría tener para ayudar al logro de los objetivos nacionales de desarrollo económico y social.

Este trabajo se basa en información incompleta, su propósito es solamente el demostrar que existen oportunidades que deben de ser evaluadas más a fondo. Ofrece un plan tentativo para llevar a cabo una mejor evaluación de las posibilidades de empleo de plásticos en la agricultura nacional y regional de tal suerte que permita tomar decisiones para implementar proyectos y definir políticas que promuevan empleo de tecnologías de agroplasticultura en las regiones agrícolas de México, en particular aquellas de las zonas áridas.

Este trabajo incluye los siguientes puntos:

2.- Tecnología de Plasticultura.

Diversos productos plásticos han sido utilizados en diferentes aplicaciones agrícolas. Entre éstos cabe mencionar al acolchado o arropado de suelos, agriculturas en sistemas controlados (como en invernaderos, macro y microtúneles), y en irrigación y drenaje. En todas estas aplicaciones se ha demostrado que el uso de plásticos permite reducir costos y/o aumentar la producción y ganancias. Los siguientes párrafos describen brevemente las técnicas más importantes e ilustran los resultados que se pueden obtener al hacer uso de ellas.

a.- Acolchado.

El acolchado.- colocar una película plástica sobre el terreno cultivado y desarrollar las plantas a través de pequeños orificios hechos a la película, permite conservar mayor volumen de agua al evitar su evaporación, aumentar la temperatura del suelo, modificar la estructura del mismo evitando su compactación, disminuir problemas de salinidad, controlar el crecimiento de maleza si se emplean películas opacas, disminuir el uso de fertilizantes, reducir los tiempos de las cosechas y en general a aumentar substancialmente la productividad y obtener productos de mejor calidad. El acolchado ha sido empleado con éxito en el cultivo de granos, hortalizas, forrajes y frutales.

La técnica de acolchado es muy simple, requiere la preparación usual del terreno, la colocación de la película ya sea manual o mecánicamente, horadación de ésta respetando el marco de plantación, transplante y (si se utilizan materiales no degradables), la remoción de la película al terminar el ciclo del cultivo. Diferentes tipos de películas pueden ser usadas, con diversas pigmentaciones, grosores y anchos dependiendo de la aplicación y el resultado deseado.

El ancho de la película está dado por la altura del surco a cubrir (si tan solo se cubre un solo surco) o por la distancia entre surcos o hileras. En algunos casos, sobre todo si se cuenta con métodos de irrigación como goteo, chorreo o aspersión, se pueden desarrollar los cultivos en terrenos profundos sin necesidad de preparar surcos, lo que disminuye la cantidad de plástico requerido. Usualmente se pueden utilizar anchos de 60 a 70 cms hasta 1.20 m. Películas- - más anchas se pueden utilizar para cubrir 3 o más surcos.

Las películas pueden ser transparentes o pigmentadas en - diversos colores. El negro opaco es generalmente la pigmentación más común. Las películas transparentes, porque permiten el paso de la luz solar, calientan más el suelo- y promueven la obtención de cosechas tempranas; tienen la desventaja de no impedir el crecimiento de muchas hierbas bajo de ellas lo que disminuye, comparativamente, los rendimientos. Las películas negras evitan lo anterior permitiendo mejores rendimientos aunque no se obtienen cosechas tan precoces como en el caso de los materiales transparentes.

El grosor de las películas puede variar desde 15 micrones (o.o15 mm, con un peso aproximado de 15 g/m^2) hasta 100 ó más micrones. El mayor grosor permite su uso en más de - un ciclo agrícola o su empleo en la protección de arbus-- tos o árboles por tres o más años.

La película se vende por kilos, siendo su precio actual - de aproximadamente $ 60.00/kg, para película transparente y de un 10 a un 15% más para películas pigmentadas. Esto significa que el transformador vende la resina hecha película con un 100 a un 120% mínimo de aumento de precio sobre el valor de la resina empleada. El costo del material, de cubrir completamente de plástico una hectárea es aproximadamente $ 9,000.00 para una película de 15 micrones (150 Kg/Ha); de $ 24,000.00 de usarse una película de 40 micrones (400 Kg/Ha), etc. Esto no incluye costos de colocación ni remoción, mismos que deberán de tomarse en cuenta al llevar a cabo un análisis económico. Es posible sin embargo que estos costos adicionales sean menores o no incidan totalmente si se toma en cuenta el ahorro de agua, fertilizantes y mano de obra para remover hierbas.

Como se mencionó antes existe gran cantidad de información que documenta las ventajas de usar acolchados en la agricultura. Generalizando se puede decir que permite obtener incrementos en el rendimiento (un aumento desde un 20% hasta más del 100%), dependiendo del cultivo, tipo de irrigación y otras técnicas agrícolas utilizadas. Permite también obtener cosechas precoces de dos hasta seis semanas y el proteger las plántulas recién trasplantadas contra bajas de temperatura, lo que en ocasiones puede significar hasta meses en el adelanto de la cosecha.

Además de las anteriores observaciones generales, experimentos realizados en México confirman el hecho de que hay excelentes posibilidades de incrementar los rendimientos de las cosechas en las condiciones climáticas y de suelo generalmente encontradas en nuestro país. El CIQA ha experimentado acolchado en -- granos y hortalizas desde 1979, concentrando esfuerzo en - hortalizas ya que se consideró que éstas podrían pagar más facilmente el costo adicional del plástico. No obstante - se han realizado experimentos para determinar las variedades de maíz y frijol que dieran mejores resultados. Los - primeros experimentos compararon 22 variedades de maíz y 4 de frijol. En el caso de maíz dos de ellas respondieron - substancialmente mejor que el resto; el frijol no dió re-- sultados sobresalientes y no ha sido investigado en deta-- lle después de esta primera experiencia.

La siguiente tabla presenta los resultados obtenidos con - las dos variedades de híbridos seleccionadas como las mejo res. Estas se investigaron bajo irrigación con tres diferentes densidades de siembra.

TABLA 1

Rendimientos de Maíz (Kg/Ha) utilizando acolchado de PVC de 50 micrones.

Plantas/Ha.	Híbrido	Acolchado	Sin acolchar
60,000	AN-460	7925	5356
	AN-466	7779	5459
70,000	AN-460	7938	6256
	AN-466	6329	5877
80,000	AN-460	7798	5866
	AN-466	7306	6575

En el caso del maíz, a pesar de que se pueden obtener incrementos substanciales en el rendimiento, el costo de la película es mayor que el valor del producto que se obtiene. Por el bajo precio relativo de los granos, el uso de plásticos para acolcharlos puede resultar incosteable a menos que películas más delgadas y consecuentemente más baratas puedan ser utilizadas.

Experimentos realizados recientemente en las cercanías de la ciudad de México ponen de manifiesto los problemas asociados con la producción de granos con esta técnica. La producción de maíz bajo acolchado fué de 1500 Kg/Ha, comparado con un rendimiento de solo 300 Kg/Ha. en las mismas condiciones, sin utilizar plásticos para acolchar. Este aumento de productividad es típico de los resultados que se pueden obtener utilizando acolchado en áreas de secano de alto riesgo. Aún cuando se quintuplicó el rendimiento, el costo del plástico es superior a los beneficios adicionales que se obtienen al utilizarlo.

Los cultivos hortícolas dan también buenos resultados bajo estas condiciones. Se ha llevado a cabo experimentación para determinar los incrementos que se pueden obtener al cultivar pimientos, tomates y otras hortalizas empleando esta técnica. La tabla 2 presenta los resultados obtenidos porinvestigadores del CIQA en el cultivo de tomates acolchados con películas de polietileno (PE), durante dos ciclos agrícolas.

TABLA 2

RENDIMIENTOS DE TOMATE BAJO ACOLCHADO (TON/HA)

Tipo de Película (Micrones)	Rendimiento Promedio 1980	1981	combinado	% de Incremento 1980	1981	combinado
PE negro (175)	55.5	56.3	55.9	79	107	92
PE negro (40)	50.4	43.7	47.1	62	61	62
PE acol- (40) chado.	48.6	41.7	45.1	57	54	55
Sin Acolchar	31	27.1	29.1	--	--	--

Como se puede observar, se pueden obtener importantes incrementos en la producción utilizando este tipo de técnicas. Otro importante resultado que se obtiene es el de la precocidad de las cosechas, como se mencionó con anterioridad. Por ejemplo, el uso de películas transparentes permitió en este caso obtener cosechas 30 días antes que el testigo, las películas negras hicieron posible una precocidad de 15 a 20 días comparada con el testigo.

Resultados igualmente favorables se han obtenido en el cultivo de pimientos con esta técnica. La tabla 3 presenta los resultados obtenidos durante dos ciclos agrícolas en el caso del cultivo de pimientos. Como con los tomates, cosechas de 23 a 27 días de precocidad se pueden obtener de esta manera.

TABLA 3

RENDIMIENTO DE PIMIENTO CON ACOLCHADO (TON/HA)

Tipo de Película (Micrones)	Rendimiento Promedio 1980	1981	combinado	% de Incremento 1980	1981	combinado
PE negro (175)	42.2	50.6	46.4	95.4	101.6	100
PE negro (40)	36	47.5	41.7	66.7	89.2	79.7
PE acolchado. (40)	32.9	52.8	42.9	52.3	110.3	84.9
Sin acolchar	21.6	25.1	23.2	--	- -	- -

En el caso de pimientos tipo Anaheim también se han obtenido incrementos substanciales en el rendimiento obtenido. La tabla 4 presenta los resultados de un experimento. En este caso la primera recolección se logró 74 días después de llevado a cabo el transplante en el campo; por comparación el testigo sin acolchar dió los primeros cortes 88 -- días después de transplantado.

TABLA 4

RENDIMIENTO DE PIMIENTO ANAHEIM BAJO ACOLCHADO (PVC NEGRO, 50 MICRONES)

Densidad de siembra/Ha	Rendimiento (Ton/ha.) Testigo	Acolchado
27 174	28.3	40.1
36 232	29.9	49.1
45 290	30.5	54.9
54 348	36.5	48.1

Buscando disminuir los costos de empleo de agroplásticos en acolchado se ha experimentado con películas potencialmente más económicas como el "Asfaleno". Este material se produce para fines de investigación en el Instituto Mexicano del Petróleo. Ya que a la resina de PE con la que se produce se le incorporan residuos de asfalto, su precio es menor que el de películas de grosores comparativos fabricados con PE exclusivamente. Cuando es suficientemente gruesa, la película es prácticamente opaca funcionando como una película pigmentada con negro de humo. Se probó en dos grosores y cubriendo uno o tres surcos, en el último caso se hicieron orificios a intervalos regulares en las regaderas, de tal suerte que el agua de irrigación pudiese penetrar por los mismos. A esta última alternativa se le denomina recubrimiento total en la siguiente tabla 5, la que presenta los resultados obtenidos al acolchar pimientos con este tipo de materiales.

TABLA 5

RENDIMIENTOS DE ASFALENO EN ACOLCHADO DE PIMIENTO (CALIFORNIA WONDER)

Tipo de película	Rendimiento Promedio (Tons/Ha).
Sin acolchar	10.6
Asfaleno CA-2 (20)	11.7
PE negro (20)	22.7
Asfaleno (137.5)	19.5
Asfaleno total (137.5)	25.3

b).- Agricultura en sistemas controlados.

Otro uso de plásticos que tiene gran importancia es su empleo en la construcción de invernaderos y túneles. Los invernaderos se cubren por lo general de películas de "larga duración" (duración mínima deseable de 18 meses) de 4 a 6 milésimas de pulgada de espesor hechas de polietileno o cloruro de polivinilo. Se emplean también otros materiales como plásticos reforzados con fibra de vidrio y, en menor cantidad, películas de poliéster, copolímeros y polifluoruro de vinilo.

Su menor costo, facilidad de manejo, resistencia y facilidad de producción de películas de varios anchos, han hecho que el polietileno se emplee extensamente para este propósito aunque su vida media es comparativamente corta. Los materiales reforzados tienen mayor resistencia al intemperismo y ofrecen mayor protección en casos de tormentas y vientos fuertes pero su costo es substancialmente mayor que el de polietileno.

Los plásticos pueden ser también importantes elementos en la conservación de energía. Por ejemplo, una doble cubierta plástica con un espacio libre entre las películas puede ayudar a conservar el calor por efecto de esta capa de aire aislante al mismo tiempo que disminuye la condensación. Este efecto aislante puede incrementarse si se -

inyecta espuma de jabón entre las cubiertas.

Los materiales plásticos pueden servir para recolectar energía solar y para distribuir agua caliente con ayuda de goteos, sobre intercambiadores de calor. Otros usos incluyen la ventilación de invernaderos y la distribución de calor a través de tubería, en irrigación, sombras, ensilaje y otras. Una innovación que se utiliza cada vez más es la hidroponia por medio de la cual los cultivos se desarrollan con las raíces dentro de tubos de plástico a través de los cuales se circula una solución de nutrientes; en estas condiciones las plantas no requieren del suelo para obtener sus alimentos.

El emplear agriculturas en medios controlados disminuye el uso de insumos (agua y fertilizantes) y aumenta los rendimientos. En la tabla 6 se ejemplifica el uso de estas técnicas para ahorrar agua; los datos son de experimentos realizados en regiones del suroeste de Estados Unidos. Como se observa, en estas condiciones pueden lograrse ahorros notables de agua si se compara con las necesidades de agua de agriculturas convencionales.

TABLA 6

USO DE AGUA: COMPARACION ENTRE AGRICULTURA DE AMBIENTE CONTROLADO Y A CIELO ABIERTO.

Cultivo	Litros de agua para irrigación /Kg de producción	
	Ambiente Controlado	cielo abierto
Pepino	10	205
Lechuga	3	96
Tomate	13	123

Los rendimientos que se obtienen pueden ser impresionantes; la tabla 7 reporta rendimientos promedio de cultivos obtenidos en invernaderos en Abu Dhabi. Estos rendimientos son muy superiores a los obtenidos a cielo abierto.

TABLA 7

RENDIMIENTO DE COSECHAS DESARROLLADAS EN INVERNADEROS EN ABU DHABI (TON/HA)

Hortaliza	Variedad	Rendimiento/Ha.	Cosechas/año	Rendimiento/ Ha/año.
Brocoli	Hybrid #5	32.5	3	97.5
Ejote	Green crop	11.5	4	46.0
Col	Exp. Cross 60	57.5	3	172.0
Col china	Tropicana	50.0	4	200.0
Pepino	Femfrance	175.0	3	525.0
Berenjena	Jersey King	28.0	2	56.0
Pimiento	New Ace	32.5	2	97.5
Tomate	N-65	150.0	2	300.0

Los mayores rendimientos se deben en parte a las condiciones ideales de crecimiento lo que permite tiempos de cultivo mayores que los usuales. Además, cultivos trepadores - como los pepinos y tomates usan más eficientemente el volumen de los invernaderos lo que permite optimizar los rendimientos. Ya que las condiciones climáticas internas pueden ser controladas, es posible el producir cosechas en -- cualquier época del año aún bajo condiciones externas adversas. De esta manera se pueden obtener productos frescos de gran calidad durante todo el año, mientras que desarrollados fuera de invernaderos el desarrollo depende de la época del año.

c).- Irrigación y Drenaje.

Los plásticos pueden también ser usados en irrigación y drenaje ya sea en tuberías de irrigación, hidráulicas, - sistemas de drenaje, recubrimiento de canales y embalses y en la cosecha de agua donde puede usarse substituyendo favorablemente otros materiales. Por ejemplo, en la tabla 8 se presentan los costos y eficiencias de varios sistemas - para cosechar agua. Como se puede observar los métodos -- que usan plásticos, aunque de mayor precio, resultan más - eficientes en la colección de agua, una ventaja muy importante en el contexto de zonas áridas.

T A B L A 8

COSTO Y EFICIENCIA DE VARIOS METODOS DE COSECHA DE AGUA

Método	Costo/Acre (1)	Vida Media (2) (Años)	Costo/año (3)	Eficiencia (4)	(3)/(4)
Tierra compactada	110	3-5	33.50	15-20	1.91
Tierra compactada y tratada con sodio	300	10-15	47.39	40-60	0.95
Plástico cubierto de grava	2200	30-40	295.13	60-80	4.13
Tratamiento con cera	2650	5-10	523.23	80-90	6.26
Fibra de vidrio cubierta de asfalto y grava	4925	15-20	703.34	85-95	7.81
Asfalto cubierto de hule y grava	5460	20-25	744.24	85-95	8.27
Plástico cubierto con mortero reforzado con polipropileno	11400	50-60	1487.64	90-95	16.08

NOTA: La computación del costo anual amaortiza los costos a una tasa de interés del 15% en un número de años igual a - la media del intervalo mostrado. El costo en relación a - la eficiencia se calcula en la media del intervalo de eficiencia reportado.

3.- Contribución potencial de la plasticultura en la pro -- ducción y beneficios agrícolas.

Lo reportado anteriormente ilustra el efecto potencial- de la plasticultura sobre los rendimientos. La perspecti -

va económica puede desarrollarse si se examinan los efectos que puede tener sobre los beneficios obtenidos. Una idea aproximada de los efectos que puede tener la plasticultura sobre los objetivos de desarrollo social y económico relacionados con la productividad agrícola y sus beneficios, puede obtenerse calculando los efectos potenciales de estas técnicas de aceptarse su uso en la agricultura mexicana.

Se escogió el acolchado, ya que es la más simple y fácil de adaptarse de las tecnologías, la que requiere menor inversión y la que posiblemente tendrá mayor efecto y relación sobre y con la industria de transformación de plásticos.

Se sugiere al lector ejerza cautela al estudiar los cálculos aquí presentados ya que se han hecho simplificaciones en el tratamiento de los datos. El propósito de este ejercicio es el de enfatizar el potencial que percibimos, por lo que se recomienda no se saquen conclusiones finales sin llevar a cabo un análisis más a fondo. Sin embargo los resultados dan indicaciones de lo que se puede esperar.

a).- Efectos sobre ganancias agrícolas.

En la Tabla 9 se presenta un análisis de los efectos que la plasticultura puede tener sobre las ganancias agrícolas. En ella se reportan incrementos estimados de las ganancias para varios cultivos (condicionados a los incrementos sobre la producción). Aunque rendimientos mucho mayores han sido obtenidos experimentalmente, como se reportó antes, el análisis considera incrementos de tan sólo 10, 20 y 30% respectivamente.

TABLA 9

EFECTO DEL ACOLCHADO SOBRE LAS GANANCIAS AGRICOLAS POR Ha.

	(1) Rendimiento promedio actual Kg/Ha.	(2) Incremento en un 10% Kg/Ha.	20%	30%	(3) Precio Rural	(4) Incremento de las ganancias. 10%	20%	30%
Ajo	4956	496	991	1487	15.2	5967	1566	9099
Cebolla	11450	1145	2290	3435	29.5	20278	54055	87833
Pimiento	6876	688	1375	2063	11.4	5661	2177	10016
Frijol	600	60	120	180	15.0	12600	11700	10800
Tomate	16050	1605	3210	4815	8.5	143	13785	27428
Maíz	1207	121	241	362	5.8	12800	12100	11400
Fresa	16020	1602	3204	4806	12.2	6044	25589	45133
Café	611	61	122	183	97.4	7549	1598	4353
Pepino	20712	2071	4142	6214	8.1	3277	20053	36830
Berenjena	18978	1880	3760	5639	9.7	4734	22960	41202

La columna (1) de la tabla reporta rendimientos promedio usando técnicas agrícolas comunes. Estos rendimientos son el promedio del reportado para los años 1970-74 en todos los casos con excepción del de pepino. En este último caso el pepino mostró grandes incrementos en productividad durante 1970-78; por esta razón se tomó el dato del año 1978 por considerarlo el más apegado a la realidad actual y es el reportado en la tabla.

Los incrementos se calcularon suponiendo que las cantidades de insumos agrícolas usados con o sin plástico permanecen - constantes. Esto es tan solo una aproximación ya que es -- probable que el empleo de estos insumos, tales como el agua y fertilizantes, se disminuiría al utilizar los plásticos;- consecuentemente la reducción de uso de estos otros insumos aumentaría la ganancia obtenida y debe de ser considerada - en los análisis futuros. Por lo tanto los incrementos re-- portados en la columna (4) son posiblemente menores a los - que se puede esperar una vez tomando en cuenta lo anterior.

b).- Efecto sobre el Consumo de Plásticos.

La tabla 1ʳ reporta estimaciones del efecto que ten--- drán sobre el consumo de plásticos, de aceptarse, las técni cas de acolchado. La columna (1) reporta el total de Has. cultivadas a nivel nacional en cada uno de los cultivos, -- éstas se tomaron como un promedio de las áreas cultivadas - durante los años 1970-74.

La columna (2) representa la cantidad de incremento en Kg/Ha suponiendo diferentes aumentos en el rendimiento, tabulando- incrementos del 10, 20 y 30%. Los resultados experimentales del CIQA y otras instituciones muestran que mayores incremen tos, del orden del 50 al 100%, pueden ser obtenidos; sin embargo en este primer análisis solamente se considera un au-- mento de hasta el 30%.

En la columna (3) se reporta un precio rural promedio estima do para cada cultivo. Los valores de esta columna se calcularon duplicando el valor de los precios rurales promedio re portados en 1972. Se supuso este incremento del 100% en el- valor para ajustar los precios después de la devaluación.

La columna (4) reporta la ganancia adicional que se puede ob tener, calculando el valor de la producción adicional y restándole el precio del plástico utilizado. En todos los ca-- sos se supuso un costo de $ 13,500/Ha. como el valor proba-- ble de la película, considerando que ésta cubriría totalmente el área de cultivo y que se utilizaría una película con - un grosor de 25 micrones (i.e., 250 kg. de plástico por Ha. X $ 54.00/Kg. de plástico). La cifra negativa significa que el incremento estimado en la ganancia sería negativo (i.e.,- que el costo de plástico sería superior al valor del incre-- mento en la producción). Como puede observarse para maíz y- frijol, en todos los casos se obtiene un incremento negativo.

T A B L A 10

CONSUMO POTENCIAL DE PLASTICOS EN EL CULTIVO EN LA AGRICULTURA NACIONAL. (Ton. Métricas).

Cultivo	Area Cultivada	Area Total (2)	Consumo de Plásticos Cultivos rentables con incrementos de 10% (3)	20% (4)	30% (5)
Ajo	6678	1670	-0-	1670	1670
Cebolla	22871	5718	5718	5718	5718
Pimiento	50934	12734	-0-	12734	12734
Frijol	1764076	441019	-0-	-0-	-0-
Tomate	65761	16440	16440	16440	16440
Maíz	7349419	1837355	-0-	-0-	-0-
Fresa	6575	1644	1644	1644	1644
Café	367019	91755	-0-	-0-	91755
Pepino	9316	2329	2329	2329	2329
Berenjena	1058	265	265	265	265
T O T A L		2410929	26396	40800	132555

La columna (2) indica la cantidad de plásticos que se requerirían utilizarse 250 Kg/Ha. para acolchado (i.e., utilizando películas de 25 micrones) en el área total bajo cultivo para las cosechas consideradas. Como puede verse, aproximadamente 2.4 millones de tons. se utilizarían anualmente si el plástico fuera utilizado para cubrir el total de las áreas agrícolas del país.

La columna (3) reporta el consumo esperado de plásticos si éste se utilizara en el total del área cultivada de aquellas cosechas que muestran una ganancia positiva, al incrementar su rendimiento en un 10% usando acolchados. Las columnas (4) y (5) - - reportan las cifras de ganancia considerando un 20 y un 30% de aumento en el rendimiento, respectivamente. Como puede- observarse el usar plásticos en acolchado exclusivamente en las cosechas en las cuales su uso arroja un incremento positivo en las ganancias, reduce considerablemente el consumo- estimado de plásti-os en la agricultura.

c).- Incrementos Mínimos Rentables.

El porcentaje de incremento en productividad que se necesita para hacer que el acolchado resulte rentable, depende del costo del acolchado y del aumento adicional de ganancia percibida por el aumento en el rendimiento. En la tabla 11 se reportan los incrementos mínimos rentables, suponiendo el costo de utilización de acolchados es de $ 13,500-.0u/Ha.

TABLA 11

INCREMENTOS MINIMOS RENTABLES PARA EL USO DE ACOLCHADO

Cultivo	Rendimiento Promedio (Kg/Ha)	Precio Rural ($/Kg)	Incrementos Mínimos Rentables (%)
Ajo	4956	15.2	18
Cebolla	11450	29.5	4
Pimiento	6876	11.4	17
Frijol	600	15.0	150
Tomate	16050	8.5	10
Maíz	1207	5.8	193
Fresa	16020	12.2	7
Café	611	97.4	23
Pepino	20712	8.1	8
Berenjeno	18798	9.7	7

Como puede verse, varios cultivos, principalmente las hortalizas, pueden resultar rentables al utilizar acolchado. El mercado potencial que puede generar este uso es lo suficientemente grande para resultar un negocio interesante para la Industria de Transformación. Las posibilidades de empleo podrían también aumentar considerablemente si se implementaran políticas nacionales que canalizaran las resinas sintéticas, con precios preferenciales, a la agricultura. Por ejemplo, aún cuando el cultivo de granos dé solamente beneficios económicos marginales (en el mejor de los casos), una política bien definida podría incrementar estos márgenes hasta hacerlos atractivos. Se puede suponer que el maíz y frijol, cultivados en áreas de irrigación, podrían utilizar plásticos siempre y cuando el aumento de precio que el transformador cargue por el proceso no fuera muy grande. Actualmente la Industria de Transformación aumenta el valor de la resina en más del 100% al - transformarlo; si este aumento no fuese tan grande ésto - permitiría que aún el cultivo de granos bajo acolchado pudiera ser rentable y de esta manera facilitaría su empleo. Si se considera que más de 300,000 Has. se utilizan para estos cultivos, un mercado adicional de un mínimo de 75,000 ton/año podría ser generado.

Las posibilidades son bastante claras, deberá de tomarse la decisión de explotarlas.

OBJETIVOS Y TAREAS.

Como se explicitó anteriormente, se perciben oportunidades para implementar el uso de plásticos en la agricultura regional y nacional. Sin embargo se contemplan también un número considerable de problemas, tanto de planteamiento como conceptuales y operativos para hacer que esta oportunidad se transforme en realidad. El taller de trabajo tiene como objetivo estructurar una primera definición de la problemática que habrá de resolverse. El propósito de éste es el discutir y definir los principales factores que contribuirán al desarrollo de la plasticultura; se pretende también el presentar la metodología que se seguirá durante el año de trabajo que se estima durará el estudio de evaluación tecnológica.

Entre los aspectos relevantes que habrá que contemplar y estudiar, para incorporar en las actuales fronteras agrícolas el uso de plásticos, se encuentran:

- Prospectiva de desarrollo petroquímico del país.
- Capacidad agrícola de regiones semiáridas.
- Impacto de innovaciones tecnológicas en las regiones semiáridas.
- Planes y programas de desarrollo regional.
- Flujo de materiales y energía de la región.
- Infraestructura de la región.
- Desertificación.

En este primer taller de trabajo se habrá de considerar si estos aspectos son efectivamente los más relevantes o si habrán de incrementarse otros más. A un nivel de mayor definición, habrán de considerarse los factores que a continuación se enlistan, tratando de definir para cada uno de ellos cuáles son las preguntas críticas que habrán de plantearse en cada una de estas áreas y, posiblemente, tratar de darles respuesta.

1.- Factores que influirán en la definición de empleo de plásticos en la agricultura mexicana.

1).- Factores Técnicos.

a.- Experimentación.

Habrán de llevarse a cabo experimentos en diversas regiones agroclimáticas para determinar las mejores prácticas agrícolas y los incrementos de producción posibles.

b.- Utilidad.

Relacionado con lo anterior, habrán de determinarse los requisitos tanto de materiales plásticos como de técnicas agrícolas y climáticos, para ubicar el desempeño de las técnicas y materiales según su uso y localidad geográfica.

2.- Factores Administrativos.

a.- Administración de desarrollos agrícolas.

Habrá de determinarse la capacidad del medio rural para aceptar un grado cualitativo mayor de complejidad en las labores agrícolas. Tendrán que considerarse aspectos de eficiencia técnica requerida, aumento en la complejidad del manejo, etc.

b.-Transferencia de Tecnología.

Tendrán que determinarse los factores que facilitarán o dificultarán la transferencia de la tecnología. Entre otros, la capacidad regional y nacional de extensionismo incorporando estas técnicas. La dificultad de que las técnicas se acepten, etc.

3.- Factores Organizativos.

a.- Tipo de Organización Actual.

Habrá que determinar cuales organizaciones ejidales, cooperativas agrícolas, pequeños propietarios, etc., están en capacidad de aceptar o promover el uso de plásticos y cuales serán las principales restricciones organizativas internas que dificultarían la aceptación y empleo de ellos.

b.- Programas Existentes.

Habrá que determinar qué planes y proyectos, actualmente en marcha, pueden incorporar, para el logro de sus objetivos los desarrollos de plasticultura propuestos.

Habrán de determinarse las restricciones para lograrlo, los métodos de carácter político que habrán de incorporarse o utilizarse para lograr difundir el empleo de las técnicas.

4.- Mercado.

a.- Agroplásticos Agrícolas.

Será necesario determinar que dificultades y restricciones pueden tenerse para el abastecimiento de agroplásticos; teniendo en cuenta factores de precio, localización, transporte al lugar de empleo, calidad de los materiales, etc.

b.- Distribución de la Producción.

No es suficiente el aumentar la producción de hortalizas y granos para asegurar el mejoramiento económico de los productores, es de gran relevancia el determinar los factores que influyen en la venta, distribución, almacenamiento, etc., de los mismos. Se tratará de determinar cuáles son los más importantes problemas a resolver de darse un desarrollo de esta índole.

5.- Aspectos Financieros.

a.- Agricultura.

Habrá de determinarse la capacidad de los agricultores y comunidades rurales para incurrir a los gastos adicionales que significa la compra de materiales plásticos. Determinar sus restricciones crediticias, capacidad de pago, etc. Así como los factores de políticas de apoyo financiero y/o subsidios que tendrían que ser conseguidos para lograr ayudar a la compra de los materiales.

b.- Gobierno.

Relacionado con lo anterior, habrán de determinarse las políticas y necesidades de ellas para ayudar a resolver las restricciones económicas de los usuarios agrícolas de plásticos. ¿Qué incentivo se puede ofrecer? ¿Cuál sería el riesgo económico para el gobierno? ¿Qué mecanismos de crédito financieros pueden asegurarse para lograrlo?.

6.- Factores Económicos.

a.- Precio de Materiales.

Usualmente el transformador carga más del 100% al transformar una resina plástica y un producto; el caso de películas plásticas agrícolas no es diferente. Habrá de determinarse la posibilidad de incidir sobre el mecanismo de precios, de tal suerte que el usuario asegure el mejor precio posible y la mejor calidad de película que satisfaga sus necesidades.

b.- Distribución del Ingreso.

Habrá que determinar en qué medida influirá el uso de plásticos en aumentar las ganancias netas y de qué manera se puede asegurar una distribución más justa que facilite ésto.

Tendrpa que darse especial consideración a esta área, sobre todo relacionando los factores comerciales y financieros antes mencionados.

7.- Factores Ambientales.

a.- Suelo.

Si bien el uso de plásticos en acolchado redunda en beneficios temporales a la estructura del suelo y su composición, su uso no restringido puede conllevar problemas de contaminación de suelo y de posible erosión. Habrá que determinar qué resultados diversos pueden esperarse al utilizarlos y de qué manera contribuir a minimizar esta problemática.

b.- Agua.

El uso de plásticos permite el ahorro de agua en diferentes proporciones, sin embargo puede tener problemas asociados con el de modificar los escurrimientos, cambiar las características de aprovechamiento del agua y de recuperación de mantos férticos. Se tiene que definir el grado de impacto que puede tener y determinar los mecanismos necesarios para evitar impactos negativos en esta área.

8.- Factores Sociales.

a.- Emigración.

Es bien sabido el proceso de emigración del campo a los centros urbanos. Se tendrá que definir en que manera el uso de plásticos puede influir favorablemente en este proceso, disminuyéndolo o incluso haciéndolo rentable. Se tendrá que determinar también si el proceso de emigración no riñe con el posible aumento en mano de obra que se requerirá a través del uso de plásticos.

b.- Bienestar Social.

Relacionado con lo anterior, se tendrá que analizar el grado de incidencia que puede tener la plasticultura sobre la necesidad de aumentar los mínimos de bienestar rurales y, de esta manera, modificar el proceso de emigración que se observa.

9.- Políticas.

a.- Políticas Relevantes.

Habrá que definir y estudiar las políticas federales y estatales que puedan ayudar en el proceso de aceptación y difusión de las técnicas de plasticultura. Cuáles son sus alcances, cuáles son los resultados obtenidos anteriormente, etc.

b.- Nuevas Políticas.

De carecer de políticas directamente relacionadas con el uso de nuevos materiales en la agricultura, habrá de determinarse la conveniencia de recomendar modificaciones a las actuales políticas, o a otras que se generen para ayudar en el proceso del uso e implementación de la plasticultura.