10
2-24/92 JSD

ORNL/SUB/88-SC616/2

**OAK RIDGE
NATIONAL
LABORATORY**

MARTIN MARIETTA

Development of a Farm-Firm Modelling System for Evaluation of Herbaceous Energy Crops

Burton C. English
Robert R. Alexander
Kitty Hawk Loewen
Sean A. Coady
Gary V. Cole
W. Robert Goodman

MANAGED BY
MARTIN MARIETTA ENERGY SYSTEMS, INC.
FOR THE UNITED STATES
DEPARTMENT OF ENERGY

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

This report has been reproduced directly from the best available copy.

Available to DOE and DOE contractors from the Office of Scientific and Technical Information, P.O. Box 62, Oak Ridge, TN 37831; prices available from (615) 576-8401, FTS 626-8401.

Available to the public from the National Technical Information Service, U.S. Department of Commerce, 5285 Port Royal Rd., Springfield, VA 22161.

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

**DEVELOPMENT OF A FARM-FIRM MODELLING SYSTEM
FOR EVALUATION OF HERBACEOUS ENERGY CROPS**

**Burton C. English
Robert R. Alexander
Kitty Hawk Loewen
Sean A. Coady
Gary V. Cole
W. Robert Goodman**

**Department of Agricultural Economics
and Rural Sociology
University of Tennessee
Knoxville, TN 37996-4500**

FINAL PROJECT REPORT

March 1991

**Research supported by
Biofuels Systems Division
Office of Transportation Technologies
Activity No. EB 24 13 01 0**

**Report prepared by
Department of Agricultural Economics
and Rural Sociology
University of Tennessee
Knoxville, TN 37996-4500
under Subcontract No. 41X-SC616C**

for

**Biofuels Feedstock Development Program
Environmental Sciences Division
OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37831-6285
managed by
MARTIN MARIETTA ENERGY SYSTEMS, INC.
for the
U.S. DEPARTMENT OF ENERGY
under contract DE-AC05-84OR21400**

DATE PUBLISHED: JANUARY 1992

MASTER

TABLE OF CONTENTS

LIST OF TABLES	v
LIST OF FIGURES	vii
ABSTRACT	ix
INTRODUCTION	1
The Integration of Biomass Production Systems With Traditional Agricultural Practices	2
The Farm Level Agricultural Resource Environmental Modelling System	2
METHODOLOGY	6
Selection of a Farm Level Simulation Model	6
Criteria for Model Selection	6
Model Selection	9
Selection of Data Support Models	14
The Budget Generator	14
The Plant Growth Simulator	16
The Optimizer	17
DATA REQUIREMENTS	18
Representative Farm Development	18
Farm Resources and Characteristics	19
Production Expenses and Financial Status	20
Macroeconomic Assumptions	21
Dynamic Simulations	22
Representative Farm Use	23
Demonstration Farms	24
Western Tennessee Representative Farms	24
Size of Farm (25); Land Use Patterns and Characteristics (25); Equipment Complements (26); Financial Resources (27)	
Southern Georgia Representative Farm	28
Size of Farm (29); Land Use Patterns and Characteristics (29); Equipment Complements (30); Financial Resources (31)	
RESEARCH RESULTS	32
Break-even Analysis for Switchgrass	32
Employing the <i>F.L.A.R.E.</i> Modeling System to Simulate Biomass Production	32
Analytical Framework	33
Erosion Levels	34
Financial Performance	39
Government Deficiency and Diversion Payments	41
Conclusions	42
BIBLIOGRAPHY	45

LIST OF TABLES

Table 1. Results of stage one criteria selection.	11
Table 2. Results of stage two criteria selection.	12
Table 3. Research conducted using FLIPSIM V.	13
Table 4. Forecasts of interest rates and percent annual change in input costs, 1988-1997.	22
Table 5. Forecast of annual mean crop prices, 1988-1997.	23
Table 6. Representative farm soils, Weakley and Haywood counties, MLRA 134.	26
Table 7. Land characteristics and USLE factors, Weakley and Haywood counties, MLRA 134.	27
Table 8. Crop hectareages and yields on the Tift county representative farm.	30
Table 9. Land and soil erosion characteristics, Tift county, MLRA 133.	31
Table 10. Break-even analysis of switchgrass as a biomass energy crop.	33
Table 11. Four alternative management systems evaluated.	34
Table 12. Weakley county farm: crop hectareages, USLE erosion factors, and erosion rates.	36
Table 13. Haywood county farm: crop hectareages, USLE erosion factors, and erosion rates.	37
Table 14. Tift county farm: crop hectareages, USLE erosion factors, and erosion rates.	38
Table 15. Simulated net farm income of representative farms, 1986-1995.	40
Table 16. Simulated net cash income of representative farms, 1986-1995.	41
Table 17. Simulated government payments to representative farms, 1986-1995.	43

LIST OF FIGURES

Figure 1. The Farm Level Agricultural, Resource, and Environmental modelling system.	4
Figure 2. Issues addressable by the <i>F.L.A.R.E.</i> system.	5
Figure 3. Recursive priority programs.	8
Figure 4. Criteria for evaluating decision-making models.	10
Figure 5. Location of representative farms.	19
Figure 6. Description of the Weakley county representative farm.	24
Figure 7. Description of the Haywood county representative farm.	25
Figure 8. Description of the Tift county representative farm.	28
Figure 9. Per hectare change in net farm income between base and alternative farm plans.	39
Figure 10. Per hectare change in government payments between base and alternative farm plans.	42

ABSTRACT

Economic analysis of agricultural production possibilities and their impacts on the producer of these commodities and his/her firm are complex. The diversity that exists in the farm enterprise, type, geographic location, size, resource endowments, and management abilities require careful consideration when evaluating the addition of a potential crop and management system to the set of production possibilities. Add to these diverse and complicating factors the various policies under consideration, and very quickly the analytical task becomes enormous.

The growing of herbaceous energy crops will require farmer acceptance if large amounts of land are to be devoted. While price of the biomass and hence net returns will play a significant role, numerous other factors require evaluation if adoption of biomass growing practices is achieved. The impacts growing this new crop have on traditional operations require exploration. Information on how government policy will assist or retard adoption need to be determined. The promoter of biomass development will be compelled to address questions regarding resource needs and their impacts on farm firm survival. Finally, in time of fund shortages, justification of subsidies required to hasten biomass production will be required. The purpose of this project is to develop a system that is capable of addressing each of the above issues.

A complete analysis is performed to simulate biomass production incorporated into a realistic whole farm situation, including or replacing a typical crop mix. Representative farms are constructed to accommodate such simulation. Four management systems are simulated for each farm, with each simulation depicting a different crop mix and/or use of different farming technologies and production methods. The first simulation was a base farm plan in which the operator would maintain the historical crop mix for the area, participate in all price support programs, and not participate in either a conservation reserve or a biomass production program. In the second simulation, the operator would again maintain the historical crop mix, would not participate in a conservation reserve or biomass production program, and would be ineligible to participate in any price support program. The third simulation introduced the Conservation Reserve Program (CRP) and included participation in all price support programs. The fourth simulation introduced a biomass crop production enterprise (switchgrass) as an alternative to enrolling highly erodible cropland in the CRP and allowed participation in price support programs. Simulations were made for three farms, two in West Tennessee and one in South Georgia.

Results indicate that erosion is likely to be reduced more by the diversion of cropland to permanent vegetative cover on farms similar to the more highly erodible West Tennessee farms than on the less erodible Tift county, Georgia farm. Equivalent reductions in erosion rates result from entering highly erodible cropland in the CRP and from production of switchgrass as a biomass energy crop. Both switchgrass and CRP farm plans result in decreased net returns from the base plan, although the biomass farm plans are, in general, more profitable than the CRP plans. Levels of government involvement can be reduced while maintaining current erosion rates if producers are permitted to produce a biomass crop for sale on land now enrolled in CRP.

INTRODUCTION

Economic analysis of agricultural production possibilities and their impacts on the producer of these commodities and his/her firm are complex. The diversity that exists in the farm enterprise, type, geographic location, size, resource endowments, and management abilities require careful consideration when evaluating the addition of a potential crop and management system to the set of production possibilities. Add to these diverse and complicating factors the various policies under consideration, and very quickly the analytical task becomes enormous.

If large quantities of herbaceous energy crops are to be produced, a significant commitment on the part of farmers to convert large amounts of farmland will be required. While price of the biomass and hence net returns will play a significant role, numerous other factors require evaluation if adoption of biomass growing practices is achieved. The impacts that growing this new crop have on traditional operations require exploration. Information on how government policy will assist or retard adoption need to be determined. The promoter of biomass development will be compelled to address questions regarding resource needs and their impacts on farm firm survival. Finally, in time of fund shortages, justification of subsidies required to hasten biomass production will be required. The purpose of this project is to develop a system that is capable of addressing each of the above issues. Specifically, the project had four objectives including:

1. To construct break-even measures that are capable of estimating the economic viability of various production practices;
2. To develop a system capable of evaluating the sensitivity of these break-even estimates caused by weather variability;
3. To provide estimates on erosion potential including the impacts that erosion might have on yield; and
4. To develop a methodology, in coordination with other Biofuels Feedstock Development Program funded studies, that will expand plot data to some level of aggregation.

The Integration of Biomass Production Systems With Traditional Agricultural Practices

Farm level models must accommodate a complex set of factors. For biomass analysis the set of factors must include the decision making process, resource availability and quality, equipment complement currently owned, agricultural

policies impacting the farm firm, tax policies,

biological production process, and

environmental impacts. Broadly speaking,

the production of energy on the farm will

depend on the productivity of the firm's

"...quantitative micro- and macro models should not be viewed as a framework for obtaining the answers... Rather, models should be viewed as learning tools that sharpen the qualitative professional judgement of economists." (Taylor, 1983, p. 71)

natural resources, the financial structure of the farm firm, current agricultural policy, as well as the prospects for profit. Tax policies, required investments, and perceived market will directly impact the decision to produce. Finally, perceived risk of the new production enterprise and the degree to which firm survivability is affected will influence the decision. To assist in incorporating these complex variables into an analytical framework, a modeling system is developed.

The Farm Level Agricultural Resource Environmental Modelling System

During the past three years, farm firm modeling has moved from one concentrating on adjustments due to agricultural policy or to resource constraints to one capable of addressing the two simultaneously. At the University of Tennessee (UT), the Micro Oriented Agricultural Production System (MOAPS) (Cole and English, 1990) and now the Farm Level Agricultural, Resource, and Environmental modeling system (*F.L.A.R.E.*) have been developed to better evaluate changes in technology, changes in production practices, and the impacts of resource and/or commodity policy changes on the ability of the farm firm to survive. These two modeling systems have been employed in evaluating farm options and the likelihood of adoption based on either a profit maximization criteria or a minimize deviation in net farm income criteria. Both criteria are required if evaluation of acceptance of an individual policy is sought. The current system employed by UT faculty, *F.L.A.R.E.*,

is designed to empirically analyze the individual and combined impacts of commodity, resource and cross-compliance policy issues at the farm level.

The *F.L.A.R.E.* modeling system integrates several models and numerous data to describe the farm firm. This modeling system provides the researcher a picture of a farm firm along with possible alternative production possibilities. Under a prescribed policy, the farm firm's likely response can be evaluated. This response depends upon the objectives of the producer, the resource and policy constraints in effect, and the option being evaluated.

The heart of the *F.L.A.R.E.* system is the central farm firm database. In the development stage, production costs, financial parameters, and farm production and environmental indicators are generated from external farm-level simulations and stored in the database. The *F.L.A.R.E.* user selects farm and policy options from an integrated user interface to construct the data set which is input into the optimizing model. This central database design offers exceptional power and flexibility in the specification of policy and environmental alternatives.

The system currently has fourteen farm firms developed. They are located in Tennessee, Georgia, Nebraska, Iowa, Kansas, Alabama, and Ohio. Additional farms are currently being constructed. The farms are designed to represent the major types and sizes of farm and ranch operations in their respective regions of the U.S. Thus the impacts of policy, alternative technologies, and restricted environmental regulations can be evaluated over farm types in different regions of the U.S. under different resource endowment levels. Existing and planned farms include a variety of commodity enterprises; soil types, slopes and lengths; and financial conditions.

The flexibility of the *F.L.A.R.E.* database results in a modeling system suitable for the analysis of a wide variety of policy issues. Among the capabilities of *F.L.A.R.E.* are the ability to assess the impacts of farm income and commodity control policies, the impacts of soil and water conservation practices, and the impacts of compliance with existing or proposed legislation on farm returns and the environment.

A schematic of the *F.L.A.R.E.* development system is shown in Figure 1. In developing the central farm firm database, a farm plan is developed based upon social, economic and geographical conditions, policy options, and the available resource base.

Currently, production costs are derived using the *Budget Planner*, a budgeting program from the University of California, Davis. The

Figure 1. The Farm Level Agricultural, Resource, and Environmental modelling system.

parameters imposed by the preliminary farm plan are used to standardize the information entering the associated simulation models.

The impacts of environmental variables on plant growth are modelled in the Erosion Productivity Impact Calculator (EPIC). EPIC provides data on yield impacts and other plant growth variables resulting from various tillage practices, weather patterns, and general plant growth environmental conditions. This provides the necessary data to measure the impacts of soil and water conservation practices, the impacts of variable soil types, slopes and slope lengths, and the impacts of erosion on farm production.

The results from the previous two simulators either go directly to the central database, or are combined with policy and macroeconomic data as input into the whole-farm simulator. The FLIPSIM V model is currently used in the *F.L.A.R.E.* system for general crop farms, but other models may also be substituted as needs for specialized enterprise simulations arise. Each farm's data are then compiled into the central farm firm database.

Figure 2 shows a conceptual representation of the types of problems the *F.L.A.R.E.* system is designed to address. Issues in biomass adoption and production are well-suited to *F.L.A.R.E.* Biomass production is an alternative technology which is dependent upon farm financial

Figure 2. Issues addressable by the *F.L.A.R.E.* system.

performance, and which will be affected by markets for biomass and other commodities, and potential environmental impacts.

METHODOLOGY

Many micro modeling components are required for the evaluation of farm level production issues. First, an estimate of production costs for a farm firm must be established. Second, a means to estimate a yield for alternative farming practices must be available. Third, the impacts alternative farming practices have on the environment must be estimated. Finally, selection of the farm plan and a description of the impacts of that plan on farm financial stability is necessary.

Selection of a Farm Level Simulation Model

The principle component of the *F.L.A.R.E.* system is the farm firm simulation module. The first phase in development of the simulation system includes identification of existing farm level simulation models, evaluation of their potential use, and the selection of the model most appropriate for use. Many farm level models previously developed were used in a single research effort to address a specific problem (Baum and Richardson, 1983). Few farm level models are sufficiently general so policy impacts on the farm firm in various regions of the country can be evaluated. This is an essential feature for this project.

Criteria for Model Selection

Before selecting a farm level simulation model, various criteria governing analysis of farm level resource/commodity policy impacts, need to be identified. Taylor (1983) indicates that a weakness in model evaluation has been a lack of post analysis. Typically, model projections have not been revisited once policies have been adopted. Model validity in the past has rested heavily on the intuition and experience of the modelers.

Several types of farm simulation models are used in firm level research. Baum and Richardson (1983) identify and characterize three major types of whole farm models commonly used by agricultural economists:

Optimization Models: These models utilize programming techniques, may be multiperiod in design, may implement goal programming methodology, and are deterministic.

Whole Farm Simulation Models: These models do not utilize a multiple constraint optimization algorithm as do optimization models. Therefore, they do not provide an optimal strategy for a firm which faces more than a single resource constraint. They may be deterministic or stochastic.

Hybrid Simulation Models: These models link or interface simulation and programming elements with recursive interactive programming and adaptive programming models.

While hybrid models allow analysis of optimization strategies, they also allow representation of behavioral or adaptive patterns of the farm operator, an extremely important characteristic when analyzing farm level impacts in response to changes in crop selection (Figure 3). Economic decisions using the adaptive process requires feedback information. Decisions are usually made in response to variables such as price, revenue, policies, and past behavior of neighbors (Day, 1983).

Models with potential for use in *F.L.A.R.E.* varied in design, capabilities, and structural components. Bradford (1983) developed a methodology which has been used extensively in the model selection process (Figure 4). There are three main areas in the hierarchical decision making structure of a model -- relevance, efficacy, and logical validity (Bradford, 1983). Additional components in evaluating a decision making model included performance and simplicity as well as containing a sound theoretical basis. Performance should be evaluated through additional criteria including predictive accuracy.

In addition to drawing on the evaluation criteria developed by Bradford (1983), an additional set of selection criteria were developed. Thus, the selection process can be classified into two stages. The first stage includes several characteristics desirable in farm simulation models including:

Figure 3. Recursive priority programs.

Generalized Commodity Selection: The model should be flexible in the types and combinations of commodities that can be analyzed. Single commodity models or specific crop models are not acceptable.

Current Time Period: Only recently developed models will be considered. Earlier models would require substantial updating to be useful.

Transferable: The model must be transferable or have a general model structure and data base to enable it to be easily transferred to other users and regions for analytical purposes.

Multiperiod Time Horizon: The model must be dynamic and must reflect impacts of the decision making process over a specified simulation period.

Alternative Sized Farms: The model must be able to handle various farm sizes.

Farm level models found acceptable in the first stage selection process were then evaluated more rigorously in the second stage. The second set of selection criteria includes:

Government Policy: The model must permit incorporation of various agricultural commodity and resource programs.

Cash Flow Analysis: The model must have a capability to simulate the cash flow process in the farm operation decision making routine. This would include such items as refinancing, depreciation, and taxes.

Decision Making or Adaptive Process: The model must have some type of decision making simulation routine, addressing issues such as when to buy land or refinance loans, or which agronomic practices to select.

Resource Use and Availability: The model must include provisions for resource endowments and distribution. Ultimately, what is achievable will be influenced by the level and location of resources available for production. Knowledge of land quantity and quality, initial cash endowments, machinery and buildings available for production purposes is necessary if analysis at the farm level is to be meaningful.

Professional Acceptance: The model must have been tested and determined to be reliable.

Model Selection

Several hundred articles of interest were identified in an extensive review of past research on farm level modeling. Table 1 includes a selected list of these research publications which relate to farm level modeling, and describe potential candidates for use in *F.L.A.R.E.* The models are grouped into

Figure 4. Criteria for evaluating decision-making models.

three categories: optimization or programming models, simulation models, and hybrid models; where hybrid models utilize both optimization and simulation modeling techniques. One of three category codes were given to each reference in response to its acceptability for stage one selection. Models which passed the stage one selection process are identified with a P in the categorization code column, and are retained for further evaluation in stage two. Table 2 provides the results of the second evaluation process. Farm level models that meet both stage one and stage two criteria are considered for use in this study.

The four models which passed the stage two selection process are indirectly related to each other, in that they all build on Richardson and Nixon's (1980) model. The Richardson and Nixon (1980) FLIPSIM model, modified the Hardin (1978) simulation model, which was capable of simulating production, marketing, financial, and income tax activities for multiperiods. Additional work conducted in the 1980s expanded on these farm level models by incorporating additional analytical components.

Table 1. Results of stage one criteria selection.

Author	Code	Author	Code
..... Optimization or Programming Models			
Barnett, Blake, and McCarl, 1982	N	Martin, Wise, and Musser, 1976	N
Boehlje and White, 1969	N	McSweeney, 1984	N
Brown and Pheasant, 1983	N	Miranowski, 1971	N
Clark, 1972	N	Morrison, Kingwell, Pannell, and Ewing, 1986	N
Crowder, Plonke, Epp, and Young, 1985	N	Musser and Stanoulis, 1981	N
Dobbins and Mapp, 1983	P	Musser, Martin, and Reid, 1983	N
Featherstone, 1986	N	Nelson, 1976	N
Fox and Driver, 1980	N	Padgitt, 1980	N
Guebert, 1973	N	Persaud, 1980	N
Hatch, 1973	N	Rahman and Lufor, 1980	N
Heidhues, 1966	N	Sanford, 1986	N
Kaiser and Boehje, 1980	N	Segarra, Kramer, and Taylor, 1985	N
Lins, 1969	N	Siefried, 1985	N
Loftsgard and Heady, 1959	N	Van Poolen, 1981	N
Longmire, 1980	N	Walker and Martin, 1966	N
..... Hybrid Models			
Armstrong, Connor, and Strickland, 1970	N	Crawford and Milligan, 1982	N
Baum, 1984	P	Hardin and Lacewell, 1979	N
Baum and Richardson, 1983	N	Harman, 1973	N
Baum, Richardson, and Schertz, 1982	P	Kaiser, 1985	N
Chein, 1972	N	Kingma, 1978	N
Chein and Bradford, 1976	N	Richardson and Nixon, 1980	P
Condra, 1978	N	Richardson and Nixon, 1986	P
		Swaney, Jones, Mishow, and Baker, 1986	N
..... Simulation Models			
Bailey, Anderson, and Helms, 1986	N	King and Oamek, 1983	N
Boehlje and Griffen, 1979	N	Klein and Lee, 1974	N
Boggess, McGrann, Heady, and Boehje, 1978	N	Ladue, 1971	N
Clements, Mapp, and Eidman, 1971	N	Nixon, 1980	N
Crenshaw, Kaufman, Little, and Watt, 1985	N	Nowak, Milligan, Knoblauch, and Fox, 1983	P
Dabbert and Madden, 1986	N	Patrick, 1978	N
Edington, 1980	II	Patrick and Eisgruber, 1968	N
Eleveld, 1979	N	Pflueger, 1985	N
Halter and Dean, 1965	N	Richardson and Condra, 1981	N
Hanson, 1982	N	Roush, Mapp, and Maynard, 1979	N
Hardin, 1978	N	Schertz, Calvin, and Willett, 1981	N
Held, 1977	N	Skees, 1983	N
Holland and Young, 1980	N	Skees, Reed, and Pederson, 1983	N
Hutton and Hinman, 1971	N	Umberger, 1972	N
Jewell, 1984	N		

N: At least one of the seven criteria were not met
 II: Insufficient information available from citation
 P: Passes Initial criteria test

In 1982, Baum et al. (1982), developed the FLIPRIP model, which expanded on the early version of FLIPSIM by incorporating additional analytical capabilities and changing the optimization procedure. The original optimization procedure, specified in FLIPSIM was deleted and XMP was substituted. Essentially, FLIPRIP, links a set of accounting decision subroutines for a farm firm with a set of optimizing subroutines. XMP is a hierarchically structured library of experimental fortran subroutines for solving linear programming problems (Baum et al. 1982). Baum and Richardson (1983) developed the next in this family of models in FLIPCOM, a set of farm-level, continuous optimization models. The FLIPCOM models consist of both the FLIPSIM and FLIPRIP models. Both models were updated and a policy evaluation sector was added. "The model is designed to recursively optimize a set of production activities over a 10 year period for a representative farm in a specified policy and economic environment" (Baum and Richardson, 1983, p. 219). The PICFARM model was developed

by Baum in 1984. This model expands on FLIPRIP and includes the Payment in Kind (PIK) government program option as well as an expanded livestock sector. This is also a multiperiod model and was "constructed to simulate the likely behavior and economic well being of a whole farm with the production sector... and to

Table 2. Results of stage two criteria selection.

Author	Code
Baum, 1984	P
Baum and Richardson, 1983	P
Baum, Richardson, and Schertz, 1982	P
Dobbins and Mapp, 1983	N
Kaiser, 1985	N
Richardson and Condra, 1981	N
Richardson and Nixon, 1980	N
Richardson and Nixon, 1986	P

N: At least one of the five criteria for stage two were not met
P: Passes Stage two criteria test

use data sets representing alternative agriculture policy environment and farm operating characteristics (Baum, 1984, p. 1).

The most recent model which met all of the established criteria is FLIPSIM V (Richardson and Nixon, 1986). Several alterations were made to the original FLIPSIM model. The model's basic components include a policy section, financial sector, crop and livestock commodity sectors, a decision making component, multiyear simulation techniques, and various stochastic features. FLIPSIM V and previous-generations of the model have been through various testing processes with its use in several research projects (Table 3). Government policy, tax, commodity marketing, management, financial, and other farm operation problems

have been studied with the model. Results from these studies indicate FLIPSIM V is a good representation of a farm firm operation for various regions of the United States. The model continually undergoes model validation and verification tests. "The process is categorized into three stages...the first stage is a formulation of the set of postulates describing the system...The second stage consists of a validation of the tentative hypotheses outlined as

postulates in stage one... Stage three calls for testing the model's ability to predict the behavior of the system (Richardson and Nixon, 1986, p. 10). In general, the models performance in representing farm

Table 3. Research conducted using FLIPSIM V.

Author
Bailey, 1983
Bailey, Brorsen, and Richardson, 1984
Baum, Richardson, and Schertz, 1984
Brorsen, Richardson, Grant, and Schnake, 1984
Duffy, Richardson, and Smith, 1984
Grant, Richardson, Brorsen, and Rister, 1984
Lemicux, Richardson, and Nixon, 1982
Nixon and Richardson, 1982
Perry, Rister, Richardson, Sij, and Grant, 1985
Richardson and Bailey, 1983
Richardson and Nixon, 1982a
Richardson and Nixon, 1982b
Richardson and Nixon, 1984
Richardson, Lemieux, and Nixon, 1983
Richardson, Nixon, and Smith, 1982
Shirley, 1981
Smith, 1982

operations is good, the data requirements are reasonably obtainable, and operational procedures are well documented.

Reviewing the four farm level models that meet the stage two criteria, FLIPSIM V was selected as the model best designed for use in the *F.L.A.R.E.* system. The model includes the most recent methodology in farm level modeling techniques and meets all the criteria established in the selection process. Modifications to FLIPSIM V were required to meet the analytical objectives of the biomass project. Modeling options to allow altering crop rotations over time and to reflect these impacts on the farm operation are two of several additional components which were incorporated.

Selection of Data Support Models

The Budget Generator

The second phase in the development of the *F.L.A.R.E.* project was the selection of models that provide data support to the main farm level simulation model (FLIPSIM V). Prior to modeling the broader aspects of the farm firm environment, the initial task was to obtain a modeling component for use in providing a budgetary description of farm enterprise operations. Estimation of the ownership and operating costs of different farm production enterprises and alternative farming systems was achieved through an enterprise budget generator. Several farm enterprise budget generators were reviewed using the following selection criteria:

1. The budget generator should be a whole-farm multiple enterprise planner. Many budget generators exist that examine the cost of producing a given commodity. These cannot address the costs of idle equipment or the costs involved in switching from one means of production to another.
2. Since resource endowments, use and quality are important aspects of the research planned for this system, the budget generator must be able to handle farm cropping practices, must be soil type specific, must contain hectareage and erosion estimates, and must be presented as a farm unit.
3. Software for the budget generator must be reasonably well documented.
4. Necessary farm data must be available.

Most budget generators are similar in that they build budgets by first specifying field operations and then determine machinery time, labor, operating inputs and fixed expenses for each enterprise of concern. The output and format of the budget generators, however, may vary. Four models were evaluated: a Texas A&M farm budget generator; *Budget Planner*, developed at North Carolina State and maintained at the University of California, Davis; a University of Tennessee crop enterprise budget generator; and the Firm Enterprise Data System (FEDS) crop and livestock budget generator.

The Texas A&M whole-farm budget generator was judged too large and detailed for our purposes, and required too much data for expedient use. The Tennessee enterprise budget generator and the FEDS budget planner are both enterprise budget generators, and as such, failed to depict the whole-farm unit or idled machinery. *Budget Planner* met the selection criteria and was selected as the budget generator for use with FLIPSIM. *Budget Planner* has been tested by various research studies including projects in California, Arkansas, South Carolina, and Georgia (UC, 1990).

Specific farm enterprise and operational information are needed to use *Budget Planner*. Input data required to operate the planner include:

1. crop mix and available hectareage;
2. type and timing of field operations;
3. machinery complement for the farm and all ownership and operating costs for each machinery item;
4. prices, interest rates and crop yields; and
5. material costs and application rates.

Budget Planner accesses data files which contain machinery complements with their associated ownership, operating, and purchase costs. Default values for machinery complements can be changed or updated. Prices of inputs, expected or actual yields, and application rates are also required by *Budget Planner*.

The output generated by *Budget Planner* is presented in tabular form. The output includes:

1. farm identification and crop mix information;
2. per unit operation costs for each crop;
3. per unit price return;
4. price and yield for each crop;

5. financial returns associated with various crop prices and yields;
6. itemized monthly cash flow for each crop;
7. per unit operating machine and material cost for each crop;
8. per hour equipment ownership and operation cost for each item used in the farm budgets; and
9. total hours per whole farm equipment use for each crop enterprise.

The *Budget Planner* output serves as firm level input data for simulating the more comprehensive farm firm environment through data linkages to other modeling modules.

The Plant Growth Simulator

The selection criteria for the plant growth simulator included:

1. ability of the model to be transferred and used in different regions of the country;
2. ease of incorporating different tillage practices;
3. ease of incorporating a variety of crop types; and
4. ease of incorporating effects of pests such as weeds and insects into the growing process.

A literature review identified three models as potentially useful in the development of the plant growth component. The three models examined were the CERES-MAIZE model (a simulation model of maize growth and development), the Soybean Crop Growth and Yield Model (SOYGROW), and the Erosion Productivity impact Calculator (EPIC).

Based on the above criteria EPIC was selected as the plant growth component. Although EPIC may be marginally less accurate than a plant growth simulator designed for a specific crop, its ability to model multiple crop species simultaneously more than compensates. EPIC is also under constant revision and improvement. A brief description of the EPIC model follows:

EPIC simulates the physical process involved simultaneously and realistically using readily available inputs. Commonly used EPIC input data (weather, crop, tillage, and soil parameters) are available from a computer filing system assembled especially for applying EPIC throughout the U. S. Since erosion can be a relatively slow process, EPIC is capable of simulating hundreds of years if necessary. EPIC is generally applicable, computationally efficient (operates on a daily time step), and capable of computing the effects of management changes on outputs.

The components of EPIC can be placed into eight major divisions for discussion-hydrology, weather, erosion, nutrients, plant growth, soil temperature, tillage, and economics...[The general plant growth model is used to simulate above-ground biomass, yield, and roots for corn, grain sorghum, wheat, barley, oats, peanuts, sunflowers, soybeans, alfalfa, cotton, and grasses (Williams et al. 1982. p. 1).

The Optimizer

The current optimization subroutine in FLIPSIM V is limited in scale. A more powerful and flexible component is required so resource quality and quantity can be evaluated under various farm plan configurations. Thus, an optimizer capable of selecting from a variety of farm plan alternatives and with the flexibility and capacity to model alternative resource options is needed. In addition, this system must also handle alternative resource options. The General Algebraic Modeling System (GAMS) was selected as the optimizer routines for use in *F.L.A.R.E.* The GAMS system provides a high-level language for the compact representation of large and complex models. It allows for the unambiguous statement of algebraic relationships and permits the development of model descriptions that are independent of the solution algorithm selected. These features allow the flexibility needed to handle a wide variety of crop production scenarios.

DATA REQUIREMENTS

The data requirements for all components of *F.L.A.R.E.* are quite large. However, many of the data entries are available from secondary sources such as the *National Resources Inventory*, the *Agricultural Census*, *Agricultural Statistics*, and various USDA publications. In addition, projections on external variables such as interest rates, commodity prices, changes in the costs of inputs, commodity and resource policy alternatives, and technological advances are required if a ten year analysis is desired.

Representative Farm Development

Integral to the application of the *F.L.A.R.E.* modeling system are the representative farms to be analyzed. At this time, 14 representative farm data sets have been constructed for locations throughout the country, and 10 more are to be developed (Figure 5). Each farm is not just the "average" farm based on mean Census of Agriculture data for its county. Rather, a representative farm is designed to be a viable full-time operation, incorporating resources, enterprises and financial status typical of its location.

Development of representative farm data is accomplished in four steps. First, typical products, farm size, operator characteristics, and other characteristics for the selected region are determined. Then typical production methods in that region are used to estimate costs of fertilizers, chemicals, and operating machinery, and any on-farm inventory is determined. Estimates of exogenous macroeconomic variables capable of impacting farm decisions are then described. Once these four steps are completed, the base farm is established. Following development of the base farm for any particular analysis, assumptions can be altered, additional farm plans considered, or resource availability changed and the

impacts of these changes compared to the base farm.

Farm Resources and Characteristics

In representative farm development, a location must first be decided upon within the designated major land resource area (MLRA). The county

Figure 5. Location of representative farms.

designated is usually one typical to the MLRA in soil resources and crops grown.

Soil and cropland specifications are drawn from the National Resource Inventory (NRI) (SCS, 1984), a comprehensive inventory of the soil resources of the United States. The inventory includes data pertaining to land capability class for agricultural production, soil type, soil loss tolerance factor (T-factor), cropping history, and soil erosion history. The NRI also contains Universal Soil Loss Equation (USLE) variables: a soil erodibility factor (K), rainfall factor (R), cropping - management factor (C), erosion control practice factor (P), slope length and percent factor (LS). Therefore, NRI data is used to determine the proportion of the farm represented by each soil type and erosion characteristic. Erosion levels for a farm can also be calculated using NRI data.

Farm size and typical crop enterprises are derived from Census of Agriculture data (BOC, 1989) along with the state's agricultural statistics publication. The size of a representative farm is determined from the reported distribution of farms in the county. Farm size is usually chosen within the size range with the greatest combination of number of farms and total hectareage. In some cases, the farm hectareage is adjusted to assure that it realistically reflects that of viable farms in the area.

Typical enterprises for a representative farm reflect the principal enterprises of the county in a characteristic proportion. They are chosen based on the level and mixture of crop and livestock sales

for the selected location. In some cases where enterprises varied greatly from one end of an MLRA to the other, two farms are described to accommodate these differences. Yields are determined for a farm, based on mean yields for the county. Since management practices of a commercial farm operation generally produce higher than average yields, these may be adjusted upward.

Land ownership, or tenure, of the operator is also defined according to the usual ratio of owned versus rented land for commercial farms in the area, as reported in census statistics.

Production Expenses and Financial Status

Once crop enterprises are designated, production expenses must be constructed. Input prices and use rates are usually available in state Agricultural Extension Service production budgets (TAES, 1989) and from budget data developed by the Center for Agricultural and Rural Development (CARD, 1983). Crop production costs and returns for a farm are developed using rates in the *Budget Planner*. FLIPSIM V calculates labor costs from labor requirements and wage rates specified by published budget data.

Other costs such as insurance, property taxes, and land rent are estimated by adjusting published rates to the farm operation's value, rented hectareage, and other parameters.

The equipment inventory for a farm is compiled from state Agricultural Extension Service recommended budgets based on the needs of each enterprise. Purchase dates are assigned to each piece of equipment. Arbitrary dates are chosen from within the previous 10 to 12 year period so that replacement costs are distributed over time. New equipment purchase prices are drawn from state Extension lists and/or the current *National Farm Tractor and Implement Blue Book*. Then values are deflated to reflect prices for the assigned purchase year by using price indices from various issues of *Agricultural Prices* (NASS). The current value of an asset is assumed to be the purchase price less straight-line depreciation plus salvage value. A final equipment list includes current value, purchase dates and prices, and replacement costs as specified by the simulation model.

A balance sheet is constructed based on long term and intermediate debt as well as real estate, equipment, and cash assets. Initial debts include long term debt on farm real estate and intermediate term debt on equipment. The total value of farm real estate equals the value of farmland and buildings as it corresponds to reported census and statistical data. The total long term debt remaining is derived using Census of Agriculture equity values. Current value and equity of intermediate term equipment are taken from the equipment inventory described above. Cash on hand is estimated using available data for similar farm operations.

Macroeconomic Assumptions

Once described, a farm's performance is simulated over a period of at least ten years. Thus, certain macroeconomic assumptions are required to provide the necessary background for developing the economic environment in which the farm operates. Farm size, crops produced, and machinery complement are factors somewhat under the control of the operator, but interest rates, crop prices, inflation rates, and government program parameters are assumed to be exogenous.

Publications of the Food and Agricultural Policy Research Institute (FAPRI) are the primary source of macroeconomic forecasts. FAPRI forecasts mean interest rates, inflation rates, crop prices, CCC commodity loan rates, Acreage Reduction Program (ARP) requirements, target prices, and other variables over a ten year period. Cost indices for variable production cost categories, labor costs, custom costs, fixed costs, insurance costs, and new and used equipment costs are also available from FAPRI. The FAPRI report also provides forecasts of prices for major commodities for the simulation period. Crop prices not available from FAPRI are developed from other sources. The macroeconomic variables and crop prices used in this analysis are shown in Table 4 and Table 5, respectively.

Average crop yields of previous years in a county may be analyzed to estimate future yields. Future yields are forecasted for the subsequent period using stepwise autoregression with the number of lag years equal to the length of the desired forecast period (lag=10 for a 10 year period). Stepwise autoregression combines a time trend line and an autoregressive model (SAS, 1984). The model uses

Table 4. Forecasts of interest rates and percent annual change in input costs, 1988-1997.

Variable	1 9 8 8	1 9 8 9	1 9 9 0	1 9 9 1	1 9 9 2	1 9 9 3	1 9 9 4	1 9 9 5	1 9 9 6	1 9 9 7
<i>Percent Interest Rates:</i>										
Long-Term	11.7	11.3	11.3	11.6	11.5	11.6	11.4	11.4	11.4	11.4
Medium-Term	11.2	10.8	10.8	11.1	11.0	11.0	10.9	10.9	10.9	10.9
Operating Cap.	10.5	10.5	10.5	10.5	11.5	11.5	11.5	11.5	11.5	11.5
Cash Balances	6.7	8.1	7.2	7.1	7.2	7.4	7.3	6.2	7.4	7.9
<i>Percent Annual Change in Input Costs:</i>										
Seed	2.0	13.0	1.0	4.0	6.0	5.0	5.0	5.0	6.0	6.0
Fertilizer	12.0	6.0	2.0	-4.0	2.0	5.0	5.0	5.0	5.0	5.0
Chemicals	3.0	5.0	1.0	-2.0	1.0	4.0	4.0	4.0	4.0	4.0
Fuel & lube	5.0	11.0	-3.0	5.0	4.0	5.0	6.0	6.0	4.0	7.0
Repairs	2.0	6.0	3.0	3.0	4.0	4.0	5.0	5.0	5.0	5.0
CPI	4.0	5.1	4.7	5.1	5.0	4.7	5.3	5.0	5.3	5.1

Sources : FAPRI (1989, 1990)

a stepwise procedure to select which lag years to incorporate in the forecast.

Dynamic Simulations

Representative farms could be simulated deterministically through the specified crop and yield information previously described. However, certain elements of farmer behavior may be more realistically modeled by stochastic simulation. Stochastic simulation of a farm requires specification of empirical probability distributions for crop yields and prices. By making prices and yields dynamic, information on the variability of farm income, commodity deficiency payments, net worth, and taxes are

Table 5. Forecast of annual mean crop prices, 1988-1997.

Year	Corn	Soybeans	Wheat	Cotton
	\$/bu.	\$/bu.	\$/bu.	\$/lb.
1988	2.54	7.35	3.72	0.560
1989	2.30	5.58	3.81	0.637
1990	2.05	5.02	3.23	0.640
1991	2.12	5.82	3.18	0.586
1992	2.04	6.03	3.35	0.613
1993	1.99	5.45	3.27	0.619
1994	2.17	6.02	3.50	0.636
1995	2.19	6.34	3.63	0.655
1996	2.40	5.84	3.48	0.669
1997	2.44		3.41	0.685

Sources: FAPRI (1989, 1990)

obtained, strengthening the analysis. Historical yields and crop prices are used to develop covariance matrices for incorporation into the simulation model. Historical county crop yields and state crop prices can be obtained from National Agricultural Statistics Service (NASS) and state agricultural statistics publications.

Representative Farm Use

Once developed, a representative farm is ready for use in comparative-static analysis and stochastic analysis of alternative farm plans and policies. The representative farms are meant as example farm firms, demonstrating potential micro-level impacts on farm firms. Changes in farm cropping plans, commodity programs, alternative soil conservation strategies, and effects of chemical restrictions can all be evaluated using this representative farm approach.

Demonstration Farms

For the purposes of demonstration, representative farms from two states in the southeast region of the country are developed. These regions have different soil characteristics, farm sizes, grow different crops under different types of weather. The two areas include a loess soil region located in West Tennessee and a Coastal Plains area in Georgia. Production on soils in West Tennessee typically generate large amounts of sheet and rill erosion while relatively small amounts of erosion occur in Georgia.

Western Tennessee Representative Farms

The Southern Mississippi Valley Silty Uplands of West Tennessee possesses relatively productive cropland. Farmers in this region produce 85 percent of Tennessee's cotton and 35 percent of Tennessee's soybeans (Thompson et al., 1989). Other major crops include corn and wheat, with wheat typically

Figure 6. Description of the Weakley county representative farm.

double cropped with soybeans. Cotton production dominates the southern portion of this region while wheat and feedgrains are produced primarily in the north. The representative farms in the northern and southern parts of the region are located in Weakly county (Figure 6) and Haywood county (Figure 7), Tennessee, respectively.

Size of Farm

Farm size and typical crop enterprises of Weakley and Haywood county farms were derived from information in the 1987 Census of Agriculture. Haywood county has many more large farms than does Weakley. In Weakley county, the average farm size is 80 hectares (200

Figure 7. Description of the Haywood county representative farm.

acres) while farms in Haywood county average 160 hectares (400 acres). For the representative commercial farms required for this analysis, farm size for Weakley and Haywood counties is 145 and 186 hectares (360 and 460 acres), respectively with four hectares (ten acres) used for the homestead.

Land Use Patterns and Characteristics

The initial mix of crop output was designed to reflect the mix of products found within the region. The distribution of crops on each of the two farms was derived from information presented in the *1987 Census of Agriculture* (Bureau of Census, 1989). Using this information, the initial crop mix for the Weakley farm was assumed to be 57 hectares (140 acres) of soybeans, 65 hectares (160 acres) of corn for grain, and 20 hectares (50 acres) of double cropped soybeans/wheat. Of the 145 hectares (360 acres), the Weakley county farmer owned 64 percent of the land. The initial crop mix for the Haywood farm consisted of 97 hectares (240 acres) of cotton, 24 hectares (60 acres) of corn for grain, 41 hectares (100 acres) of soybeans, and 20 hectares (50 acres) of double cropped soybeans/wheat with 48 percent of the land owned.

The soil cropped in the region is characterized by a relatively homogeneous distribution of loess soils (Grenada, Loring, and Memphis soils) which vary in fertility but are moderate to well drained (SCS, 1987). In addition, there are several soils, such as Collins and Falaya, that are acidic and moderately to poorly drained (Table 6). The well drained soils are typically classified as highly erodible

Table 6. Representative farm soils, Weakley and Haywood counties, MLRA 134.

Soil Series	<u>Weakley County</u>		<u>Haywood County</u>	
	Percent of Farm Hectares	Farm Hectares	Percent of Farm Hectares	Farm Hectares
Collins Silt Loam	12.8	18.6	11.9	22.3
Falaya Silt Loam	21.4	31.2	20.0	37.2
Grenada Silt Loam	23.1	33.0	21.8	40.5
Loring Silt Loam	30.5	44.5	12.6	23.5
Memphis silt Loam	<u>12.2</u>	<u>17.8</u>	<u>33.7</u>	<u>62.7</u>
TOTAL	100.0	145.1	100.0	186.2

Source: SCS (1984)

and can exhibit high erosion rates if not protected. Approximately 45 percent of the soils in the region have an Erodibility Index (EI)¹ greater than or equal to eight (Table 7).

Equipment Complements

The initial farm plans require equipment for implementation. The equipment quantity and size were obtained from the Tennessee Agricultural Extension Service (1989). Purchase dates were arbitrarily assigned to each piece of equipment in order to spread replacement costs over the time period of analysis. The current purchase price for each piece of equipment was determined and then

¹The Erodibility Index is designed to indicate whether or not a soil is inherently erosive. It uses the KLSR coefficients from the Universal Soil Loss Equation and divides the result by the soil tolerance limit ("T"). The result is an Erodibility Index.

Table 7. Land characteristics and USLE factors, Weakley and Haywood counties, MLRA 134.

Erodibility Index Class	Farmland Distribution	Universal Soil Loss Equation					
		K	R	LS	C	P	T [†]
	Percent						
> 40	4.89	.48	250	9.94	.34	.95	3.92
15-40	18.46	.47	250	3.48	.36	.94	3.54
8-15	21.12	.47	250	1.68	.34	.93	3.67
< 8	55.53	.43	250	0.61	.33	.97	4.69

K is the soil erodibility factor

R is the rainfall factor

C is the average cropping or tillage practices factor (describes historical tillage and erosion control practices subject to change under alternative farm organizations)

LS is the slope length and percent factor

P is the erosion control practice factor

[†]This factor is expressed in English Tons per Acre.

deflated by an index of prices paid for tractors and self propelled equipment and the index for other farm machinery as reported in various Agricultural Prices issues. The current value of the equipment was assumed to be the purchase price less straight-line depreciation plus salvage value and was estimated at slightly more than \$63,000 for Weakley and \$104,000 for the Haywood farms.

Financial Resources

Both the Haywood and Weakley county farms are assumed to have cash reserves of \$3,000 and off-farm investments of \$2,000. Other assets for the Weakley county farm include \$139,840 for cropland and the farmstead and \$63,207 for the farm machinery. The Haywood farm's assets are slightly higher in both cropland and machinery. It is estimated that the Haywood farm has \$155,400 in assets for cropland and \$104,201 for farm machinery.

Liabilities, based on information provided by ERS (1988), were assumed to be 8.7 percent of the value of owned real estate (long-term debt) and 22.4 percent of non-real assets (intermediate debt). Thus, the Weakley county farm has \$26,324 and Haywood county farm has \$36,861 of liabilities.

The beginning net worth for the Weakley and Haywood county farms was \$182,000 and \$228,000, respectively.

Southern Georgia Representative Farm

The Southern Coastal Plains has considerably different soil and weather characteristics from these farms in Western Tennessee. Farms in the area differ significantly from other southeastern farms in having significantly higher total crop hectareages (Bureau of the Census, 1984). Farms in the area also have a different crop mix with large hectareages of peanuts and tobacco (Georgia Agricultural Statistical Service, 1988).

Another feature of the soil resources being cropped in the Southern Coastal Plains is its relatively low erosion rates.

Tift county, Georgia was selected as the specific location of the representative farm for Major Land Resource Area 133. Tift county is a central county in the area with historical production of all major crops in the region (Figure 8).

Figure 8. Description of the Tift county representative farm.

Size of Farm

Farm size and typical crop enterprises of Tift county farms were derived from information in the *1982 Census of Agriculture* (Bureau of Census, 1984) and from the Georgia Agricultural Statistics Service (1988). The size of the representative farm was determined in part by the distribution of farms that exist in the county. In 1982, the majority of cropland in farms was greater than 80 hectares (200 acres). In addition, a large number of farms ranged in size from 105 to 202 hectares (260 to 500 acres). However, since nearly 40 percent of the land was held by farms larger than 202 hectares (500 acres), total hectares on the farm was set at 196 hectares (484 acres), close to the upper limit of the 105 to 202 hectare (260 to 500 acre) range and approximately 25 percent above the county average.

Land Use Patterns and Characteristics

The initial mix of crop output was designed to reflect the mix of products found within the region. The distribution of crops was derived from information presented in the *1982 Census of Agriculture* (Bureau of Census, 1984). Using this information, the initial crop mix for the Tift county farm was assumed to be 55 hectares (135 acres) of soybeans, 79 hectares (195 acres) of corn for grain, 8 hectares (20 acres) of wheat, 28 hectares (70 acres) of peanuts, and 22 hectares (55 acres) of double cropped soybeans/wheat² (Table 8). The remainder of the land is in farmstead, roads, and ditches.

The cropland soil in the region is deep and has a thermic temperature regime. Generally, the soils are flat and do not exhibit extensive erosion problems (SCS, 1981). Approximately ten percent of the soils in the region have an Erodibility Index (EI) greater than or equal to eight (Table 9). Only two percent of the soils under cultivation have an erodibility index exceeding 40. The majority of soils having an erosion problem can be treated through appropriate residue management to maintain current cropping practices.

²As mentioned above, the area also produces tobacco. Tobacco was not included in the analysis because of the complexities that a tobacco program would add to the analysis.

Table 8. Crop hectareages and yields on the Tift county representative farm.

Equipment Complements

Tillage, planting, and harvesting, necessary activities in agricultural production, require equipment for implementation. The equipment quantity and size for the Tift county farm were obtained from the Georgia Agricultural Statistical Service and the Georgia Cooperative Extension Service. Purchase

Crop	Planted Hectareage	Yield
	(hectares)	(Units/ hectare)
Corn (Bushels)	79	210
Soybeans (Bushels)	55	69
Wheat (Bushels)	8	86
Soybeans/Wheat (Bushels)	22	62/77
Peanuts (Kilograms)	28	2,800
Tobacco (Kilograms)	12	2,879

dates for the equipment were arbitrarily assigned to each piece of equipment in order to spread replacement costs over the time period of analysis. The current purchase price for each piece of equipment was determined and then deflated by an index of prices paid for tractors and self propelled equipment or the index for other farm machinery as reported in various *Agricultural Prices* issues (NASS). The current value of the equipment was assumed to be the purchase price less straight-line depreciation plus salvage value. The equipment inventory's current value was slightly more than \$127,000.

Financial Resources

The Tift county farm was assumed to have cash reserves of \$3,000 with no off-farm investments. Other assets for the farm include \$335,000 for cropland and the farmstead and \$127,000 for farm machinery. Liabilities, based on information provided by the ERS (1988), were assumed to be 40 percent of the value of owned real estate (long-term debt) and 35 percent of non-real assets

(intermediate debt). The Tift county farm has \$178,000 of liabilities and a beginning net worth of \$286,000.

Table 9. Land and soil erosion characteristics, Tift county, MLRA 133.

Erodibility Index Class	Universal Soil Loss Coefficients					T [†] Factor
	K	R	LS	C		
	Percent					
Greater than 40	0.22	0.28	340	0.46	0.36	3.17
15 to 40	3.67	0.25	340	0.26	0.36	3.55
8 to 15	5.64	0.21	340	0.15	0.36	4.13
Less than 8	90.47	0.14	340	0.05	0.37	4.59

K is the soil erodibility factor

R is the Rainfall factor

C is the cropping and tillage practice factor (Average for the Major Land Resource Area 133 located in Georgia)

LS is the slope and length of slope factor

Source: SCS (1984)

[†]This factor is expressed in English Tons per Acre.

RESEARCH RESULTS

Break-even Analysis for Switchgrass

One of the earliest attempts to research the economic viability of biomass production was a break-even analysis of switchgrass as an energy crop. Switchgrass is a warm-season perennial grass. It is handled as a hay crop and is assumed to be baled into large round bales. As a perennial crop, it is excellent for controlling soil erosion. Production was evaluated for a representative farm developed for Tift county, Georgia, according to methods outlined previously in this report.

First, an enterprise budget for switchgrass was constructed. Cost of production data for the switchgrass enterprise was obtained from *Evaluation of Potential Herbaceous Biomass Crops on Marginal Lands* (Dobbins et al., 1990). Establishment cost data as well as custom harvesting costs were derived from the Tennessee Agricultural Extension Service's *Crop Enterprise Budgets* and from *Tennessee Custom Harvest Rates*, respectively. Equipment expenses were derived from Tennessee and Georgia budget data and calculated using the *Budget Planner* farm budget generator.

Once basic costs of switchgrass production were determined, a series of cost figures were developed to correspond to different yield levels: as yields increase, costs increase due to higher harvest expense. Then profit or loss per hectare was estimated by subtracting costs for each yield from the revenue for that yield at various prices [(Yield x price) - cost] (Table 10).

Employing the *F.L.A.R.E.* Modeling System to Simulate Biomass Production

The break-even analysis provided new, beneficial information on the economics of herbaceous energy crop production. Yet more complete analysis was needed to simulate biomass production incorporated into a realistic whole farm situation, including or replacing a typical crop mix. Representative farms, discussed previously, have been constructed to accommodate such simulation.

Table 10. Break-even analysis of switchgrass as a biomass energy crop.

PRICE (\$/Mg)	YIELD (Mg/ha)						
	4.48	5.60	6.73	7.85	8.97	10.09	11.21
	-- (dollars per hectare) --						
27.56	-171.96	-141.07	-110.18	-79.30	-48.41	-17.52	13.37
33.07	-147.25	-110.18	-73.12	-36.05	1.01	38.08	75.14
38.58	-122.54	-79.30	-36.05	7.19	50.43	93.68	136.92
44.1	-97.83	-48.41	1.01	50.43	99.85	149.28	198.70
49.6	-73.12	-17.52	38.08	93.68	149.28	204.87	260.47
55.12	-48.41	13.34	75.14	136.92	198.70	260.47	322.25
60.63	-23.70	44.26	122.21	180.16	248.12	316.07	384.02

The *F.L.A.R.E.* modeling system was employed to simulate impacts at the farm firm level precipitated by the incorporation of herbaceous energy crop production into the management system. In one such study, erosion control and profitability were compared under four alternative cropping systems on each of three Southeastern farms. Included here is a brief overview of the analysis and results to illustrate the use of farm level modeling in biomass production research.

Analytical Framework

Developing renewable energy resources such biomass crops is an important issue on the agricultural agenda. Erosion control and farm profitability measures account for a large percentage of federal farm program expenditures. Production of an energy crop on highly erodible cropland may enable Southeastern farmers to achieve a high level of erosion control while maintaining an acceptable level of profitability and augmenting scarce energy resources. This study evaluates the feasibility of biomass production technology in terms of farm financial performance and gross sheet and rill erosion levels. Federal farm program savings are also examined that might accrue by allowing production of a salable energy crop on highly erodible cropland enrolled in the Conservation Reserve Program (CRP).

Table 11. Four alternative management systems evaluated.

Farm Plans Considered in the Analysis	Management System Employed
Base	Conventional farming practices, Conservation tillage on highly erodible land
No Program	Conventional farming practices, No government commodity programs
CRP Enrollment	Base plan with highly erodible cropland enrolled in the Conservation Reserve Plan
Biomass	Base plan growing switchgrass as a biomass crop on highly erodible cropland

Four management systems were simulated for each farm, with each simulation depicting a different crop mix and/or use of different farming technologies and production methods (Table 11). The first simulation was a base farm plan in which the operator would maintain the historical crop mix for the area, participate in all price support programs, and not participate in either a conservation reserve or a biomass production program. In the second simulation, the operator would again maintain the historical crop mix, would not participate in a conservation reserve or biomass production program, and would be ineligible to participate in any price support program. The third simulation introduced the Conservation Reserve Program (CRP) and included participation in all price support programs. The fourth simulation introduced a biomass crop production enterprise (switchgrass) as an alternative to enrolling highly erodible cropland in the CRP and allowed participation in price support programs.

Erosion Levels

Analysis of the 1982 National Resources Inventory (NRI) indicates that the soils of MLRA 133 (Tift county, GA) and MLRA 134 (Weakley and Haywood counties, TN) possess different characteristics. Erosion on the Tift county farm was much lower, based on application of the Universal

Soil Loss Equation (USLE), than on either of the West Tennessee farms. Characteristic soil physical properties ("K" Factors) as well as representative field lengths and slopes ("LS" Factors) were lower in Tift county. Further, based on the 1982 NRI, land in Tift county exhibited a much higher proportion of land in the lower Erodibility Index (EI) class ($EI < 8$). Less than ten percent of cropland in Tift county was classified as highly erodible under Soil Conservation Service Guidelines ($EI > 8$).

Soil physical properties ("K" Factor), and land slope percent and length of slope characteristics ("LS" Factor) of the typical soils of Weakley and Haywood counties in West Tennessee were more conducive to erosion than those soils in Tift county. Even though rainfall ("R" Factor) was higher in Tift county, land in Weakley and Haywood counties was eroding at a considerably greater rate. Differences in proportions of land in each erodibility index group between farms in Weakley and Haywood counties were also evident. The representative Weakley county corn farm, while eroding under the base plan at a marginally greater rate than the Haywood county cotton farm, was calculated to have an average erosion loss of less than 4.5 tons per hectare per year when highly erodible cropland was placed under permanent vegetative cover (Table 12). However, the cotton-producing farm under the same plan exhibited an average erosion level of over nine tons per hectare annually (Table 13).

Differences in erosion rates between farms was a result of differences in relative proportions of soils in the higher erodibility index groups, and thus to differences in the proportion of cropland requiring conservation tillage practices to comply with the conservation compliance provisions of the 1985 Food Security Act (FSA).

Total erosion on the Tift county farm was only slightly reduced by the application of permanent cover on highly erodible cropland (Table 14). According to the 1982 NRI, only a small fraction of land in Tift county was eroding at rates greater than 10 megagrams per hectare (four tons per acre) annually. As a result, only a small fraction of land required the application of conservation tillage practices for compliance with provisions of the 1985 FSA.

Table 12. Weakley county farm: crop hectareages, USLE erosion factors, and erosion rates.

Crop	Hectares-Farm Plans ^a					Erosion ^c			
	Base	Bio	CRP	EI ^d	CP ^e	Mg/ha	Base	Bio	CRP
Corn: (Conv)	40	0	0	Low	.235	7.4	286		
(No-Till)	0	40	40	Low	.103	3.2		125	125
Soybeans: (Conv)	11	0	0	Low	.372	11.7	127		
(No-Till)	0	11	11	Low	.125	3.9		43	43
(Conv)	18	0	0	Med	.372	31.7	552		
(No-Till)	0	6	6	Med	.125	10.6		60	60
Wheat/Soy Doublecrop:	1	13	13	Med	.125	10.7	13	135	135
	18	0	0	High	.125	22.3	393		
	5	0	0	VHi	.125	65.6	285		
Switchgrass:	0	14	0	Med	.003	.2		0	
	0	18	0	High	.003	.5		9	
	0	5	0	VHi	.003	1.6		7	
Conservation Reserve:	0	0	.4	Med	.003	.2			0
	0	0	18	High	.003	.5			9
	0	0	5	VHi	.003	1.6			7
TOTAL:	92	92	92				1658	379	379
Average erosion (Mg/ha)							18.4	4.2	4.2

^a The Farm plans are (1) Base farm plan (Base), (2) Biomass enterprise farm plan (Bio), (3) Conservation Reserve Program (CRP). The Farm plan with no government programs is identical to the base farm plan in crops produced and hectareages and is therefore excluded.

^b USLE factors are:

R = Rainfall factor

K = Soil Erodibility factor

C = Crop Management factor

LS = slope length and gradient factor.

^c Erosion estimates based on USLE factors are in metric tons (000kg).

^d EI classifications are: EI < 8: Low 15 <= EI < 40: High
8 <= EI < 15: Med 40 <= EI : VHi

^e "CP" Factor is a product of the "C" factor and "P" factor.

Source: SCS (1984)

Table 13. Haywood county farm: crop hectareages, USLE erosion factors, and erosion rates.

Crop	Hectares-Farm Plans ^a					Erosion ^c			
	Base	Bio	CRP	EI ^d	CP ^e	Mg/ha	Base	Bio	CRP
Cotton: (Conv)	57	0	0	Low	.300	9.4	522		
(No-Till)	0	57	57	Low	.289	9.1		503	503
Soybeans: (Conv)	17	0	0	Low	.372	11.7	189		
(No-Till)	0	17	17	Low	.125	3.9		66	66
(Conv)	18	0	0	Med	.372	31.7	565		
(No-Till)	0	5	5	Med	.125	10.6		190	190
Wheat/Soy Doublecrop:	10	10	10	Med	.125	10.7	99	99	99
	26	17	17	High	.125	22.4	577	367	367
	6	0	0	VHi	.125	65.6	405		
Switchgrass:	0	14	0	Med	.003	.2		4	
	0	10	0	High	.003	.5		5	
	0	6	0	VHi	.003	1.6		10	
Conservation Reserve:	0	0	33	Med	.003	.2			4
	0	0	23	High	.003	.5			5
	0	0	15	VHi	.003	1.6			11
TOTAL:	134	134	134				2366	1244	1244
Average erosion (Mg/ha)							18.0	9.5	9.5

^a The Farm plans are (1) Base farm plan (Base), (2) Biomass enterprise farm plan (Bio), (3) Conservation Reserve Program (CRP). The Farm plan with no government programs is identical to the base farm plan in crops produced and hectareages and is therefore excluded.

^b USLE factors are:

R = Rainfall factor

K = Soil Erodibility factor

C = Crop Management factor

LS = slope length and gradient factor.

^c Erosion estimates based on USLE factors are in metric tons (000kg).

^d EI classifications are: EI < 8: Low 15 ≤ EI < 40: High
8 ≤ EI < 15: Med 40 ≤ EI : VHi

^e "CP" Factor is a product of the "C" factor and "P" factor.

Source: SCS (1984)

Table 14. Tift county farm: crop hectareages, USLE erosion factors, and erosion rates.

Crop	Hectares-Farm Plans ^a					Erosion ^c			
	Base	Bio	CRP	EI ^d	CP ^e	Mg/ha	Base	Bio	CRP
Corn:	81	81	81	Low	.235	1.2	96	96	96
Peanuts:	29	29	29	Low	.372	1.9	54	54	54
Soybeans:	45	45	45	Low	.372	1.9	85	85	85
Tobacco:	12	12	12	Low	.235	1.2	14	14	14
Wheat/Soy Doublecrop:	18	10	44	Low	.125	.65	12	7	120
	7	0	0	Med	.125	0.7	0.5		
	5			High	.125	0.15	.7		
	.3			VHi	.125	2.6	.8		
Switchgrass:	0	8	0	Low	.003	.02		1	
	0	7	0	Med	.003	.07		.5	
	0	2	0	High	.003	.15		.3	
	0	.3	0	VHi	.003	.29		.9	
Conservation Reserve:	0	0	7	Med	.003	.07			.5
	0	0	.5	High	.003	.15			.7
	0	0	.3	VHi	.003	.29			.9
TOTAL:	198	198	198				263	263	263
Average erosion (Mg/ha)							1.3	1.3	1.3

^a The Farm plans are (1) Base farm plan (Base), (2) Biomass enterprise farm plan (Bio), (3) Conservation Reserve Program (CRP). The Farm plan with no government programs is identical to the base farm plan in crops produced and hectareages and is therefore excluded.

^b USLE factors are:

R = Rainfall factor

K = Soil Erodibility factor

C = Crop Management factor

LS = slope length and gradient factor.

^c Erosion estimates based on USLE factors are in metric tons (000kg).

^d EI classifications are: EI < 8: Low 15 <= EI < 40: High
8 <= EI < 15: Med 40 <= EI : VHi

^e "CP" Factor is a product of the "C" factor and "P" factor.

Source: SCS (1984)

Financial Performance

The effect of each alternative plan on the financial condition of each representative farm was examined. Overall, the results indicated that farms producing biomass, such as switchgrass, offered producers a return comparable to, and in some cases superior to, enrolling highly erodible cropland in the CRP (assuming the future market price of switchgrass follows the general rate of inflation)³.

The average per hectare change in net farm incomes between the base farm plan and the alternative farm plans is shown in Figure 9. Net farm income for each farm and each farm plan for the first and tenth year simulations are presented in Table 15. Under the CRP plan, the average per hectare net farm income declined just over one percent for the Tift county farm, and under the biomass plan, average net farm income declined by only slightly more than one-half of a percent. A somewhat different situation was found for the West Tennessee farms. For both these farms, the biomass enterprise caused only modest declines in net farm income, with net income declining by 4.5 percent on the Haywood county cotton farm and 1.5 percent on the Weakley county corn farm. However, net farm income under the CRP plan declined by over 75 percent on the Weakley county corn farm and by over 15 percent on the Haywood county cotton farm. Although the ten year path of net farm income was generally downward, all farms experienced an increase in net farm income over base plan levels under the biomass plan. One possible explanation for this result was the assumption that the price for switchgrass would follow the general rate of inflation. Justification of this

Figure 9. Per hectare change in net farm income between base and alternative farm plans.

³Switchgrass yield and price assumed in the analysis are 8.1 dry metric tons per hectare (3.6 dry tons per acre) and \$49.61 per metric ton (\$45 per ton) respectively.

assumption rests with the fact that a biomass enterprise, as an energy crop, will face a different set of demand factors than will other farm commodities.

Net cash income (Table 16) declined by just over one percent for the Tift county farm, 22 percent for the Weakley county corn farm and 38 percent for the Haywood county cotton farm under

Table 15. Simulated nominal net farm income of representative farms, 1986-1995.

County and Year of Simulation	Farm Plan			
	Base	No Program	CRP	Biomass
Tift County, GA				
	--thousand dollars--			
1986	91.4	56.5	90.7	91.3
1995	83.9	65.7	66.7	64.2
AVG.	87.4	62.5	74.4	74.0
Haywood County, TN				
1986	-25.7	-29.2	-28.8	-27.5
1995	0.3	-4.9	-4.4	0.3
AVG.	4.0	-1.7	1.0	3.8
Weakley County, TN				
1986	-28.9	-40.1	-33.1	-32.1
1995	-31.9	0	0	0
AVG.	-15.5	-19.8	-17.9	-15.8

the CRP plan. Under the biomass plan, average net cash income declined by one-half of a percent for the Tift county farm, seven percent for the Weakley county corn farm, and approximately 17 percent for the Haywood county cotton farm. With the exception of the Haywood county cotton farm, net cash income under the biomass plan was similar to or exceeded net cash income under the base plan during the latter years of the simulation period.

The Tift county farm consistently registered significantly less proportional declines in net farm income and net cash income than the West Tennessee farms, most likely due to higher income levels resulting from income support from the peanut program and to the smaller proportion of highly erodible cropland devoted to either a CRP or biomass enterprise. For the Tift county farm and the Weakley county corn farm, the biomass enterprise provided producers a return comparable to the base farm plan, particularly near the end of the simulation period. However, the Haywood county cotton farm became insolvent in 1994 for the CRP and biomass plans and in 1995 under the base plan.

Table 16. Simulated nominal net cash income of representative farms, 1986-1995.

County and Year of Simulation	Farm Plan			
	Base	No Program	CRP	Biomass
Tift County, GA				
	--thousand dollars--			
1986	128.0	93.7	128.0	128.9
1995	89.8	82.5	83.4	84.6
AVG.	103.6	88.4	100.4	100.0
Haywood County, TN				
1986	22.3	18.8	19.1	20.5
1995	6.9	1.7	2.1	6.8
AVG.	18.3	11.5	14.2	17.9
Weakley County, TN				
1986	6.8	-4.5	2.6	3.6
1995	-25.6	0	0	0
AVG.	-5.1	-9.0	-8.4	-6.2

Government Deficiency and Diversion Payments

The difference in government payments to each farm under the alternative plans versus the base plan are presented in Figure 10. The loss of deficiency and diversion payments created a significant loss

in both net farm income and net cash income. By requiring that highly erodible cropland be placed in either a conservation reserve or biomass enterprise, the government may also reduce outlays for price support programs even assuming no reduction in participation rates. Total receipts for deficiency and diversion payments for each farm are presented in Table 17. Deficiency payments on the Tift county farm were reduced by over seven and a half percent under the CRP plan and by over 12.5 percent under the biomass plan. The difference in deficiency payments under the CRP plan versus the biomass plan is a result of planted hectareages of program crops. Twenty hectares (50 acres) was established as the lower limit for an economically viable biomass enterprise, but only 12 hectares (30 acres) of the Tift county farm were eligible

Figure 10. Per hectare change in government payments between base and alternative farm plans.

for the CRP program, creating an eight hectare (20 acre) difference in program crop hectareages on this farm. Deficiency and diversion payments on the Weakley county corn farm declined by approximately 13 percent under both the CRP and biomass plans, while payments declined by over 23 percent on the Haywood county cotton farm. Examination of the deficiency and diversion payment receipts for each farm indicated that the majority of government savings for all farms occurred early in the simulation, perhaps a result of assumptions regarding declining target prices and decreasing government involvement in agriculture.

Conclusions

Analysis indicates that the resources that a farm has available will play a role in the adoption of technology. Biomass is not different from other technologies. To develop a picture of the potential for growing biomass as a crop instead of more traditional crops requires careful analysis at the farm

level as well as at the federal level. The modeling system developed in this paper will provide many economic and environmental answers. However, since a new technology is being contemplated, many of the engineering and biological factors are as of yet undiscovered. Thus, working with experimental data, a feeling as to the agronomic potential of biomass can be established. Once that is established, the development of potential cropping systems must occur. Analysis of these cropping systems on the economic aspects of the farm firm and its and societies resources can occur through simulation.

The example in this study focused on the effect of biomass crop production on highly erodible

Table 17. Simulated government payments to representative farms, 1986-1995.

County and Year of Simulation	Farm Plan			
	Base	No Program	CRP	Biomass
Tift County, GA				
	--thousand dollars--			
1986	23.5	0.0	21.7	20.5
1995	1.0	0.0	0.8	0.7
AVG.	11.6	0.0	10.7	10.1
Haywood County, TN				
1986	11.5	0.0	10.0	10.0
1995	0.4	0.0	0.2	0.2
AVG.	6.7	0.0	5.9	5.9
Weakley County, TN				
1986	11.5	0.0	9.0	9.0
1995	0.3	0.0	0.0	0.0
AVG.	5.8	0.0	4.4	4.4

cropland in terms of farm profitability, erosion control and farm program costs. The *F.L.A.R.E.* Modeling System was applied to model the production of switchgrass on three representative farms in the Southeast.

Results indicated that erosion was likely to be reduced more by the diversion of cropland to permanent vegetative cover on farms similar to the more highly erodible West Tennessee farms than on the less erodible Tift county, Georgia farm. Equivalent reductions in erosion rates resulted from entering highly erodible cropland in the CRP and from production of switchgrass as a biomass energy crop.

Both switchgrass and CRP farm plans resulted in decreased net returns from the base plan, although the biomass farm plans were in general more profitable than the CRP plans.

Levels of government involvement could be reduced while maintaining current erosion rates if producers were permitted to produce a biomass crop for sale on land now enrolled in CRP.

BIBLIOGRAPHY

- Armstrong, D. L., L. J. Connor, and R. P. Strickland. 1970. "Combining Simulation and Linear Programming in Studying Farm Firm Growth." In *Simulation Uses in Agricultural Economics*. Edited by D. L. Armstrong and R. E. Epp. East Lansing, MI: Michigan State University.
- Bailey, D., J. C. Anderson, and G. L. Helms. 1986. "Improving Profits for Utah Dairy Farms: A Computer Simulation of Management Practices." Utah State University, Agricultural Experiment Station Report 47 (2).
- Bailey, D. V. 1983. "Economic Analysis of Selected Marketing Strategies for Cotton in the Texas Southern High Plains: A Whole-Farm Simulation Approach." Ph.D. Dissertation, Department of Agricultural Economics, Texas A&M University.
- Bailey, D. V., B. W. Brorsen, and J. W. Richardson. 1984. "Dynamic Stochastic Simulation of Daily Cash and Futures Cotton Prices." *Southern Journal of Agricultural Economics*, 16 (1).
- Barnett, D., B. Blake, and B. A. McCarl. 1980. "Goal Programming Via Multidimensional Scaling Applied to Senegalese Subsistence Farms." *American Journal of Agricultural Economics*, 64(4).
- Baum, K. H., J. Richardson, and L. P. Schertz. 1982. "A Stochastic Recursive Programming Model for Analyzing Representative Farms." Staff Report No. AGES811223, National Economics Division, Economic Research Service, United States Department of Agriculture, Washington, D.C.
- Baum, K. H. 1984. "Resource Policy and Representative Farm Models: Micro Analytic and Data Needs." Seminar at the Center for Agricultural and Rural Development, Iowa State University.
- Baum, K., J. Richardson, and L. Schertz. 1984. "A Stochastic Recursive Interactive Programming Model for Farm Firm Policy Analysis." *Computers and Operations Research*, 11 (2).
- Baum, K. H., and J. W. Richardson. 1983. "FLIPCOM: Farm-Level Continuous Optimization Models for Integrated Policy Analysis." In *Modeling Farm Decisions for Policy Analysis*. Edited by K. H. Baum and L. P. Schertz. Boulder, CO: Westview Press.
- Boehlje, M., and S. Griffin. 1979. "Financial Impacts of Price Supports." *American Journal of Agricultural Economics*, 51 (2).
- Boehlje, M., and T. K. White. 1969. "A Production-Investment Decision Model of Farm Firm Growth." *American Journal of Agricultural Economics*, 58 (3).
- Boggess, W. G., J. M. McGrann, E. O. Heady, and M. Boehlje. 1978. "A Farm Level Financial Analysis of Alternative Soil Loss Control Policies." *American Journal of Agricultural Economics*, 60 (5).
- Bradford, G. L. 1983. "Optimizing Models: Some Observations and Opinions on the State of Progress." In *Modeling Farm Decisions for Policy Analysis*. Edited by K. H. Baum and L. P. Schertz. Boulder, CO: Westview Press.
- Brorsen, B. W., J. W. Richardson, W. R. Grant, and L. D. Schnake. 1984. "Impacts of Price Variability on Marketing Margins and Producers Viability in the Texas Wheat Industry." *Western Journal of Agricultural Economics*, 9.

- Brown, D. J. and J. Pheasant. 1983. "An Assessment of Economic Damages From Ozone to a Set of Representative Midwest Farms." Agricultural Experiment Station Bulletin, Purdue University.
- Bureau of the Census. 1989. *1987 Census of Agriculture*. United States Department of Commerce, Washington, D.C.
- Bureau of the Census. 1984. *1982 Census of Agriculture*. United States Department of Commerce, Washington, D.C.
- Center for Agricultural and Rural Development. 1983. "Crop Budgets, 1982." (Produced in association with Oklahoma State University and Economic Research Service). United States Department of Agriculture, Washington, D.C.
- Chien, Yins I. 1972. "Developing a Multiperiod Linear Programming-Simulation Farm Firm Growth Model. Thesis, Department of Agricultural Economics, University of Kentucky.
- Chien, Y. I., and G. L. Bradford. 1976. "A Sequential Model of the Farm Firm Growth Process." *American Journal of Agricultural Economics*. 58 (3).
- Clark, R. T. 1972. "Predicted Economic Effects of Environmental Quality Control Policies on Linear Firm Models and an Application to an Irrigated Farm Model." Ph.D. Dissertation, Department of Agricultural Economics, Oregon State University.
- Clements, A. M., Jr., H. P. Mapp, Jr., and V. R. Eidman. 1971. Technical Bulletin T-131, Oklahoma Agricultural Experiment Station, Oklahoma State University.
- Cole, G. C. and B. C. English. 1990. "The Micro Oriented Agricultural Production System (MOAPS): A Documentation." Research Report 90-03. Department of Agricultural Economics and Rural Sociology, The University of Tennessee, Knoxville.
- Condra, G. D. 1978. "An Economic Feasibility Study of Irrigated Crop Production in the Pecos Valley of Texas." Ph.D. Thesis, Department of Agricultural Economics, Texas A&M University.
- Crawford, E. W., and R. A. Milligan. 1982. "A Multi-year, Stochastic, Farm Simulation Model for Northern Nigeria: An Experimental Design Approach." *American Journal of Agricultural Economics*, 64(4).
- Crenshaw, J., B. Harrold, K. Kaufman, R. Little, and D. Watt. 1985. "Advancing Technology in Swine Production: A Simulation Model of Swine Performance." North Dakota Farm Research, North Dakota Agricultural Experiment Station, North Dakota State University. 43 (3).
- Crowder, B. M., H. B. Pionke, D. J. Epp, and C. E. Young. 1985. "Using CREAMS and Economic Modeling to Evaluate Conservation Practices: An Application." *Journal of Environmental Quality*. 14 (3).
- Dabbert S., and P. Madden. 1986. "The Transition to Organic Agriculture: A Multi-Year Simulation Model of a Pennsylvania Farm." *American Journal of Alternative Agriculture*. 1 (3).
- Day, R. H. 1983. "Farm Decisions, Adaptive Economics, and Complex Behavior in Agriculture." In *Modeling Farm Decisions for Policy Analysis*. Edited by K. H. Baum and L. P. Schertz. Boulder, CO: Westview Press.

- Dobbins, C. L., and H. P. Mapp, Jr. 1983. "A Recursive Goal Programming Model of Intergenerational Transfers by Farm Firms." In *Modeling Farm Decisions for Policy Analysis*. Edited by K. H. Baum and L. P. Schertz. Boulder, CO: Westview Press.
- Dobbins, C. L., P. Preckel, A. Mdafr, J. Lowenberg-DeBoer, and D. Stucky. 1990. "Evaluation of Potential Herbaceous Biomass Crops on Marginal Crop Lands: 2) Economic Potential, Final Report 1985-1989." Oak Ridge National Laboratories, U.S. Department of Energy, Oak Ridge, Tennessee.
- Duffy, P. A., J. W. Richardson, and E. G. Smith. 1984. "The Effects of Alternative Farm Programs and Levels of Price Variability on Different Size Farms." Paper presented at the American Agricultural Economics Association Meetings, Ithaca, New York.
- Economic Research Service. 1988. "Agricultural Income and Finance Situation and Outlook Report." United States Department of Agriculture. Washington, D.C. September.
- Edington, C. W. 1980. "Impacts of Federal Tax Policies on Potential Growth in Size of Typical Farms." *American Journal of Agricultural Economics*. 62(5).
- Eleveld, B. 1979. "The Impact of Increasing Input Price on the U.S. Farm Sector: A Dynamic Simulation Approach." Ph.D. Dissertation, Department of Agricultural Economics, Texas A&M University.
- Featherstone, A. M. 1986. "A Portfolio Choice Model of the Financial Response of Indiana Farms to Alternative Price and Income Support Programs." Ph.D. Dissertation, Department of Agricultural Economics, Purdue University.
- Food and Agricultural Policy Research Institute (FAPRI). 1989. "Preliminary Summary of the FAPRI Baseline." Staff Report. Food and Agricultural Policy Research Institute, University of Missouri, Columbia. September.
- Food and Agricultural Policy Research Institute (FAPRI). 1990 "FAPRI 1990 U.S. Agricultural Outlook." Staff Report 1-90. Food and Agricultural Policy Research Institute, University of Missouri, Columbia and Iowa State University. March.
- Fox, G. C., and H. C. Driver. 1980. "Developing Farm Stratification Procedures for Representative Farm Linear Programming Analysis." Proceedings of the Canadian Agricultural Economics Society Annual Meetings. Canadian Agricultural Economics Society, August.
- Georgia Agricultural Statistics Service. 1988. *Georgia Agricultural Facts*. Athens, GA: Georgia Department of Agriculture.
- Grant, W. R., J. W. Richardson, B. W. Brorsen, and M.E. Rister. 1984. "Economic Impacts of Increased Price Variability; A Case Study with Rice." *Agricultural Economics Research*. 36.
- Guebert, S. R. 1973. "Farm Policy Analysis Within A Farm Sector Model." Ph.D. Dissertation, Department of Agricultural Economics, University of Wisconsin, Madison.
- Halter, A. N., and G. W. Dean. 1965. "Use of Simulation in Evaluating Management Policies Under Uncertainty: Application to a Large Scale Ranch." *Journal of Farm Economics*. 47 (3).
- Hanson, G. D. 1982. "Agricultural Income Tax Expenditures and Their Effects on Farm Growth." Ph.D. Dissertation, Department of Agricultural Economics, University of Minnesota, St. Paul.

- Hardin, M. L. 1978. "A Simulation Model for Analyzing Farm Capital Investment Alternative." Ph.D. Thesis, Department of Agricultural Economics, Oklahoma State University.
- Hardin, D. C. and R. D. Lacewell. 1979. "Implication of Improved Irrigation Pumping Efficiency on Farmer Profit and Energy Use." TA-14654, Texas Agricultural Experiment Station, Texas A&M University.
- Harman, W. L., 1973. "Evaluating the Growth Potential of Irrigated Farms with Diminishing Water Supplies: A Multiple Goals Approach to Decision Making." Ph.D. Thesis, Department of Agricultural Economics, Oklahoma State University.
- Hatch, R. E. 1973. "Growth Potential and Survival Capability of Southern Plains Dryland Farms: A Simulation Analysis Incorporating Multiple-Goal Decision Making." Ph.D. Thesis, Department of Agricultural Economics, Oklahoma State University.
- Heidhues, T. 1966. "A Recursive Programming Model of Farm Growth in Northern Germany." *Journal of Farm Economics*. 48 (3).
- Held, L. J. 1977. "Growth and Survival of a Wheat Farm Under Selected Financial Conditions: A Simulation Analysis." Ph.D. Thesis, Department of Agricultural Economics, University of Nebraska, Lincoln.
- Holland, D., and D. Young. 1980. "An Examination of Cash Flow Conventional Net Income Measures for Evaluating the Economic Variability of Farms of Varying Size." *Western Journal of Agricultural Economics*. 5 (1).
- Hutton, R. F., and H. R. Hinman. 1971. "Mechanics of Operating the General Agricultural Firm Simulator." In *Agricultural Production Systems Simulation*. Edited by V.R. Eidman. Stillwater, OK: Oklahoma State University Press.
- Jewell, D. K. 1984. "An Economic Analysis of the 1983 Payment-in-Kind (PIK) Program Using a Farm Program Simulation Model." Ph.D. Dissertation, Department of Agricultural Economics, University of Nebraska, Lincoln.
- Kaiser, H. M. 1985. "An Analysis of Farm Commodity Programs as Risk Management Strategies for Minnesota Corn-Soybean Producers." Ph.D. Dissertation, Department of Agricultural Economics, University of Minnesota, St. Paul.
- Kaiser, E., and M. Boehlje. 1980. "A Multiperiod Risk Programming Model for Farm Planning." *North Central Journal of Agricultural Economics*. 2 (1).
- King, R. P., and G. E. Oamek. 1983. "Generalized Risk-Efficient Monte Carlo Programming: A Technique for Farm Planning Under Uncertainty." In *Modeling Farm Decision for Policy Analysis*. Edited by K. H. Baum and L. P. Schertz. Boulder, CO: Westview Press.
- Kingma, O. T. 1978. "A Recursive Stochastic Programming Model of Farm Growth." In *Modelling Economic Change: The Recursive Programming Approach*. Edited by R. H. Day and A. Cigno. Amsterdam: North-Holland Publishing Co.
- Klein, K. K., and G. E. Lee. 1974. "Comparative Analysis Information as an Aid to Decision Making." *Canadian Journal of Agricultural Economics*. 22 (3).

- Ladue, E. L. 1971. A Computerized Farm Business Simulator for Research and Farm Planning." Ph.D. Dissertation Department of Agricultural Economics, Michigan State University.
- Lemieux, C. M., J. W. Richardson, and C. J. Nixon. 1982. "Federal Crop Insurance vs. ASCS Disaster Assistance for Texas High Plains Cotton Producers: An Application of Whole-Farm Simulation." *Western Journal of Agricultural Economics*. 7 (2).
- Lins, D. A. 1969. "An Empirical Comparison of Simulation and Recursive Linear Programming Firm Growth Models." *Agricultural Economic Research*. 41 (1).
- Loftsgard, L. D., and E. O. Heady. 1959. "Application of Dynamic Programming Models for Optimum Farm and Home Plans." *Journal of Farm Economics*. 41 (1).
- Longmire, J. L. 1980. "Demand for Concentrate Feed in British Agriculture: An Aggregative Programming Approach." *Journal of Agricultural Economics*. 31 (2).
- Martin, N. R., Jr., J. O. Wise, and W. N. Musser. 1976. "The Impact of Managerial Response in Enterprise Organization to Changes in Price Relationships on Profit Potential." *Journal of American Society of Farm Managers and Rural Appraisers*. 40 (2).
- McSweeney, W. T. 1984. "A Risk Programming Analysis of Farm Level Soil and Nutrient Loss Control Decisions Under a Program of Cross-Compliance." Ph.D. Dissertation, Department of Agricultural Economics, Virginia Polytechnic Institute and State College.
- Miranowski, J. A. 1971. "Effects of Energy Price Rises, Energy Constraints, and Energy Minimization on Crop and Livestock Production Activities." *North Central Journal of Agricultural Economics*. 1 (1).
- Morrison, D. A., R. S. Kingwell, D. J. Pannell, and M. A. Ewins. 1986. "A Mathematical Programming Model of a Crop-Livestock Farm System." *Agricultural Systems*. 20 (4).
- Musser, W. N., and K. G. Stamoulis. 1981. "Evaluating the Food and Agriculture Act of 1977 with Firm Quadratic Risk Programming." *American Journal of Agricultural Economics*. 63 (3).
- Musser, N., N. R. Martin, Jr., and D. W. Reid. 1983. "A Polyperiodic Firm Model of Swine Enterprises." In *Modeling Farm Decision for Policy Analysis*. Edited by K. H. Baum and L. P. Schertz. Boulder, CO: Westview Press.
- National Agricultural Statistics Service. Various issues. *Agricultural Prices*. United States Department of Agriculture, Washington, D.C.
- Nelson, G. S. 1976. "An Exploratory Use of Group Decision Theories in Evaluating Farm Planning Programming Models." Ph.D. Dissertation, Department of Agricultural Economics, University of Manitoba, Canada.
- Nixon, C. J., and J. W. Richardson. 1982. "The Economic Recovery Tax Act of 1981: Consequences for Farm Operators." *Agricultural Finance Review*. 42.
- Nixon, C. J. 1980. "Farm Tax Management Simulation Model." Departmental Program and Model Documentation, Department of Agricultural Economics, Texas Agricultural Experiment Station, College Station, Texas.

- Nowak, C., R. Milligan, W. Knoblauch, and D. Fox. 1983. "Profitability and Investment Potential of the Part-Time Beef Cow-Calf Enterprise." Department of Agricultural Economics, Cornell University, Ithaca, New York.
- Padgett, M. M. 1980. "An Analysis of On-Farm Impacts for Soil Conservation and Non-Point Source Pollution Abatement Practices and Policies on Representative Farms in Southeast Minnesota." Ph.D. Dissertation, Department of Agricultural Economics, Michigan State University.
- Patrick, G. F., and L. M. Eisgruber. 1968. "The Impact of Managerial Ability and Capital Structure on Growth of the Farm Firm." *American Journal of Agricultural Economics*. 50 (3).
- Patrick, G. F. 1978. "Some Impacts of Inflation on Farm Firm Growth." *Southern Journal of Agricultural Economics*. 10 (1).
- Perry, G. M., M. E. Rister, J. W. Richardson, J. Sij, and W. Grant. 1985. "The Impact of Tenure Arrangements and Crop Rotations on Upper Gulf Coast Rice Farms: A Survival Approach." Texas Agricultural Experiment Station, Department of Agricultural Economics, Texas A&M University.
- Persaud, T. 1980. "Decision Making Relating to Risk Management Strategies in a Farm Planning Model." Ph.D. Dissertation, Department of Agricultural Economics, Oklahoma State University.
- Pflueger, B. W. 1985. "Lender Response to Federal Crop Insurance: Their Effects on Farm Business Performance." Ph.D. Dissertation, Department of Agricultural Economics, University of Illinois, Urbana-Champaign.
- Rahman, M. D. 1980. "Variable Amortization and Financial Control Under Uncertainty: Application to Texas Rice Farms." Ph.D. Dissertation, Department of Agricultural Economics, Texas A&M University.
- Richardson, J., and C. Nixon. 1980. "The Farm Level Income and Policy Simulator." Technical Report 81-2, Department of Agricultural Economics, Texas A&M University, College Station, Texas.
- Richardson, J. W., and D. V. Bailey. 1983. "Debt Servicing Capacity of Producers in the Northern High Plains." Report to the Farm Credit Banks of Texas, Department of Agricultural Economics, Texas A&M University, (Thirteen reports with a similar title for different regions in Texas).
- Richardson, J. W., and G. D. Condra. 1981. "Farm Size Evaluation in the El Paso Valley: A Survival/Success Approach." *American Journal of Agricultural Economics*. 63 (3).
- Richardson, J. W., C. M. Lemieux, and C. J. Nixon. 1983. "Entry into Farming: The Effects of Leasing and Leverage and Firm Survival." *Southern Journal of Agricultural Economics*. 15 (2).
- Richardson, J. W., and C. J. Nixon. 1982a. "Producer's Preference For a Cotton Farmer Owned Reserve: An Application of Simulation and Stochastic Dominance." *Western Journal of Agricultural Economics*. 7 (1).
- Richardson, J. W., and C. J. Nixon. 1982b. "The Economic Recovery Act of 1981: Impacts on Farmer's Liquidity, Equity, and Growth." *Western Journal of Agricultural Economics*. 7 (1).
- Richardson, J. W., and C. J. Nixon. 1984. "Effects of the 1980, 1981, and 1982 Tax Laws on Texas Rice Farmers." *Southern Journal of Agricultural Economics*. 16 (1).

- Richardson, J. W., and C. J. Nixon. 1986. "Description of FLIPSIM V: A General Firm Level Policy Simulation Model." Bulletin B, Texas Agricultural Experiment Station, Texas A&M University.
- Richardson, J. W., C. J. Nixon, and E. G. Smith. 1982. "Economic Impacts of the 1981 Agricultural Act and the 1981 Tax Act on Texas High Plains Farmers." *Southern Journal of Agricultural Economics*. 14 (2).
- Roush, C. E., H. P. Mapp, and C. D. Maynard. 1979. "Implications of the Tax Reform Act of 1976 for Farm Estate Planning." *Western Journal of Agricultural Economics*. 4 (2).
- Sanford, S. O. 1986. "Farm Income Enhancement Opportunities for Small, Part-Time, and Limited-Resource Farming Operations in the East Central Oklahoma." Ph.D. Dissertation, Department of Agricultural Economics, Oklahoma State University.
- SAS Institute Inc. 1984. *SAS/ETS User's Guide, Version 5 Edition*. Cary, NC: SAS Institute, Inc.
- Schertz, L. P., L. Calvin, and L. S. Willett. 1981. "FAHM 1981: A System Dynamics Model of Financial Behavior of Farming-Related Households." In *Modeling Farm Decisions for Policy Analysis*. Edited by K. H. Baum and L. P. Schertz. Boulder, CO: Westview Press.
- Segarra, E., R. A. Kramer, and D. B. Taylor. 1985. "A Stochastic Programming Analysis of the Farm Level Implications of Soil Erosion Control." *Southern Journal of Agricultural Economics*. 17 (2).
- Shirley, C. K. 1981. "The Structural Impacts of Commodity Farm Programs on Farms in the Southern Texas High Plains." M.S. Thesis, Department of Agricultural Economics, Texas A&M University.
- Siegfried, D. H. 1985. "A Comparison of Optimum Farm Plans From Two Alternative Risk Estimates." Ph.D. Dissertation, Department of Agricultural Economics, University of Kentucky.
- Skees, J. R., M. R. Reed, and G. D. Pederson. 1983. "Inflation/Disinflation, Some Effects at the Farm Level." Staff Paper, Department of Agricultural Economics, University of Kentucky.
- Skees, J. R. 1983. "FLOSSIM: A Multiple-Farm Opportunity Set Simulation Model." In *Modeling Farm Decisions For Policy Analysis*. Edited by K. H. Baum and L. P. Schertz. Boulder, CO: Westview Press.
- Smith, E. G. 1982. "Economic Impact of Current and Alternative Farm Programs on Farm Structure in the Southern High Plains of Texas." Ph.D. Dissertation, Department of Agricultural Economics, Texas A&M University.
- Soil Conservation Service. 1981. "Land Resource Regions and Major Land Resource Areas of the United States." Agriculture Handbook 296. United States Department of Agriculture, Washington, D.C.
- Soil Conservation Service. 1984. "1982 National Resources Inventory." Data Tape. United States Department of Agriculture, Washington, D.C.
- Soil Conservation Service. 1987. "1982 National Resources Inventory." Statistical Bulletin No. 756. United States Department of Agriculture, Washington, D.C.

- Swaney, D. P., J. W. Jones, J. W. Mishoc, and F. Baker. 1986. "A Combined Simulation-Optimization Approach for Predicting Crop Yields." *Agricultural Systems*. 20 (2).
- Taylor, R. C. 1983. "Complementarities Between Micro- and Macro-Systems Simulation and Analysis." In *Modeling Farm Decisions for Policy Analysis*. Edited by K. H. Baum and L. P. Schertz. Boulder, CO: Westview Press.
- Tennessee Agricultural Extension Service. 1989. "Field Crop Budgets for 1990." The Tennessee Agricultural Extension Service, The University of Tennessee, Knoxville. December.
- Tennessee Agricultural Statistics Service. 1989. *Tennessee Agriculture 1989*. Tennessee Department of Agriculture, Nashville, Tennessee. October.
- Thomson, L., W. R. Goodman, B. C. English, R. R. Alexander, and G. C. Cole. 1989. "An Evaluation of the Effects of Conservation Compliance on Selected Financial Characteristics of Two Representative West Tennessee Farms." Research Report #89-22, University of Tennessee Agricultural Experiment Station, September.
- Umberger, D. E. 1972. "Factors Affecting Farm Growth Rates: A Simulation Analysis of Columbia Basin Irrigated Farms." Ph.D. Dissertation, Department of Agricultural Economics, Washington State University.
- University of California. 1990. "Budget Planner Version 2.0." Department of Agricultural Economics, University of California, Davis, California.
- Van Poolen, H.W. 1981. "Optimal Beef Production Management Strategies for Hawaii: A dynamic Programming Approach." Dissertation, Department of Agricultural Economics, University of Hawaii.
- Walker, O. L., and J. R. Martin. 1966. "Firm Growth Research Opportunities and Techniques." *Journal of Farm Economics*. 48 (5).
- Williams, J. R., P. T. Dyke, and C. A. Jones. 1982. "EPIC -- A Model for Assessing the Effects of Erosion on Soil Productivity." Paper presented at the Third International Conference on State-of-the-Art in Ecological Modeling, Colorado State University, May 24-28.

INTERNAL DISTRIBUTION

ORNL/Sub/88-SC616/2

1. L. D. Bates	15. R. B. Shelton
2. R. S. Carlsmith	16. D. S. Shriner
3. J. H. Cushman	17. S. H. Stow
4. M. P. Farrell	18-37. A. F. Turhollow
5. D. E. Fowler	38. G. A. Tuskan
6. W. Fulkerson	39. R. I. Van Hook
7. C. W. Gehrs	40. L. L. Wright
8. R. L. Graham	41. Central Research Library
9. S. G. Hildebrand	42-46. ESD Library
10. C. R. Kerley	47-48. Laboratory Records Dept.
11. R. M. Lee	49. Laboratory Records, RC
12. S. B. McLaughlin	50. ORNL Patent Office
13. J. W. Ranney	51. ORNL Y-12 Technical Library
14. D. E. Reichle	

EXTERNAL DISTRIBUTION

51. C. S. Accola, 1496 Agronomy Hall, Iowa State University, Ames, IA 50011
- 52-61. R. R. Alexander, Department of Ag. Econ. and Rural Soc., 308 Morgan Hall, University of Tennessee, Knoxville, TN 37901-071
62. I. C. Anderson, Dept. of Agronomy, Iowa State University, Ames, IA 50011
63. Brad Ashton, BATTELLE, Pacific Northwest Laboratories, 901 D Street, S.W., Suite 900, Washington, DC 20024-2115
64. D. L. Auld, Dept. Agronomy, Horticulture and Entomology, Texas Tech University, Box 122, Lubbock, TX 79409-2122
65. Suresh Babu, Institute of Gas Technology, Biomass Conversion, 3424 South State Street, Chicago, IL 60616
66. P. C. Badger, Biomass Energy Program, P. O. Box 1010, Tennessee Valley Authority, Muscle Shoals, AL 35660
67. M. O. Bagby, Northern Agricultural Energy Center, USDA, ARS, Northern Regional Research Center, Peoria, IL 61604
68. Bill Barfield, Kentucky Water Resources Res. Inst., University of Kentucky, 346 Bowman Hall, Lexington, KY 40506-0059
69. J. Berning, Electric Power Research Institute, 3412 Hillview Ave., P. O. Box 10412, Palo Alto, CA 94303
70. M. Bhat, Department of Ag Econ and Rural Soc, 308 Morgan Hall, University of Tennessee, Knoxville, TN 37901-071
71. Melvin Blase, University of Missouri, 228 Mumford Hall, Columbia, MO 65211
72. D. Bransby, Dept. of Agronomy and Soils, Auburn University, Auburn University, AL 36849
73. S. Bull, National Renewable Energy Laboratory, 1617 Cole Blvd., Golden, CO 80401
74. J. L. Butler, 2823 Rainwater, Tifton, GA 31794
75. D. R. Buxton, Dept. of Agronomy, Iowa State University, Ames, IA 50011
76. M. Carlton, Iowa Energy Policy Council, Lucas Bldg., Capital Complex, Des Moines, IA 50317
77. Don Challman, Center for Applied Energy Research, University of Kentucky, 3572 Iron Works Pike, Lexington, KY 40511-8433

78. J. H. Cherney, Soil, Crop and Atmospheric Sciences, 150 Emerson Hall, Cornell University, Ithaca, NY 14853
79. David Chynoweth, University of Florida, Dept. of Agricultural Engineering, Rogers Hall, Gainesville, FL 32611
80. John Clarke, Global Studies Program, Battelle, Pacific Northwest Laboratories, 901 D Street, S.W., Suite 900, Washington, DC 20024-2115
81. Sean A. Coady, West Central Research and Extension Center, Route 4, Box 46A, North Platte, NE 69101
82. Gary V. Cole, U.S. EPA, TS-779, 401 M Street, SW, Washington, DC 20460
83. Joe Colletti, Iowa State University, 251 Bessey Hall, Ames, IA 50011
84. M. Collins, University of Kentucky, N-122 Agricultural Sciences Bldg.-N, Lexington, KY 40546-0091
85. R. Conway, Office of Energy, U.S. Dept. of Agriculture, Administration Building, Route 194E, 14th and Independence Ave., Washington, DC 20250-2600
86. Dennis T. Curtin, Tennessee Valley Authority, Forestry Building, Norris, TN 37828
87. R. R. Duncan, Georgia Experiment Station, University of Georgia, Griffin, GA 30212
88. David Ellis, Department of Horticulture, University of Wisconsin-Madison, 1575 Linden Drive, Madison, WI 53706
- 89-138. B. C. English, Dept. of Agricultural Economics and Rural Sociology, P. O. Box 1071, University of Tennessee, Knoxville, TN 37901-1071
139. D. O. Erickson, Animal and Range Science Dept., North Dakota State University, Fargo, ND 58105
- 140-141. J. E. Ferrell, Biofuels Systems Division, Department of Energy, MS CE-331, Forrestal Building, 1000 Independence Avenue, S.W., Washington, DC 20585
142. G. W. Fick, Department of Agronomy, Cornell University, Ithaca, NY 14853
143. P. Fox, Bonneville Power Administration, P. O. Box 3621, Portland, OR 97208
144. J. F. Franklin, Bloedel Professor of Ecosystem Analysis, College of Forest Resources, University of Washington, Anderson Hall (AR-10), Seattle, WA 98195
145. H. A. Fribourg, Department of Plant and Soil Science, University of Tennessee, Knoxville, TN 37901
146. Robert Friedman, BATTELLE, Pacific Northwest Laboratories, 901 D Street, S.W., Suite 900, Washington, DC 20024-2115
147. E. E. Gavett, 2608 Bowling Green Drive, Vienna, VA 22180
148. T. J. Gross, Department of Energy, CE-22, Forrestal Building, 1000 Independence Ave., Washington, DC 20585
149. A. J. Hallam, Dept. of Economics, Iowa State University, Ames, IA 50011
150. L. Hansen, ERS/USDA, 1301 New York Ave., N.W., Washington, DC 20005-4788
151. G. M. Hornberger, Department of Environmental Sciences, University of Virginia, Charlottesville, VA 22903
152. Evan Hughes, Electric Power Research Inst., P.O. Box 10412, Palo Alto, CA 94303
153. K. D. Johnson, Department of Agronomy, Purdue University, West Lafayette, IN 47907
154. R. G. Johnson, Agricultural Economics Department, North Dakota State University, Fargo, ND 58105
155. G. Y. Jordy, Director, Office of Program Analysis, Office of Energy Research, ER-30, G-226, U.S. Department of Energy, Washington, DC 20545
156. Anthony Juo, Dept. of Soil & Crop Sciences, Texas A&M University, College Station, TX 77843
157. Mike Kennedy, Department of Geography, University of Kentucky, 1451 Patterson Office Tower, Lexington, KY 40506-0027
158. Jim Kiniry, USDA/ARS, Temple-Blackland Research Center, 808 E. Blackland Road, Temple, TX 76502

159. E. J. Kladvko, Department of Agronomy, Purdue University, West Lafayette, IN 47907
160. F. J. Kuzel, Council of Great Lakes Governors, 35 E. Wacker Drive, Suite 1850, Chicago, IL 60601
161. M. Ladisch, Laboratory of Renewable Resources Engineering, A. A. Potter Engineering Center, Purdue University, West Lafayette, IN 47907
162. D. J. Lathwell, Department of Agronomy, Cornell University, Ithaca, NY 14853
163. Otto J. Loewer, Biology & Agr. Engineering Dept., University of Arkansas, Fayetteville, AR 72701
164. J. Lowenburg-DeBoer, Department of Agricultural Economics, Purdue University, West Lafayette, IN 47907
165. D. W. Meyer, Agronomy Department, North Dakota State University, SU Station, Fargo, ND 58105
166. Peter Molton, BATTELLE, International Program Support, Pacific Northwest Laboratories, Battelle Blvd., Richland, WA 99352
167. R. Moorer, Biofuels Systems Division, Department of Energy, MS CE-341, Forrestal Building, 1000 Independence Avenue, S.W., Washington, DC 20585
168. Robert D. Nielsen, USDA/Soil Sur. Interpretation & Geo., Federal Bldg., Room 152, 100 Centennial Mall, North Lincoln, NE 68508-3866
169. R. O'Connell, Coalition of Northeastern Governors, 400 North Capitol Street, Suite 382, Washington, D. C. 20001
170. R. H. Olsen, Vice President for Research, University of Michigan, Medical Sciences Building II, #5605, 1301 East Catherine Street, Ann Arbor, MI 48109-0620
171. R. Overend, National Renewable Energy Laboratory, 1617 Cole Blvd., Golden, CO 80401
172. Blaine Parker, Dept. of Agricultural Engineering, 114 Agricultural Eng. Bldg. #2, University of Kentucky, Lexington, KY 40506-0276
173. D. J. Parrish, Department of Agronomy, Virginia Tech, Blacksburg, VA 24061
174. A. Patrinos, Acting Director, Environmental Sciences Division, Office of Health and Environmental Research, ER-74, U.S. Department of Energy, Washington, DC 20585
175. Fred Payne, Dept. of Agricultural Engineering, University of Kentucky, 220 Agricultural Eng. Bldg. #2, Lexington, KY 40506-0276
176. Leonard Peters, University of Kentucky on Special Assignment to Battelle, Pacific Northwest Laboratories, Battelle Blvd., Richland, WA 99352
177. D. C. Petritz, Department of Agricultural Economics, Purdue University, West Lafayette, IN 47907
178. V. Phillips, Hawaii Natural Energy Institute, University of Hawaii at Manoa, 2540 Dole Street, Homes 246, Honolulu, HI 96822
179. Walt Podolski, Argonne National Laboratory, Chemical Technology Division, 9700 S. Cass Ave., Argonne, IL 60439-4837
180. N. Rader, Public Citizen, 215 Pennsylvania Ave, S.E., Washington, D.C. 20003
181. Richard Rapoport, BATTELLE, Pacific Northwest Laboratories, 901 D Street, S.W. Suite 900, Washington, DC 20024-2115
182. Norm Rask, Dept. of Agricultural Economics, Ohio State University, 2120 Fyffe Road, Columbus, OH 43210
183. Rich Ready, Dept. of Agricultural Economics, University of Kentucky, 318 Agricultural Eng. Bldg. #2, Lexington, KY 40506-0276
184. Remesh Reddy, Department of Soil Science, University of Florida, Gainesville, FL 32611-0313
185. John Reilly, Economic Research Service, USDA/ERS, 1301 New York Ave., N.W., Room 528, Washington, DC 20005-4788

186. J. C. Roetheli, USDA/SPPS, 14th and Independence Ave., S.W., Suite 342, Aerospace Bldg., Washington, DC 20251-2200
187. Rick Saylor, Center for Applied Energy Research, University of Kentucky, 3572 Iron Works Pike, Lexington, KY 40511-8433
188. L. Smith, North American Permaculture, 9508 Potomac Drive, Fort Washington, MD 20744
189. John Stencel, Center for Applied Energy Research, University of Kentucky, 3572 Iron Works Pike, Lexington, KY 40511-8433
190. G. D. Stephenson, Southeastern Regional Biomass Energy Program, P. O. Box 1010, Tennessee Valley Authority, Muscle Shoals, AL 35660-1010
191. D. Stevens, P. O. Box 6752, Kennewick, WA 99336
192. Charles Strauss, Penn State University, 104 Ferguson Bldg., University Park, PA 16802
193. D. Swanson, Western Area Power Authority, 1627 Cole Blvd., P.O. Box 3402, Golden, CO 80401
194. K. S. Tyson, National Renewable Energy Laboratory, 1617 Cole Blvd., Golden, CO 80401
195. J. J. Volenec, Department of Agronomy, Purdue University, West Lafayette, IN 47907
196. Larry P. Walker, Dept. of Agricultural & Biological Eng., Riley-Robb Hall Engineering, Cornell University, Ithaca, NY 14853
197. E. Wan, Science Applications Int. Corp., 1710 Goodridge Drive, McLean, VA
198. Donald Wise, Northeastern University, 342 Snell Engineering Ctr., Boston, MA 02115
199. Elmer Whittler, Martin School for Public Adm., University of Kentucky, 427 Patterson Office Tower, Lexington, KY 40506-0027
200. A. Wiselogle, National Renewable Energy Laboratory, 1617 Cole Blvd., Golden, CO 80401
201. F. J. Wobber, Environmental Sciences Division, Office of Health and Environmental Research, ER-74, U.S. Department of Energy, Washington, DC 20585
202. D. D. Wolf, Department of Agronomy, Virginia Tech, Blacksburg, VA 24061
203. E. Woolsey, Energy Bureau, Iowa Department of Natural Resources, Henry A. Wallace Building, Des Moines, IA 50319
204. N. A. Wright, Geophyta, Inc., 2685 C. R. 254, Vickery, OH 43464
205. Elmon Yoder, 808 Surrey Lane, Lexington, KY 40503
206. Supak Yongsuwan, Auburn University, 209 ADS Building, Auburn, AL 36849
207. Jeff Young, KY Natural Resources & Environmental, Protection Cabinet, Division of Energy, 691 Teton Trail, Frankfort, KY 40601
208. Cathy Zoi, EPA, 401 M Street, S.W., Washington, DC 20460
209. Office of Assistant Manager for Energy Research and Development, Oak Ridge Operations, P.O. Box 2001, U.S. Department of Energy, Oak Ridge, TN 37831-8600
- 210-219. Office of Scientific and Technical Information, P.O. Box 62, Oak Ridge, TN 37831

END

**DATE
FILMED**

3 / 18 / 92