A STUDY OF ECONOMIC FEASIBILITY OF U.S. KENAF MARKETS

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Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
DOCTOR OF PHILOSOPHY
May, 1994

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U.S. KENAF MARKETS

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ACKNOWLEDGMENTS

I wish to express my sincere gratitude to my advisor, Dr. Michael R. Dicks for his academic counsel, his patience and understanding throughout my graduate program. I wish to thank Dr. B. Wade Brorsen for his very helpful comments, suggestions, and academic advise throughout my graduate research work; Drs. James Trapp and Charles Hibberd for their helpful comments.

My appreciation is extended to Min-Fah Teo who provided a lot of help in the computer work; Dr. Charles Taylor who provided invaluable data and assistance for this project.

I am very grateful to all the faculty, staff and secretaries in the Department of Agricultural Economics of the Oklahoma State University for their assistance throughout my graduate program.

Finally, I would like to thank my wife Chunming Fan, my son Jeffrey, and my parents for their constant encouragement, support and understanding throughout my graduate program.

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CHAPTER I

PROBLEM SETTING

Introduction

Over the years, instability of farm prices and low farm incomes have been the symptoms of farm problems in American agriculture. The persistent low farm incomes are often associated with economic vulnerability resulting from growing only one or two commodities on farms. Diversifying farm enterprises can reduce vulnerability and increase farm incomes.

Farmers in all areas of the country have been seeking crop alternatives to enable them to diversify enterprises and reduce economic vulnerability. However, finding crops which not only have economic potential but also meet government program requirements is difficult. Kenaf (*Hibiscus cannabinus* L.), a fiber and potential forage crop, may be a potential alternative crop. Studies by Taylor (1992a, 1992b) have indicated that many industrial products can be made using kenaf fibers (i.e., pulp products, newsprint, poultry litter, packing materials, etc.). Preliminary research has also shown that kenaf can be grown for a high quality forage (Phillips et al.; Dicks et al.; and Hibberd et al.).

As a nonwoody plant fiber in pulp and paper, kenaf has been under consideration by the U.S. Department of Agriculture since 1930s. Kenaf has been identified as the most promising alternative fiber based on its ability to resist lodging and its consistently high yield. The various attributes of kenaf as an alternative fiber suggest that kenaf should be seriously considered by both producers and consumers. For farmers, kenaf represents a major alternative crop which could be incorporated to diversify farm enterprises and improve the profitability of their crop rotation. Newsprint manufacturers could benefit by replacing some of their higher cost pulpwood with locally produced kenaf. In addition to reducing energy and labor costs, kenaf may also reduce capital investments in the long run. Kenaf's annual renewability allows a mill the opportunity to keep its fiber supply close and thus hold transportation costs down. As far as raw material is concerned, the mill's planning horizon is reduced to a maximum of one year for kenaf, whereas pine requires anywhere from 15 to 30 years. Newspaper publishers would benefit in the long run by a reduction in the rate of newsprint price increases. Newsprint comprises as much as 40 percent of a newspaper's total operating cost, any measure that could reduce the rate of price increases would benefit the society. Therefore, a study of the potential of kenaf to increase domestic newsprint production and constrain increases in manufacturing costs can be of considerable interest to publishers. However, kenaf's commercial supply relies on multilateral decisions. Everyone concerned is reluctant to commit resources without knowing the market structures and potential production system. Farmers must become committed to sustained kenaf production in a given area. On the other hand, they require dependable markets and fair returns for their products. A mill (or mills) must become convinced that kenaf is both technically and economically feasible to pulp and to make into newsprint. In addition, manufacturers are also concerned about dependable supplies and customer satisfaction. Newspaper publishers must decide to use kenaf newsprint which will create a demand for kenaf, if it satisfies their concerns regarding quality and price.

Using kenaf as a forage in livestock feeding is a very recent development. Kenaf leaf contains as high as 30 percent crude protein and was found to be 75-80 percent digestible (Dicks et al.). The advantage of growing kenaf forage over other perennial and annual forage crops are its ability to withstand heat and drought, its multiple harvesting times, and its relatively high yields. Producing kenaf forage may benefit farmers whose enterprises are winter wheat and stocker cattle. Farmers who produce winter wheat and raise stocker cattle usually plant wheat in early fall and allow stocker cattle to graze winter wheat pasture from November to the following March. The wheat is harvested in late May and early June and the land traditionally remains idle until wheat is planted in September and October. Kenaf forage could be grown on summer fallowed land, generating additional farm income without affecting the following wheat yield (Dicks et al.).

Despite the favorable economic characteristics of kenaf fiber and forage, little is known about the kenaf market structures and potential production levels. Although kenaf has been cultivated in Africa, Asia and many other parts of the world for many years, it is still a relatively new crop to the United States. Many questions remain to be answered by agricultural economists and agronomists. While the agronomic characteristics of kenaf can be identified through field experiments, the feasibility of commercial production of kenaf has to rely on analysis of profitability of producing kenaf, aggregate demand for various products of kenaf and potential economic gains by interest groups. Introducing a new crop into the present production system requires not only careful identification of potential markets and their structures, but also thorough investigation of possible risks associated with production and marketing activities.

This research attempts to address the economics of introducing kenaf into current farm enterprises. The analysis focuses on three questions:

1. How much acreage of kenaf will be required to meet the demand for kenaf pulp, poultry litter, and forage, respectively?

2. Given the present expectations of prices and other exogenous factors, how much acreage could be planted to kenaf?
3. Given the estimated acreage of kenaf, how much marginal farm income can be generated from planting kenaf rather than other crops?

Objectives

The overall objective of this study is to determine the feasibility of kenaf production for potential markets in various parts of the United States. The specific objectives are:

1. to determine acreage requirements of kenaf supplying pulp, poultry litter, and forage; and
2. to determine potential farm supply of kenaf in the identified production regions.

Research Methods

Three types of analytical tools are used to achieve the objectives of the study: descriptive, theoretical, and empirical. The description summarizes the history of kenaf research activities focusing on using kenaf as sources for different products in the United States and other parts of the world. The description pays particular attention to research on using kenaf for newsprint production, poultry litter, and livestock forage. The description of the previous research can provide more information to further understanding of multiple utilizations of kenaf. Results obtained from these analyses are the fundamental justification for introducing kenaf into the present farm enterprises.

Concepts of uncertainty, production risk, and utility function are vigorously reviewed and discussed. Discussions of production economic theories focus on risk and uncertainty models and the associated properties. Extensive review of economic theory establishes theoretical foundation for empirical model development to accomplish objective two.

Three potential markets are the focus of this study: newsprint, poultry litter, and livestock forage. Each of the three potential markets is analyzed and discussed separately. A description of the kenaf newsprint market focuses on the present newsprint demand and supply situations, change in demand for newsprint for the last two decades. The capacities of existing paper mills which are technically ready to process kenaf for newsprint are analyzed and discussed. Empirical estimates of potential acreage requirement of kenaf fiber are obtained based on the mills capacities. These information are critical to further estimate farm supply of kenaf.

The poultry litter market considers the present U.S. poultry production level and the amount of litter required every year. Potential poultry litter required by the leading poultry producing states are estimated based on a 100 percent substitution of kenaf for conventional woody chips. The results are used to approximate the potential acreage of kenaf required in these states.

The description of kenaf forage centers on the potential economic returns generated by integrating kenaf into the winter wheat-stocker cattle enterprises. Enterprise budgets are developed for wheat-kenaf-stocker enterprises.

The second objective involves a micro-oriented model designed to represent postulated individual farmer behavior. Individual states will be aggregated to comprise total aggregate supply of kenaf focusing on newsprint, poultry litter and forage markets. Particular attention will be paid to minimizing aggregation bias and to incorporate production risk in each production region. Quadratic programming (QP) technique is used to derive supply for any given year under different market scenarios. In addition to the technical assumptions which do not have value judgements and/or preference bias, assumptions of the QP model developed will be based on current production and market conditions. For instance, farmers may grow kenaf on contract basis, risk associated with price variation may be insignificant. However, farmers may still face production risk associated with yield variability. Aggregate supply of kenaf for newsprint, poultry litter and forage are solved under different price scenarios and other exogenous factors. Theoretical analysis is used to evaluate the plausibility of the results in light of the imposed restrictions.

Study Area

Kenaf is a major source for pulp and poultry litter. However, newsprint and poultry litter markets can not be commercially targeted simultaneously due to the bulky nature of the crop. In addition, kenaf could be feasibly grown in the areas where cotton can be economically produced. Thus, states where newsprint and paper mills and large commercial poultry farms are located are considered in this study. Three production regions are included: Atlantic South (North Carolina, South Carolina, and Virginia); South Central (Arkansas, Louisiana, Oklahoma, and Texas); and Southeast (Alabama, Florida, Georgia, and Mississippi) (see figure 1.1).

Organization of the Dissertation

The remainder of this dissertation is organized as follows. Chapter II reviews and summarizes the studies and research programs on kenaf. Chapter III presents a review of the relevant literature and lays the theoretical foundation for the empirical economic analysis in this study. Chapter IV analyzes the potential markets for commercialization of kenaf and estimates the potential acreage required for various kenaf products. An analytical model used to conduct economic analysis of potential supply of kenaf in the U.S. is developed in Chapter V. Chapter VI provides detailed descriptions of the model and data collection procedures. An economic analysis of potential supply of kenaf in the U.S. is conducted and presented in Chapter VII. Finally, summary and conclusions are presented in Chapter VIII.

Figure 1.1. Location of States in the Study Area (Shaded Area)

CHAPTER II

KENAF RESEARCH: PAST AND PRESENT

Introduction

This chapter provides a review of past and present research pertaining to the utilization and economic analysis of kenaf in the United States. The results from these studies form the economic rationale for integrating kenaf into farm enterprises. A brief description of the crop's origin and characteristics is presented followed by a thorough review of various research efforts and their results.

Kenaf was introduced into the U.S. in the 1930s. Since then, various research efforts have been undertaken to evaluate the crop's agronomic characteristics, utilizations, and economics in various places across the U.S. continent. Research has been conducted to evaluate kenaf's yield response to various factors, the fiber content and utilization. The research on agronomic characteristics and cultural practices has been documented by Taylor (1984). This chapter reviews research where multiple utilization and economic analysis of kenaf were the primary focus.

Kenaf: Description and Origin

Kenaf (*Hibiscus cannabinus.* L) is a short-day length, annual hibiscus member of the mallow family, which includes those well known crops such as okra and cotton. It is native to sub-saharan Africa, attaining its greatest morphological diversity in east Africa which suggests this as its place of origin. In Kenya and Tanzania, kenaf grows wild as a tall, spiny annual or short-lived perennial with palmately lobed leaves and purple flowers. It occurs in a variety of habitats, from the edges of Typha swamps to semi-arid grasslands and roadside ditches (Wilson, 1978).

Kenaf can be cultivated under a wide range of soil and temperature conditions. The stem color can be green, red, or purple and the leaf shape may be deeply lobed or shallow. While highly fertile, kenaf is considered a cross-pollinated crop and depending upon variety is either day-neutral or photoperiod sensitive. The day neutral varieties will flower from 100-150 days after planting, depending upon the variety. Flowering is indeterminate with most cultivars having a critical photoperiod of less than 12.5 hours. When grown in the warm areas of the temperate zone, e.g., the southern tier of the cotton belt in the United States, the photo-period sensitive varieties of kenaf will produce a large tonnage of biomass in about 150 to 180 days as the plant will not shift from vegetative to reproductive grown until the shorter days of fall (Taylor, 1992).

The crop is grown in relatively dense plant populations and given the appropriate levels of moisture, nutrients, and sunlight, kenaf stalks will attain heights exceeding 12 feet and dry weight yields, ranging between 6 to 8 tons per acre at optimum maturity, e.g., mid October in south Texas (Taylor, 1992). Higgins (1974) showed that mean temperature, day length, radiation, and soil moisture significantly affect the development of new leaves at the terminal growing point for kenaf.

Kenaf has been under cultivation for thousands of years (Simmonds, 1976). Kenaf is believed to have became domesticated as early as 4000 BC in Western Sudan (Dempsey, 1975). For most of the history of kenaf, it has been a 'backyard' crop, supplying some crude fiber for handicraft purposes and leaves and shoots for food (Taylor, 1984). Kenaf can be also used for other purposes. As an example of its wide range of uses, kenaf seedlings are consumed as a green vegetable in parts of Africa.

Kenaf Research Activities

Kenaf is a plant species that has been used for centuries as a source of jute-like bast fibers. Research on kenaf utilization began in the mid-1940s in the U.S. Most of the kenaf research has concentrated on using kenaf as a source for manufacturing newsprint. However, kenaf can be processed into various other products as well. Recently, Taylor (1992) identified numerous products which can be made using kenaf fibers. These products either have been or are currently being considered, e.g., pulp products (intermediate kenaf commodities); paper products (most notably kenaf newsprint); packing materials; animal litter; cordage products (burlap, twine, etc.); fiberboard products; absorbent and filtration products; horticultural products; forage and animal feed; and fiber mat products.

Kenaf was first introduced into the United States during the period of World War II for supplying cordages. Extensive kenaf research began in 1943 when the U.S. Department of Agriculture (USDA) and the Cooperative Fiber Commission (CFC) initiated a program to assess the feasibility of producing, harvesting, and processing the bast fiber of kenaf in southern Florida. Extensive work was done in developing management systems, breeding programs, and utilization of kenaf as a fiber. In the late 1950s, the Agricultural Research Service (ARS) started a screening program to identify plants that may be suitable for the production of paper pulp. As a result of this study, kenaf was selected based on its ability to resist lodging and to produce consistently high yields. In the late 1980s and early 1990s, research on uses other than for fiber products has focused on use as a livestock feed and for animal bedding materials.

As a Pulp Fiber: Historical Background and Current Situation

Since the early 1930s, the USDA has considered the possible use of non-woody plant fibers (especially crop residue such as sugarcane bagasse and grain straw) in pulp and paper. Beginning in 1956, USDA/ARS identified new plant species that could compete with pulpwood, furnishing fibers for pulp, providing farmers with additional income from a new crop. Botanical/analytical screening systems evaluated 387 species (Nieschlag et al., 1960), kenaf and sunn hemp (*Crotalaria juncea* L.) were selected to be the most promising crops. The later decision to concentrate on kenaf was based largely on the ability of kenaf to resist lodging and to produce consistently higher yields (White et al., 1970).

During the next two decades, USDA field tested kenaf in the Midwest and shifted the bulk of the research effort to the Southeast. Some limited breeding work was maintained at Beltsville, Md. and Experiment, Ga., and agronomic research was conducted in the Southwest and in Pennsylvania with the support of newspaper publishers.

Most of the commercial development activities for kenaf newsprint are carried out by Kenaf International (KI) which was formed in 1981. The goal of KI is to develop kenaf as a commercially viable fiber for the pulp and paper industry. KI is a joint venture company presently composed of Agrifuture Inc., The Bakersfield Californian, and Charles S. Taylor. In addition to experience and expertise in business and economics, KI linked agricultural production of industrial raw materials with the ultimate consumer of the industrial product. Professional farming and newspaper publishing were brought together with a vested interest in building a vertically integrated industry from kenaf seed to a published newspaper on kenaf newsprint. Based on promising demonstrations of feasibility for growing, pulping, and newsprint manufacturing, KI began a systems approach to commercialization by intensifying agronomic and agricultural economics work for commercial seed and fiber production. Simultaneously, KI sought the interest and support from pulp and paper mill management and owners for converting or adding processing capacity at existing mills for kenaf. The support and interest of newspaper publishers was also sought and secured as kenaf newsprint showed advantageous qualities (Kugler, 1988). KI has focused its efforts on South Texas since late 1985. In 1992, KI initiated a fibers processing project (K-Fibers) based on the fiber separation system developed by H. Willet & Associates, Inc.

The Kenaf Demonstration Project was initiated in March 1986 under a cooperative agreement between KI and the USDA. The cooperative effort joins public and private resources to develop kenaf products and product markets and make kenaf industries a reality. A Joint Kenaf Task Force was established to accomplish the objective of the project. Under the direction of the Joint Kenaf Task Force, kenaf is undergoing a three-phase program for commercialization. The first phase used a systems approach to determine the feasibility of using agricultural fiber production for newsprint manufacture on a high-speed machine. The second phase was to scale-up for an extended run on a commercial newsprint machine, pressroom runs and analyses by major newspaper publishers. The third phase was to coordinate traditional research, education, and extension resources and establish a kenaf newsprint mill in south Texas. While newsprint is the focus of project activities, market and product development for other kenaf fiber applications will continue during the 2-3 year period for site planning, construction, and startup for the Kenaf Rio Grande newsprint mill in the Lower Rio Grande Valley of south Texas.

Other similar projects are also being conducted at various places in the U.S. For example, in Louisiana, a new company, Natural Fibers of Louisiana, Inc., was formed to produce, process, and market separated kenaf products. The company successfully completed the pilot plant trials in August 1991 and initiated commercial production on January 22, 1992 with the processing of approximately 3,600 tons of kenaf.

As Poultry Litter: Recent Development

Kenaf's woody core makes up about 55-65 percent of the stem and has market potential for use as poultry litter. The suitability of kenaf core particles as a potential broiler litter material was evaluated at the University of Delaware and Texas A&M University. Malone et al. (1990) at Delaware evaluated the suitability as broiler litter of kenaf core in two floor-pen experiments. The experiment results show that fresh and reused kenaf appear comparable to pine sawdust as a broiler litter material. Hyatt et al. (1990) conducted trials to compare kenaf core material to pine shavings as a bedding material for market turkey hens at Texas A&M University Poultry Science Research Center. Preliminary results indicate there are no differences in growth rate, feed conversion or total mortality when comparing turkey hens on conventional pine shavings versus those reared on kenaf core. Mold count, moisture content and aerobic plate count show very slight differences between litter types initially and there are virtually no differences detected when litter was evaluated toward the latter part of the growing period (Hyatt, 1990). The study indicates that based on turkey hen performance and retail carcass quality, kenaf core material is found to be comparable to pine shavings when used as floor litter.

As Livestock Forage: New Uses

Early in 1967, Wing (1967) evaluated the nutritional value of kenaf. He found that the kenaf leaf, leaf stem, flower buds and growth tip contain as much as 30 percent protein. Ether extract content is high, moreover, the fiber is largely cellulose which may be digested well by ruminants. Thus, kenaf appeared to be a potential source of protein for animal feeds.

Research carried out by Pinkerton (1978) of Thailand evaluated kenaf as a substitute feed in livestock and broiler rations. The study consisted of trials which included broiler, fattening swine and cattle. Kenaf was compared to conventional feeds used in feeding broiler, swine and cattle. The study concluded that kenaf leaves and fine stems may be satisfactory substitutes for conventional feeds for broilers and fattening swine at levels up to 12 percent for broiler and less than 10 percent for swine. The study also indicates that kenaf leaf hay has shown preliminary promise as a supplement to rice straw for dry season feeding of cattle. The trial data demonstrated that kenaf hay may be equal in feed quality to cowpea hay.

Phillips et al. (1989) conducted experiments using kenaf leaves to feed sheep to analyze the nutrient content and digestibility of kenaf forage. Kenaf was harvested on different dates to compare forage yields in terms of dry matter harvested, dry matter content and crude protein content for leaves and stems. The study showed that the leaf contains up to 30 percent crude protein and is 75-80 percent digestible by lambs. The data collected from the feeding trial showed that the majority of digestible plant fiber, soluble nutrients and protein are located in the leaf-stem portion, which is readily consumed by lambs. The results also indicated that once a certain biomass of leaf material was accumulated, additional biomass formed was in the stem portion. Harvesting after 103 days will lower the quality (crude protein content) of the forage but will increase total dry matter production. Further, the study determined that the optimal harvest time was 40-60 days and that 2.5 tons of forage per acre could be produced during this time period. The study findings imply that kenaf may provide the opportunity to cultivate a small area to produce high quality forage for supplementation of ruminant diets and a potential source of medium quality forage if the tops of the mature plant are harvested. Using kenaf as a feed source for ruminants may increase its acceptability to producers in the Southern Great Plains and create a reserve of kenaf production for the pulp industry to build on as demand for the plant as fiber source increases.

Dicks et al. at Oklahoma State University is currently field testing growing and harvesting kenaf as a forage crop. A feeding trial consisting of 40 crossbred heifers (638 lb average weight) was conducted in 1992. Preliminary results show that immature kenaf hay contains 10.4 percent crude protein with an in vitro digestibility of 51 percent. The results support the hypothesis that immature kenaf may provide quality forage and has some nutritional characteristics that could justify its use as a livestock feed. Kenaf may become a viable forage crop in the Southern Plains and other areas which fall into the same climatic conditions if more technical problems (e.g., forage varieties, cultural practice, harvesting and feeding forms, etc) are resolved.

Economic Analysis: Foundation for Commercialization

Kenaf has been identified by USDA as one of the potential crops to provide U.S. farmers with alternative opportunities to traditional enterprises and practices in a changing economy. However, studies on potential economic benefits of producing kenaf at the farm level are essential in new crop development. The most comprehensive economic analysis of kenaf was conducted by Taylor (1984). Taylor developed a systematic approach to introduce kenaf into U.S. agriculture. The study deals with development of the production-marketing-consumption (PMC) of kenaf as a fiber crop. The author defines the PMC system as a functioning system which is essentially the product of the decisions, actions, and reactions of participants during the introduction, establishment, and development of a crop and its products. Taylor further states that the approach enables us to anticipate, identify, evaluate, monitor, and coordinate participation in the development process within the entire production and marketing system. The study identified three potential kenaf production regions in the US (i.e., Southeast, South-Central, and Southwest) and analyzed the economic projections of kenaf production in each region given the existing agronomic, economic and social conditions. The study found that the PMC offers a method for both determining the potential of a new crop and integrating it into the agricultural economy.

Moore et al. (1976) compared production costs and returns of producing kenaf with those of timber and major crops in selected areas of the southern regions. Comparing the growing costs of pulpwood with that for kenaf, the study showed that if the production costs of pulp fiber is the major consideration, kenaf is competitive with pine pulpwood. Under specified assumptions, dry kenaf material could be produced at perhaps half the cost per unit of pulpwood, and three to five times as much per hectare could be produced annually. The study also compared production costs and returns of corn, soybeans, cotton and kenaf. The results showed that kenaf could compete very well with the major crops.

Masud et al. (1990) examined production, market potential, transportation costs, expected prices, and potential acreage requirements of kenaf core if used for all poultry litter in Texas and the U.S. They developed production budgets for kenaf used as poultry litter, and analyzed potential economic gains of supplying kenaf core at the farm level. The study indicates that farmers can keep more dollars per acre by growing kenaf than they can generally expect to receive from corn, milo, and cotton. Their study demonstrated that the returns to kenaf core are sensitive to price and transportation distance, and that distance traveled is a critical factor in determining the competitiveness of kenaf core as poultry litter.

Fuller and McGowann (1991) evaluated harvesting costs under different kenaf harvesting systems. The harvesting systems identified in the study are generally based on equipment developed for sugarcane, cotton, silage, and hay. The study shows that total capital requirements range from $115,835 for a hay mower-conditioner/round bale system to over $550,000 for a modified sugarcane system cutting kenaf into billets of moduling. Harvesting costs per acre is lowest for the mower-conditioner/round bale system followed by the forage harvester/module system and the modified sugarcane system/whole stalk.

Dicks et al. (1992) analyzed potential economic benefits of producing kenaf forage in the southern Great Plains. Production budgets were developed for different cropping systems. The study demonstrated that net returns could be increased from $22.25 under a Wheat-Stocker enterprise to $41.25 under Wheat-Kenaf-Stocker enterprise. The study indicated that the major benefits of kenaf for forage is the availability of a crop that requires no additional equipment to grow and harvest, provides significant yields a short time after planting and offers flexibility in harvest scheduling, requires minimum tillage to plant and prepare the seedbed for the following wheat, and provides significant cost reduction in the stocker cattle portion of the farm operation in the Southern Great Plains.

Summary

This chapter reviewed various research programs and results on kenaf utilization in the United States. Kenaf has been traditionally grown as a fiber to be used in handicrafts. Studies show that kenaf can be grown to supply raw materials to manufacture many products, such as newsprint and paper, animal bedding materials, absorbent and filtration products, livestock feed, etc.

Kenaf research projects are being conducted throughout the country, many projects are currently being designed to investigate new uses of kenaf. The research results obtained in the past show a promising future for kenaf, and also provide the foundation for further research on multiple uses of kenaf.

CHAPTER III

REVIEW OF STOCHASTIC DECISION MODELS

Introduction

This chapter reviews the economic theories and provides the theoretical foundations and analytical methods for constructing the conceptual framework in Chapters IV and V. Topics include neoclassical theory of the firm, firm facing uncertainty and risk in production, Bernoulli's principle of expected utility maximization, mathematical programming models, and a review of some empirical studies using quadratic risk programming models (QP).

Agricultural Production Decision

The agricultural production decision at the farm level involves resolving three basic problems: what should be produced, how should it be produced, and how much of it should be produced (Nelson, 1984). The "what to produce" problem requires analyzing information about the demand and supply situation for outputs, market prices of inputs and outputs, potential economic returns of producing the outputs, and the quantity of inputs available on farms. The "how to produce" problem involves finding the mix of inputs which minimizes the production costs subject to planned output level. The "how much to produce" problem is to find the optimum output level from a given set of variable and fixed inputs, and other exogenous random conditions. This study attempts to answer all three questions when kenaf is assumed to be a competitive crop in the present farm enterprises in the Atlantic south, South-central, and Southeast regions of the U.S.

While the solution to the first problem is obvious through analysis of potential economic returns generated from the hypothesized crop and livestock, the respective solutions to the second and third problems can be derived from the neoclassical theory of crop and livestock production. Assuming the firm produces a single output (y) with the known price (p), and uses n-variable inputs (X) in the production process, its profit function can be as

$$\pi = py - c^T X - b \tag{3.1}$$

where X is a n×1 vector of variable inputs, c is a n×1 vector of known coefficients (i.e., inputs' prices), the superscript T denotes transpose, and b is the fixed cost. The solutions to the two problems above require the following conditions to hold:

$$\frac{MPP_i}{MPP_j} = \frac{MFC_i}{MFC_j} \qquad \forall \;\; i,j=1,2,\ldots,n \;\; i \neq j \tag{3.2}$$

and

$$MVP_i = MFC_i \qquad \forall \;\; i=1,2,\ldots,n \tag{3.3}$$

where

MPP_i = marginal physical product of the *i*th input;

MFC_i = marginal factor cost of the *i*th input; and

MVP_i = marginal value productivity of the *i*th input.

The two neoclassical results require the following assumptions:

1. The production function is given by a single, twice continuously differentiable function.

2. The production function presupposes technical efficiency and states the maximum attainable output from each $(x_1,...,x_n)$ combination.

3. Inputs and outputs are rates of flow per unit of time, *t*, where: (a) *t* is sufficiently long to allow for completion of technical processes; (b) *t* is sufficiently short that the technology remains fixed; and (c) *t* is sufficiently short so that entrepreneurs cannot vary inputs specified as fixed; if *t* is lengthened beyond this point the analysis is shifted from the short run to the long run.

4. The production process is monoperiodic. The production process does not change during the time period, and does not incorporate time as an explicit factor.

5. The goal of the decision agent is to maximize profits. And the decision agent acts rationally in pursuit of his or her goal.

6. The decision agent has perfect knowledge of technical production relationships, and input and output price relationships.

7. Perfectly competitive input and output markets: all inputs and outputs of the firm are homogenous in the sense that there are no quality differences for different levels of a particular input or output.

8. There is a given distribution of resource ownership and well-defined property rights.

9. Firms have unlimited funds for purchase of variable factors of production.

10. Absence of externalities as a source of market failure.

However, this set of assumptions of neoclassical theory of the firm is often challenged by the stochastic environment under which the decision agents usually act. Relaxing some of the assumptions will lead to abandoning the widely accepted results in an essential way. Suppose assumption six is relaxed where the firm is facing stochastic demand for its output but known input prices, then, the firm's profit function (Eq. (3.1)) should be rewritten as

$$\pi = p(y,\mu)\,y(p,\mu) - c^{T}X - b \tag{3.4}$$

where μ is the stochastic random factor, and has a subjective probability density function (*pdf*) $dF(\mu)$. In addition, the following conditions are true:

$$\frac{\partial p(y,\mu)}{\partial y} < 0; \quad \frac{\partial y(p,\mu)}{\partial p} < 0. \tag{3.5}$$

The optimum solution to equation (3.4) differs from that of equation (3.1) because of the random factor μ which has a unique subjective probability distribution. Under this circumstance, the optimum solution must be based on the economic agent's personal belief (or subjective probabilities) about the occurrence of uncertain events (i.e., μ in this example) and personal valuation (or utility) of potential consequences. Thus, rather than maximizing profit under certainty, the economic agent's goal is to maximize expected profit subject to a higher priority goal, that actual profit exceeds some minimum level with some specified probability in a stochastic case.

This type of decision problem represents a farmer's decisions on planting kenaf - a crop that farmers themselves have little experience with. Farmers not only face uncertainties about market situations of kenaf such as the potential demand and expected price, but also production risk such as expected yield. Therefore, the decision problem addressed in this study can be resolved through methods of expected profit and utility maximization.

Expected Utility Theorem

If there is no uncertainty about the outcome of each alternative action (or no subjective probability associated with each alternative action) and if the economic agent's goal is to maximize the profit, then the choice of action is clearly defined as equation (3.1). However, if uncertainty about the outcome is present, the economic agent's decision procedure for handling choice must involve two components: personal valuation of consequences and personal strengths of belief about the occurrence of uncertain events (Dillon, 1971, p.7). In appraising risky alternatives, utility analysis provides the practical means whereby preferences are crystallized and consistent choice simplified (Anderson et al., 1977, p.66).

Bernoulli's Principle, also known as the expected utility theorem (EU) provides the theoretical foundation for ordering uncertain outcomes. Daniel Bernoulli postulated his principle recognizing the fact that an extra dollar is worth more to a poor man than to a rich man. This principle was further extended by von Neumann and Morgenstern in the 1940s. They showed that Bernoulli's Principle has the normative justification of being a logical deduction from a small number of postulates or axioms which many people agree are absolutely reasonable and should be met by a person who wishes to be consistent and rational in his workday decisions (Dillon, 1971, p.7). The set of axioms sufficient for deducing Bernoulli's Principle for the case of a single goal are as follows (Anderson et al., 1977, p.67; Dillon, 1971, p.8):

> 1. **Ordering.** A person either prefers one of two risky prospects G_1 and G_2 or is indifferent between them.
>
> 2. **Continuity.** If a person prefers G_1 to G_2 to G_3, then there exists a unique probability $P(G_1)$ such that he is indifferent between G_2 and a gamble with a probability $P(G_1)$ of yielding G_1 and a probability $1-P(G_1)$ of yielding G_3.
>
> 3. **Independence.** If G_1 is preferred to G_2, and G_3 is any other risky prospect, a gamble with G_1 and G_3 as outcomes will be preferred to a gamble with G_2 and G_3 as outcomes when $P(G_1)=P(G_2)$.

The expected utility theorem states that given a decision maker whose preferences do not violate the axioms of Ordering, Continuity and Independence, there exists a function U, called a utility function, which associates a single real number or utility index with any risky prospect faced by the decision maker. This function has the following properties (Dillon, 1971, pp.8-9):

> 1. If the risky prospect G_1 is preferred to G_2, then the utility index of G_1 will be greater than the utility index of G_2. Conversely $U(G_1) > U(G_2)$ implies G_1

is preferred to G_2.

2. If G is the risky prospect with a set of outcomes $\{g\}$ distributed according to the probability distribution $f(g)$, then the utility of G is equal to the statistically expected utility of G, that is

$$U(G) = EU(G) \tag{3.6}$$

If $f(g)$ is discrete,

$$EU(G) = \sum_{g} U(g) f(g), \tag{3.7}$$

and if $f(g)$ is continuous,

$$EU(G) = \int_{-\infty}^{\infty} U(g) f(g)\, dg. \tag{3.8}$$

3. Uniqueness of the function is only defined up to a positive linear transformation. That is, given a utility function U, any other function U^* such that

$$U^* = aU + b, \qquad a > 0 \tag{3.9}$$

will serve as well as the original function.

Because a person's utility function reflects his own personal valuations, it is impossible to compare one person's utility indices with another's. EU provides a fundamental mechanism for ranking risky prospects in order of preference, the most preferred prospect being the one with the highest utility. Hence, maximization of utility is equivalent to maximization of expected utility. Therefore, equations (3.8) and (3.9) provide the empirical basis for application of the theory.

Utility Maximization of the Individual Firm

Consider an agricultural firm that would like to commercially produce kenaf, the firm's production function can be written as

$$y = f(X, Z, G) \tag{3.10}$$

where X is a vector of inputs that can be controlled by the decision maker, e.g., crop variety, seed quality and quantity, fertilizer, etc; Z is a vector of the variables not controlled by the decision maker, e.g., temperature, rainfall, hail, etc; and G is a vector of the predetermined variables.

Uncertainty of yields arises from the influence of the uncontrolled variables. Yields and, thus, returns become stochastic and can be described by a probability distribution. Random variable profit (π) function is thus given by

$$\pi = py - c^T X - b \tag{3.11}$$

where b is fixed costs. Unlike equation (3.1), here y and p are stochastic. All uncertainty about profits now arise from the stochastic output y and output price p.

According to the expected utility theorem, the decision maker will choose the optimal combination of X that maximizes his expected utility over the joint distributions of y and p,

$$MAX \quad E\{U[\pi(p, y(X))]\} \tag{3.12}$$

where $E\{U[\cdot]\}$ is the expected utility function. Since y is some function of X, the distribution of y will generally be conditioned by X. Furthermore, under the reasonable assumption of perfect competition among agricultural producers, *p* will be independent of *X* (Anderson et al., 1977, p. 161).

Because utility maximization cannot proceed directly, numerous alternative approaches have been employed in the past. The most common approach widely adopted in the literature is the method of moments of distributions. The basis of the moment method is a Taylor series expansion. Let $U(\pi)$ be the utility function, expanding about the mean, we have

$$\begin{aligned} U(\pi) = {} & U([E(\pi)] + U_1[E(\pi)][\pi - E(\pi)] \\ & + U_2[E(\pi)][\pi - E(\pi)]^2/2! \\ & + U_3[E(\pi)][\pi - E(\pi)]^3/3! + \cdots \end{aligned} \tag{3.13}$$

where U_1, U_2, and U_3 are respectively the first, the second and the third derivative. Using the expected utility theorem and taking the expectation of equation (3.13), we obtain

$$\begin{aligned} E[U(\pi)] = {} & U[E(\pi)] + U_1[E(\pi)]E[\pi - E(\pi)] \\ & + U_2[E(\pi)]E[\pi - E(\pi)]^2/2 \\ & + U_3[E(\pi)]E[\pi - E(\pi)]^3/6 + \cdots \end{aligned} \tag{3.14}$$

Note that $E[\pi - E(\pi)] = 0$ and that the *k*th moment about the mean $M_k(\pi) = E[\pi - E(\pi)]^k$, we can write

$$\begin{aligned} E[U(\pi)] = {} & U[E(\pi)] + U_2[E(\pi)]M_2(\pi)/2 \\ & + U_3[E(\pi)]M_3(\pi)/6 + \cdots \end{aligned} \tag{3.15}$$

Thus, utility has been expressed as a function of the mean, variance, skewness, kurtosis, and whatever higher moments about the mean of profit exist.

The mean of the profit equation (3.11) is given by

$$\begin{aligned} E(\pi) &= E(py-c^TX-b) \\ &= E(p)E(y)-c^TX-b \\ &= E(p)f(X)-c^TX-b \end{aligned} \tag{3.16}$$

where f(·) is an empirical function of the expected value of output y relating to input X. Likewise, the variance of profit equation (3.11) is given by

$$\begin{aligned} V(\pi) &= V(py-c^TX-b) \\ &= [E(p)]^2V(y)+[E(y)]^2V(p)+V(p)V(y) \\ &= [E(p)]^2g(X)+[f(X)]^2V(p)+V(p)g(X) \end{aligned} \tag{3.17}$$

where g(·) is an empirical function of the variance of output y relating to input X.

Using the result of equation (3.14) by Taylor series approximation, we can write

$$\begin{aligned} E[U(\pi)] &= U[E(\pi)]+U_2[E(\pi)]V(\pi)/2 \\ &\quad +U_3[E(\pi)]S(\pi)/6+U_4[E(\pi)]K(\pi)/24+\cdots \end{aligned} \tag{3.18}$$

where $S(\cdot)$ and $K(\cdot)$ are the skewness and kurtosis of profit equation (3.11), respectively.

Under some fairly theoretical assumptions, the number of moments considered can be reduced to only the first two moments (mean, variance, or E, V) of the utility function. These assumptions can be summarized as follows:

1. If the net returns follow a normal distribution, the utility function is completely specified by mean and variance even if the utility function is not quadratic. This is simply because that the normal distribution always has odd moments about the mean equal to zero, i.e., $M_k(\pi)=0$ for $k = 1, 3, 5, \ldots$, and even moments about the mean given by $M_k(\pi)=(k-1)(k-3)(k-5)\ldots(3)(1)V^{k/2}$ for $k = 2, 4, 6, \ldots$, and $(k-1), (k-3), \ldots > 0$. The assumption of normality is justified by the central limit theorem (CLT) which states that the distribution of the sum of n random variables

approaches the normal distribution as $n \to \infty$ (Anderson et al., 1977, pp. 192-93).

2. Likewise, the utility function is completely specified by the first two moments if the net returns follow a log-normal distribution.

3. If the series can be shown to be convergent sufficiently fast, the terms beyond the second moments can be neglected even if the utility function is not quadratic, and the uncertain outcomes not normally distributed. Thus, the utility function can be approximately determined by the first two moments. One condition required is that the risk V considered by the decision maker must be a fairly small fraction of his total wealth, including not only his entire net worth but also his human capital (Tsiang, 1977, pp. 356-61).

4. In reality, the decision maker usually does not know what the exact shapes of the distribution functions of net returns are. One has only some vague idea of the degrees of skewness of the distributions. Higher moments may be completely unknown (Tsiang, 1977, p. 361).

Therefore, the problem of maximizing the expected utility function with risk becomes;

$$MAX \quad U(\pi) = U[E(\pi), V(\pi)] \tag{3.19}$$

The first order condition yields the following

$$\frac{dU(\pi)}{dx_i} = \left[\frac{\partial U(\pi)}{\partial E(\pi)}\right]\left[\frac{dE(\pi)}{dx_i}\right] + \left[\frac{\partial U(\pi)}{\partial V(\pi)}\right]\left[\frac{dV(\pi)}{dx_i}\right] = 0 \tag{3.20}$$

which results in the following equations:

$$\frac{dE(\pi)}{dx_i} = -\left[\frac{\partial U(\pi)/\partial V(\pi)}{\partial U(\pi)/\partial E(\pi)}\right]\left[\frac{dV(\pi)}{dx_i}\right] \tag{3.21}$$

and

$$\frac{dE(\pi)}{dV(\pi)} = -\frac{\partial U(\pi)/\partial V(\pi)}{\partial U(\pi)/\partial E(\pi)} \tag{3.22}$$

The result of equation (3.22) can be obtained directly by simply taking the total differential of the utility function (3.19),

$$dU(\pi) = \frac{\partial U(\pi)}{\partial E(\pi)} dE(\pi) + \frac{\partial U(\pi)}{\partial V(\pi)} dV(\pi) \qquad (3.23)$$

Setting $dU = 0$, we obtain

$$\frac{dE(\pi)}{dV(\pi)}\bigg|_U = -\frac{\partial U(\pi)/\partial V(\pi)}{\partial U(\pi)/\partial E(\pi)} \qquad (3.24)$$

The right hand side of equation (3.24) determines the decision maker's risk attitude in terms of being either risk averse, risk prefered, or risk neutral, and is termed by Magnusson (1969) as the "risk evaluation differential quotient" (REDQ). It is interpreted as the marginal rate of substitution in utility of $E(\pi)$ for $V(\pi)$.

Since we have assumed all decision makers have positive marginal utility for money income, i.e., $\partial U(\pi)/\partial E(\pi)>0$, therefore, the trade-off between $U(\pi)$ and $V(\pi)$ is the determining factor of decision maker's risk attitude. The following risk attitudes and associated conditions can be generalized:

1. **Risk Aversion:** $\partial U(\pi)/\partial V(\pi)<0$ implies $dE(\pi)/dV(\pi)>0$, utility of profit decreases as the variance of profit increases. In other words, as the variance of profit increases, satisfaction is maintained if the expected profit increases at an increasing rate.

2. **Risk Neutral:** $\partial U(\pi)/\partial V(\pi)=0$ implies $dE(\pi)/dV(\pi)=0$, utility of profit is not affected by the variance of profit. As the variance of profit increases, satisfaction is maintained with the expected profit constant.

3. **Risk Preference:** $\partial U(\pi)/\partial V(\pi)>0$ implies $dE(\pi)/dV(\pi)<0$, utility of profit increases as the variance of profit increases. In other words, as the

variance of profit increases, satisfaction is maintained even if the expected profit decreases.

4. **Plunger:** Plunger is a special case of risk aversion and possesses the mathematical properties equivalent to risk aversion, i.e., $\partial U(\pi)/\partial V(\pi)<0$ implies $dE(\pi)/dV(\pi)>0$. Unlike risk aversion, plunger is the case where satisfaction is maintained if the expected profit increases at a decreasing rate (i.e., $d^2E(\pi)/dV(\pi)^2<0$) when the variance of profit increases.

If we hold utility at some constant level with an order that $U_1 > U_2 > \ldots > U_n$, then, we can map a set of iso-utility curves onto mean-variance space. Assuming the utility function is in some arbitrary quadratic form, the set of iso-utility curves is depicted in figure 3.1.

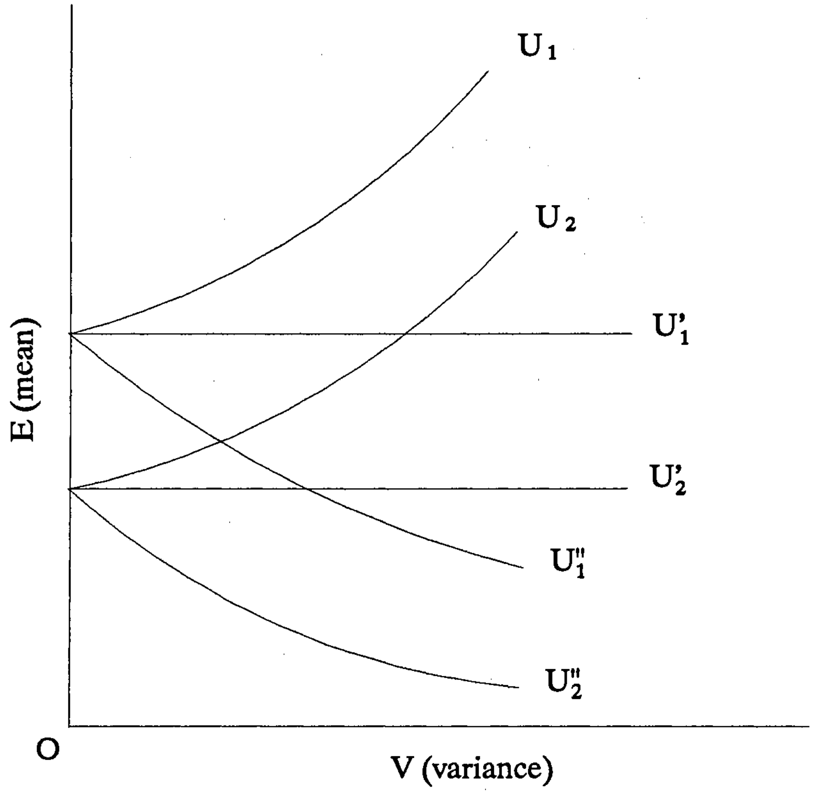
The utility maximization decision maker will choose the input level such that the condition of equation (3.20) is met. Obtaining $dE(\pi)/dx_i$ and $dV(\pi)/dx_i$ from equations (3.16) and (3.17), and substituting these expressions into (3.20) using the fact of (3.24), we have

$$\begin{aligned} 0 = E(p)\frac{dE(y)}{dx_i} - c_i - REDQ\,(\{[E(p)]^2+V(p)\}\cdot \\ \frac{dV(y)}{dx_i} + 2V(p)\,E(y)\frac{dE(y)}{dx_i}) \qquad \forall\ i \end{aligned} \tag{3.25}$$

This expression can be further simplified if we assume that price p is known with certainty or $E(p)=p$ and $V(p)=0$. Thus, we obtain

$$c_i = p\frac{dE(y)}{dx_i} - REDQ\left(p^2\frac{dV(y)}{dx_i}\right) \qquad \forall\ i \tag{3.26}$$

Equation (3.26) implies that the agricultural firm will use the *i*th input up to the level where the marginal factor cost



U_1, U_2 : risk averse
U'_1, U'_2 : risk neutral
U''_1, U''_2 : risk preference

Figure 3.1. Iso-Utility Curves for Risk Averse, Risk Neutral, and Risk Preference

(i.e., input price) is equal to the value of the marginal expected product minus a marginal risk deduction that depends on the utility function and the marginal variance of profit.

The remaining problem for the decision maker is to choose a mixture of risky prospects (or enterprises) from among some available set of possible prospects which could maximize his utility. Tobin (1965) has shown that for the risky prospects all relevant combinations between expected profit and variance are located on a positively sloped function, the *EV*-frontier. Diagrammatically, this situation is as depicted in figure 3.2, where the optimum solution point C is at the tangency between the *EV*-frontier AB and the iso-utility curve U_2. If two risky prospects i and j are correlated, the EV-frontier is a hyperbola (see Anderson et al., 1977, pp.193-194).

Review of Mathematical Programming Models

This section reviews the mathematical programming approach widely adopted to solve agricultural decision problems. Since the first application of linear programming during World War II, numerous mathematical programming methods have been developed and constantly refined so that they can be applied with greater precision to a wide range of problems. Topics reviewed in this section include linear and nonlinear programming models applied in agricultural production planning, marketing strategies, risk analysis,

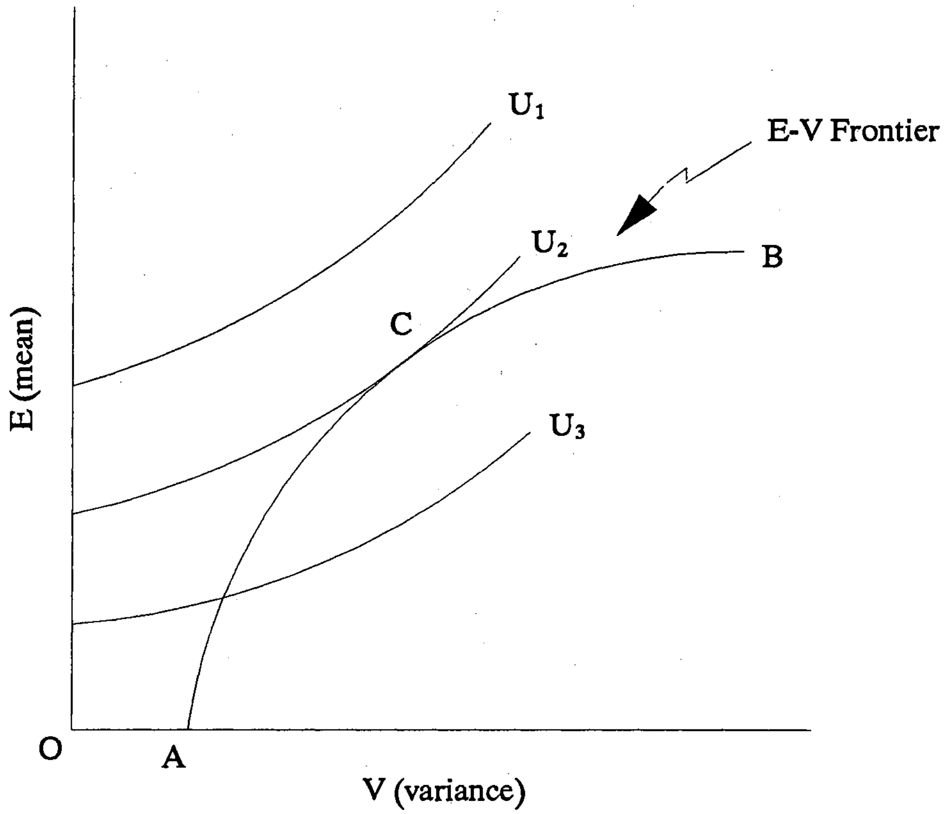


Figure 3.2. An Illustration of E-V Frontier Analysis

etc.

Linear Programming

Perhaps the most widely used mathematical programming model in applied decision analysis and agricultural supply response is linear programming (LP). Linear programming, as the name implies, is characterized by linear functions of unknowns, i.e., the objective is linear in the unknowns, and the constraints are linear equalities or linear inequalities in the unknowns. Because of the characteristics of linear functional forms, linear programming is no doubt the most natural mechanism for formulating a vast array of problems with modest effort. Specifically, a linear programming problem can be represented by the following in standard form

$$\begin{array}{ll} \textit{maximize} & R^T X \\ \textit{subject to} & AX = b \\ & X \geq 0. \end{array} \tag{3.27}$$

where X is an n-dimensional column vector, R is an n-dimensional column vector, A is an $m \times n$ matrix, and b is an m-dimensional column vector. The vector inequality $X \geq 0$ means that each component of X is nonnegative.

If the decision maker has to determine which crop rotations will lead to the maximum net returns, equation (3.27) can serve as the best model, where X denotes a set of crop activities, R a set of net returns generated by X, A a production coefficients matrix, and b a set of available inputs. Solutions to this problem require the following assumption

> **Full rank assumption.** The $m \times n$ matrix A has $m < n$, and the m rows of A are linearly independent.

Under the above assumption, the system (3.27) will always have a solution and, in fact, it will always have at least one basic solution. The fundamental theorem of linear programming can be generalized as (Luenberger, 1984, p.19)

> Given a linear program in standard form (3.27) where A is an $m \times n$ matrix of rank m,
>
> i) if there is a feasible solution, there is a basic feasible solution;
>
> ii) if there is an optimal feasible solution, there is an optimal basic feasible solution.

There are variety of algorithms available to solve the system (3.27). Although some efficient algorithms have been developed, the simplex method is preferred for small systems. The idea of the simplex method is to proceed from one basic feasible solution (i.e., one extreme point) of the constraint set of a problem in standard form to another until an optimum is reached. Let B denote the submatrix of the original A matrix consisting of the m columns of A corresponding to the basic variables, D the submatrix corresponding to the non-basic variables. Then by partitioning A, X, and R^T as

$$A = [B, D], \quad X = [X_B, X_D], \quad R^T = [R_B^T, R_D^T], \qquad (3.28)$$

equation (3.27) becomes

$$\begin{aligned} &\textit{maximize} \quad R_B^T X_B + R_D^T X_D \\ &\textit{subject to} \quad BX_B + DX_D = b \\ &\qquad X_B \ge 0, \quad X_D \ge 0. \end{aligned} \tag{3.29}$$

The basic solution corresponding to the basis B is $X = (X_B, 0)$ where $X_B = B^{-1}b$. The basic solution results from setting $X_D = 0$. However, we can also compute the value of X_B given any value of X_D from (3.29) as

$$X_B = B^{-1}b - B^{-1}DX_D \tag{3.30}$$

substituting this expression into the objective function in (3.29) yields

$$\begin{aligned} Z &= R_B^T(B^{-1}b - B^{-1}DX_D) + R_D^T X_D \\ &= R_B^T B^{-1}b + (R_D^T - R_B^T B^{-1}D)X_D \end{aligned} \tag{3.31}$$

Thus, the cost vector corresponding to any solution for (3.29) is

$$C_D^T = R_D^T - R_B^T B^{-1}D \tag{3.32}$$

and it is also the relative cost vector (for nonbasic variable). The components of this vector are used to determine which vector to bring into the basis.

The simplex tableau can also be written in matrix form. The initial tableau can be written as

$$\begin{bmatrix} A & b \\ R_B^T & 0 \end{bmatrix} = \begin{bmatrix} B & D & b \\ R_B^T & R_D^T & 0 \end{bmatrix} \tag{3.33}$$

If the matrix B is used as a basis, then the corresponding tableau becomes

$$T = \begin{bmatrix} I & B^{-1}D & B^{-1}b \\ 0 & R_D^T - R_B^T B^{-1}D & -R_B^T B^{-1}b \end{bmatrix} \tag{3.34}$$

which is the matrix form corresponding to the optimum solution, and the optimal solution is reached when equation (3.32) is greater than or equal to zero.

In applied agricultural decision analysis, the following information is generally required by LP (Beneke and Winterboer, 1973, pp.5-6):

> 1. Activities: activities include production and marketing activities carried out by the decision maker, e.g., crops and livestock productions, buying and selling inputs and outputs, etc. The number of activities the decision maker should include in a model are always a function of the answers he is seeking.
>
> 2. Production Coefficients: production coefficients refer to the amount of input required per unit of activity.
>
> 3. Product and Input Prices: price levels may affect the optimal farm plan in the essential way. Prices used in programming should accurately reflect the relative prices rather than the simple average prices.
>
> 4. Constraints: constraints are referred to as restrictions, e.g., resource restrictions, inputs requirements, etc. Maximum constraints are "no more than" constraints. Planning models may also include "no less than" (minimum) constraints or "equal to" (equality) constraints.

Despite the popularity, LP models have been criticized on several grounds. First, they assert all the assumptions of neo-classical theory of the firm which are often found inconsistent with reality. For example, the assumption of profit maximization and perfect knowledge implicitly imply risk neutrality of the decision maker. In addition, the assumption of exogenously determined output price becomes unrealistic when the LP model is aggregated to regions and countries. Second, as the name implies, linearity in both objective and constraint functions exclude the possibilities of accounting for a decision maker's non-neutral attitude to risk as well as "overhead" resource requirements.

Linear Risk Programming

Although LP models have gained wide acceptance as tools for analysis of agricultural supply response at both the regional and sectoral levels, the deficiencies of LP models restrict economists and agricultural economists from solving problems when risk and uncertainty are present. Methodologies have been developed that account for the stochastic nature of profits in the decision making process, but still retain properties of linear programming. These various linear risk programming models include game theory (McInerney, 1969; Hazell, 1970), constraining the maximum admissible loss (Boussard and Petit, 1967; Boussard, 1971), minimization of total absolute deviations (MOTAD) (Hazell, 1971), and Target MOTAD (Tauer, 1983). The common property of these various linear risk programming models is that they all can be cast as the minimization of a measure of risk for a range of possible levels of expected profit, subject to the ordinary farm constraints and restrictions (Anderson et al., 1977, p.203).

Game Theory The basic idea of game theory in decision analysis is to incorporate additional constraints in LP models. Data used to construct the additional constraints are based on the sample activity profits observed in the previous years. The criteria such as Wald maximin, Laplace and Hurwicz can be incorporated into a planning matrix (McInerney, 1967 and 1969; Kawaguchi and Maruyama, 1972). The purpose of the game theory is to maximize w, the profit in the event that the most adverse of s possible states of nature occurs. The value of w is defined by the additional constraints

$$R_j^T X - w \geq F \qquad j = 1, \ldots, s \tag{3.35}$$

where R_j is a column vector of net returns of activity X for state of nature j, and F is the fixed cost.

Maximum Admissible Loss The maximum admissible loss approach also involves imposing additional constraints within the LP model. The problem is to define a loss function (L) for a decision maker such that L is the difference between his expected profit and the minimum level of profit he needs to maintain his business. The admissible loss can be defined as

$$L = E(Z) - Z_c = E[R^T X] - E(F) - Z_c \tag{3.36}$$

where Z_c is known as the focus loss and is the minimum level of profit necessary to meet inescapable production expenditures. The value of Z_c can be either positive or negative depending upon whether the decision maker is able to borrow to invest in production.

Minimization of Total Absolute Deviations (MOTAD) The mean absolute deviation or MOTAD developed by Hazell (1971) provides an alternative model which can incorporate risk in the production planning process. It is theoretically close to quadratic programming, but without the need for a nonlinear programming algorithm. The objective of the model is to minimize the total mean absolute deviations. Given a set of sample data of activity profits from previous years, the mean absolute profit deviation (denoted by *A*) can be defined by the following form

$$A = s^{-1}\sum_{h=1}^{s}\left|\sum_{j=1}^{n}(c_{hj}-g_j)x_j\right| \tag{3.37}$$

where $h=1$ to s denotes observations in a random sample of gross margin, and g_j is the sample mean; c_{hj} is the gross margins for the jth activity; x_j is the activity level. Hazell (1971) shows that *A* can be minimized for a given level of expected profit $E(Z)$ varied parametrically over the relevant range so that the (E,A) efficient set of optimal plans can be generated. Thus, the MOTAD model can then be expressed as a linear programming model

$$\textit{minimize} \qquad sA = \sum_{h=1}^{s}(y_h^{+}+y_h^{-}) \tag{3.38}$$

such that

$$\sum_{j=1}^{n} (c_{hj} - g_j) x_j - y_h^+ + y_h^- = 0 \qquad \forall \ h = 1, \ldots, s \tag{3.39}$$

$$\sum_{j=1}^{n} f_j x_j = \lambda \qquad (\lambda = 0 \rightarrow \mathit{unbounded}) \tag{3.40}$$

$$\sum_{j=1}^{n} a_{ij} x_j \leq b_i \qquad \forall \ i = 1, \ldots, m \tag{3.41}$$

and

$$x_j,\ y_h^+,\ y_h^-,\ \geq 0 \qquad \forall \ h,\ j \tag{3.42}$$

where

$$y_h^+ = \left| \sum_{j=1}^{n} (c_{hj} - g_j) x_j \right| \tag{3.43}$$

and

$$y_h^- = \left| \sum_{j=1}^{n} (c_{hj} - g_j) x_j \right| \tag{3.44}$$

equation (3.43) is the sum of the absolute values of the positive total gross margin deviations from the expected income, and (3.44) is the sum of the absolute values of the negative total gross margin deviations from the expected income based on sample mean gross margins.

Hazell (1971) shows that the use of A as a measure of risk can be justified by the fact that the unbiased estimate of the population variance is given by $A^2[\pi s/2(s-1)]$ when the population is normal or approximately normal. The Monte Carlo sampling study shows that the efficient set of plans generated using this measure corresponds closely with the (*E,V*) efficient set (Thomson and Hazell, 1972).

Target MOTAD Using the *E-A* approach to measure risk as the deviation (positive or negative) from the mean has been criticized on the grounds that if risk is measured as any deviation from average income, then any actual return in which income is greater than expected would be considered risky. Thus, they may be inappropriate in developing farm plans for farmers who are risk averse. Also, if the sample returns are not normally distributed, then, the efficient set of the optimal solutions generated with MOTAD may differ from the SSD solution (Second Degree Stochastic Dominance).

An alternative approach has been developed by Tauer (1983), which is referred to as the Target MOTAD. In the Target MOTAD model, risk is measured as the expected sum of the negative deviations of the solution from a target-return level. Risk is varied parametrically so that a risk-return frontier is traced out. The Target MOTAD model is theoretically appealing, because if a farm operator is risk averse, he wishes to maximize expected returns, but concerns about net returns may fall below the critical target. The Target MOTAD model offers the additional advantage that its solution set is contained in the set of production plans that are second degree stochastic efficient. Target MOTAD does not require that returns be normally distributed to have solutions that are SSD (see Tauer, 1983).

Following Tauer, the mathematical representation of the

Target-MOTAD model is

$$Max \quad E(Z) = \sum_{j=1}^{n} c_j x_j \tag{3.45}$$

subject to:

$$\sum_{j=1}^{n} a_{ij} x_j \{\geq \; = \; \leq\} b_i \qquad \forall \;\; i=1,\ldots,m \tag{3.46}$$

$$T_k - \sum_{j}^{n} c_{kj} x_j - y_k \leq 0 \qquad \forall \;\; k=1,\ldots,s \tag{3.47}$$

$$\sum_{k=1}^{s} p_k y_k = \lambda \qquad \lambda = M \rightarrow 0 \tag{3.48}$$

$$x_j, \; y_k \geq 0 \qquad \forall \;\; j,k$$

where $E(Z)$ is expected return of the solution or plan; c_j, expected return per unit of activity j; x_j, level of activity j; a_{ij}, amount of resource i required by one unit of activity j; b_i, availability of resource i; T_k represents the target income level; c_{kj}, return of activity j for state of nature or observation k; y_k, deviations below T_k for state of nature k; p_k, probability that state of nature or observation k will occur; λ, constant parameterized from M to 0; m, number of constraints and resource equations; s, number of state of nature or observation; and M is a large arbitrary number.

A Target MOTAD efficient frontier is developed by parametrically varying deviations (λ) from levels associated with the LP solution to zero. The risk-efficient frontier can be developed for various fixed targets allowing for differences across firms for returns required for long-run survival. For each target, a risk-efficient frontier can be developed for an optimal (maximum expected returns) solution over a range of expected deviations.

Nonlinear Programming - Quadratic Risk Programming (QP)

The quadratic programming (QP) approach can be regarded as the first attempt to explicitly take account of risk in mathematical programming formulations. In the QP models, risk is measured as the variance-covariance of the activity profits, and the objective is to minimize the risk. Although the objective function is in nonlinear form, the constraint functions are still in linear form and are regarded as deterministic. The QP models usually contains assumptions that the activity profits are distributed multivariate normally, and the relevant statistics are sample means, variances and covariances of the activity profits. The assumption of a multivariate normal distribution for activity profits can be justified by the CLT, and it implies that the total profit will also be distributed normally so that the utility can be assessed with the expected income-variance (E-V) criterion. The QP models further assumes that the iso-utility curves are convex, or the decision maker is risk averse which implies that $\partial E/\partial V>0$ and $\partial^2 E/\partial V^2>0$. Given these assumptions, a rational decision maker should restrict his choice among those plans for which the associated utility level is optimal, subject to the resource constraints of expressions (3.27). The objective of QP is to develop the set of feasible solutions corresponding to the minimum variance V for associated expected income level E (Hazell, 1971, p. 53).

Generally, the QP model can be expressed as

$$\begin{array}{lll} \textit{minimize} & V = cX^{T}\Omega X & \\ \textit{subject to} & A_{i}X\{\leq\ =\ \geq\}B_{i} & \forall\ i\in E \\ & R^{T}X = \lambda & (\lambda = 0 \rightarrow \textit{unbounded}) \\ & X\geq 0. & \end{array} \tag{3.50}$$

where E is the index set for equality and inequality constraints. The matrix Ω is symmetric and positive semidefinite (if not actually positive definite). The QP model can be applied to agricultural decision problem if we adopt the following notations:

X = an n×1 vector of activities included in the farm enterprise,

R = an n×1 vector of expected (forecasted) gross margins of the activities,

Ω = an n×n variance and covariance matrix of gross margins,

A_i = an m×n matrix of technical requirements of the activities in the model for i type of constraint,

B_i = an m×1 column vector of i type of resource constraints,

c = a constant, and

λ = a scalar.

The conditions of unique solution existing for the problem are that the matrix A is of full rank and the matrix Ω is positive definite on the subspace $M = \{X\colon AX = 0\}$. If we rewrite system (3.50) in the simplified form as

$$\begin{array}{ll} \mathit{minimize} & f(x) \\ \mathit{subject\ to} & h(x) = 0 \end{array} \tag{3.51}$$

where x is n-dimensional and $h(x)$ is m-dimensional, then the first order necessary condition yields

$$\begin{aligned} \nabla f(x) + \lambda^T \nabla h(x) &= 0 \\ h(x) &= 0 \end{aligned} \tag{3.52}$$

where ∇ is the gradient. Thus, the Lagrange necessary conditions for the system (3.50) are

$$\begin{aligned} 2c\Omega X + A^T\lambda &= 0 \\ AX \quad -B &= 0 \end{aligned} \tag{3.53}$$

which corresponds to the general conditions (3.52), and in this case they comprise an $(n+m)$ dimensional linear system of equations. Note that the constraint conditions are expressed in the standard form rather than the original form in (3.50). The critical question is whether the system is nonsingular. The following proposition shows that the system is indeed nonsingular (Luenberger, 1989, p.424):

> **Proposition.** Let Ω and A be n×n and m×n matrices, respectively. Suppose that A has rank m and that Ω is positive definite on the subspace $M = \{X\colon AX = 0\}$. Then the matrix

$$\begin{bmatrix} \Omega & A^T \\ A & 0 \end{bmatrix} \tag{3.54}$$

is nonsingular.

Under this proposition, we can explicitly derive the theoretical solutions for the system. From the first equation in (3.53) we have

$$X = -\frac{1}{2c}\Omega^{-1}A^T\lambda \tag{3.55}$$

substituting this into the second equation in (3.53) yields

$$-\frac{1}{2c}A\Omega^{-1}A^T\lambda - B = 0 \tag{3.56}$$

simultaneously solving for λ and X, we obtain

$$\lambda = -2c[A\Omega^{-1}A^T]^{-1}B \tag{3.57}$$

and

$$X = \Omega^{-1}A^T[A\Omega^{-1}A^T]^{-1}B \tag{3.58}$$

However, in practice, we may obtain the optimal feasible solutions using parametric method (i.e., parameterizing λ from zero to unbounded). Solutions are obtained for critical turning points in the solutions basis, such that for the current total gross margin. These optimal feasible solutions represent an efficient set in *E-V* terms which implies that any risk averse decision maker whose goal is to maximize the *E-V* utility will choose the solution in the set (Anderson et al., 1977, p.199).

Using the *E-V* criterion in risk analysis has the following advantages:

1. The criterion is consistent with the Separation Theorem and allows more general solution to the decision maker diversification problem given a riskless option (Johnson, 1967).

2. The criterion is consistent with the probability theory that the probability of an outcome is described by the likelihood of occurrence of each of the outcomes (Pyle and Turnovsky, 1970).

3. The variance of the activity *V* is totally specified by the variance and covariance coefficients; and when subjective values of these parameters are available, the variance-covariance is no longer estimated from the sample data (Hazell, 1971).

Some of the data required for the QP models are similar to that of the LP models. However, we must have prior information about the mean gross margins for each activity included in the model and the corresponding variances and covariances. In most cases, these parameters are unknown, it is necessary to obtain some unbiased estimates using time series or cross-sectional data of observed gross margins.

Review of Selected Studies Using QP models

Quadratic programming, as its name implies is quadratic in its functional form which normally appears in the objective function. Quadratic programming models have been applied extensively in agricultural decision analysis and have been proved very useful to deal with risks in selecting production alternatives.

Early studies centered on using quadratic programming models to derive efficient portfolios of investors in the financial markets (e.g., Markowitz, 1952; Tobin, 1958; Baumol, 1963). Markowitz (1952) examined the investor's behavior in placing his funds in the securities, and suggested that there is a portfolio which gives both maximum expected return and minimum variance which can be called *E-V* rule. Markowitz further suggested that the *E-V* principle can be used both in theoretical analyses and in the actual selection of portfolio. Tobin (1958) extended the early work of Markowitz and generated three different results of optimum portfolio with respect to decision makers' different attitudes towards risk (i.e., risk-averters, risk-lovers, and plungers). Baumol (1963) expanded the *E-V* rule and suggested using an E-$\phi\sigma$ formulation instead of the conventional *E-V* criterion. With Baumol's approach, the decision maker is assumed to establish subjectively a confidence limit and a floor on expected returns, to which the limit is applied (Hazell and Scandizzo, 1974).

Since the pioneering study by Freund (1956), the *E-V* criterion and QP models have been used extensively to identify the optimal profit level considering risks and expected returns (Musser and Stamoulis, 1981; Hazell, 1971; Rae, 1971; Wiens, 1976) and in agricultural risk analysis (Anderson, et al.,1977; Robison and Brake, 1979; Berck, 1981; Lin, et al., 1974;). Freund (1956) explicitly incorporated risk associated with crops' productions into a mathematical programming model. Risk is defined in the variance-covariance of production activities (e.g., potatoes, corn, beef and fall cabbage) which is minimized in quadratic programming. His work was later expanded by

Hazell (1971) to approximate the variance-covariance into a linear programming framework (e.g., MOTAD).

Robison and Barry (1980) developed a modified *E-V* portfolio model to account for the effects of asset indivisibility. They contend that the assertion of asset divisibility is inappropriate for investments in land, machinery, buildings, irrigation systems, futures contracts, and some financial assets issued in large denominations. Their results show that introducing asset indivisibility yields less risk efficient *E-V* sets, thus increases relative use of the asset to that if the asset is assumed to be divisible.

Kaiser and Boehlje (1980) applied the static risk programming model in the dynamic fashion. They developed a multiperiod risk programming model that includes a risk-free discount factor in the analysis. However, they discussed that if a premium for risk is included in the discount factor, the return from a prospect would be adjusted for risk in the discounting process, and the probability distribution of the resulting value would be used to assess the risk of the prospect.

Studies of stochastic properties of the input-output coefficients and prices in the risk programming models have also been extensive (Hazell and Scandizzo, 1974; Paris and Easter, 1985; Simmons and Pomareda, 1975). Hazell and Scandizzo (1974) incorporated the stochastic demand functions into a MOTAD model to analyze the Mexican agriculture where prices of the products are included as a set of inverse demand functions into the model. Simmons and Pomareda (1975) also used the MOTAD model to analyze the Mexican vegetable exports strategies. Monthly demand functions for fresh vegetables were included in the programming model which was simulated under alternative price scenarios. Paris and Easter (1985) developed a quadratic risk programming model with both stochastic technology and prices to analyze the Australian agriculture. In their model, probability is assigned to the resource constraints conditions, and the conventional resource constraint condition is rewritten as

$$P[A_i^T x \leq b_i] \geq \alpha_i \quad \forall \ i = 1, \ldots, m \tag{3.59}$$

where A^T_i is the ith row of random technical coefficients of production relative to the nonrandom ith input availability b_i. P stands for probability and α_i is the minimum probability by which the ith constraint must be satisfied. They contend that for a risk-averse producer, α_i is typically large and always greater than 0.5.

Summary

This chapter reviewed relevant economic theories and empirical models commonly adopted to analyze real world economic problems. The neoclassical theory of the firm is found to be unable to solve economic problems under stochastic and uncertain situations. Bernoulli's Principle, also known as the expected utility theorem (EU) provides a theoretical foundation for the development of numerous economic models (e.g., QP, MOTAD, Target MOTAD, etc.) commonly adopted in the literature. Empirical studies show that economic models based on the *E-V* criteria are robust to solve economic problems.

CHAPTER IV

HYPOTHESIZED MARKETS FOR KENAF

Introduction

This chapter estimates potential acreage required for kenaf assumed to supply pulp, poultry litter, and forage. Market development is essential to ensure the success of a new crop venture such as kenaf. New crop ventures that have been successful have been able to meet a need in the market place. The initial stage of such market development is market identification. Although many products can be made out of kenaf, an identified potential market has to have the ability to absorb a large quantity of the product in order to establish a system in which the market signals (i.e., prices) will significantly influence production decisions and profits of producing such product. This chapter attempts to analyze the structures of hypothesized potential kenaf markets including newsprint, poultry litter, and forage; and determine potential demand for kenaf acreages for each identified market.

Estimating potential demand is particularly difficult when a rather new product is developed and is to be marketed. Three approaches have been commonly adopted in the literature to obtain information about expected demand:

(1) estimations with econometric models;

(2) inquires and interviews of potential customers; and

(3) the application of normative models.

The first approach is useful if comparable goods are already marketed. Analysis of the demand situation for these goods can be applied to the new product if we assume analogous market reactions for the new product. In addition, time series and/or cross-sectional data availability is essential for econometric models. The second approach may be adopted when we are not able to obtain sufficient data to use the first approach. Information obtained through interviews or survey of potential customers can provide some implications on expected demand from these potential customers. However, using this approach requires some technical assumptions such as consumers' knowledge about the new product and consumers' appraisal of their own demand. The third approach assumes rational behavior of producers, but ignores the consumers' actual behavior or their self-assessment. Despite some doubts with each of the three approaches, we use the second and the third approaches in an attempt to estimate potential demand for kenaf newsprint, poultry litter and forage. We also assume that newsprint manufacturers, poultry farmers and livestock producers are able to appraise their own demand for fiber, poultry litter and forage, respectively, and producers behave rationally in the sense of profit maximization and risk minimization in the long run.

Newsprint Market

Newsprint production capacity is associated with the number of newspapers published each year. According to the statistics published by the American Newspaper Publishers Association (ANPA), from 1970 to 1992, the average adult weekday and sunday/weekend readers have increased from 98 million to 115 million and from 91 million to 125 million, respectively. The strong demand for newspaper and increasing production costs have led to substantial price increase for newsprint. Between 1970 and 1991, newsprint consumption increased from 8,271 million metric tons to 11,490 million metric tons at an annual rate of about 2 percent on average (table 4.1). The increase was not steady during the 1970s. As illustrated in figure 4.1, consumption and imports (mainly from Canada) fluctuated considerably with a major decline occurring in 1974 and 1975. The decline may be attributed to a combination of increased fiber and energy costs, rapidly rising newsprint prices and tight supplies. However, consumption and imports have steadily increased, with a slightly higher rate of increase during the late 1980s. Consequently, prices of newsprint have also increased. The price per metric ton of newsprint increased more than 3.5 times, from $179 in 1970 to $685 in 1991 (1982 dollars)(see figure 4.2). Because of the consistent increase in the demand for newsprint, the U.S. has had to rely on imports in order to meet the demand in the domestic market, even with a 77 percent production

TABLE 4.1

NEWSPRINT: PRODUCTION, CONSUMPTION AND IMPORTS, 1970-1989

Year	Production	Consumption	Imports
	--------- *millions of metric tons* ---------		
1970	3.142	8.271	5.861
1971	3.153	8.390	5.864
1972	3.317	9.016	6.131
1973	3.391	9.249	6.565
1974	3.230	9.164	6.497
1975	3.348	8.321	5.009
1976	3.389	8.688	5.722
1977	3.512	9.279	5.751
1978	3.418	9.881	6.443
1979	3.685	10.205	6.504
1980	4.239	10.088	7.280
1982	4.574	10.107	6.531
1983	4.688	10.589	6.919
1984	5.025	11.431	7.899
1985	4.924	11.587	8.472
1986	5.107	11.937	8.589
1987	5.300	12.322	8.976
1988	5.427	12.244	8.592
1989	5.523	12.241	8.765

Source: Statistical Abstract of the U.S., various issues.

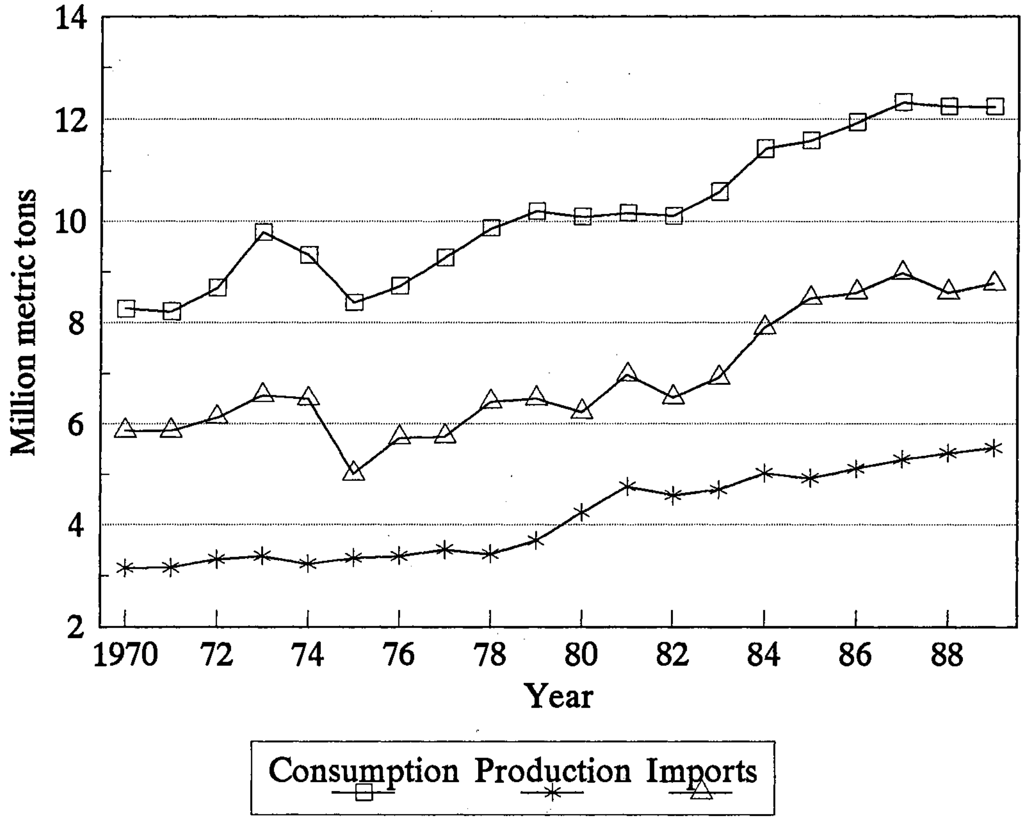


Figure 4.1. Newsprint Consumption, Production and Imports in the U.S., 1970-89

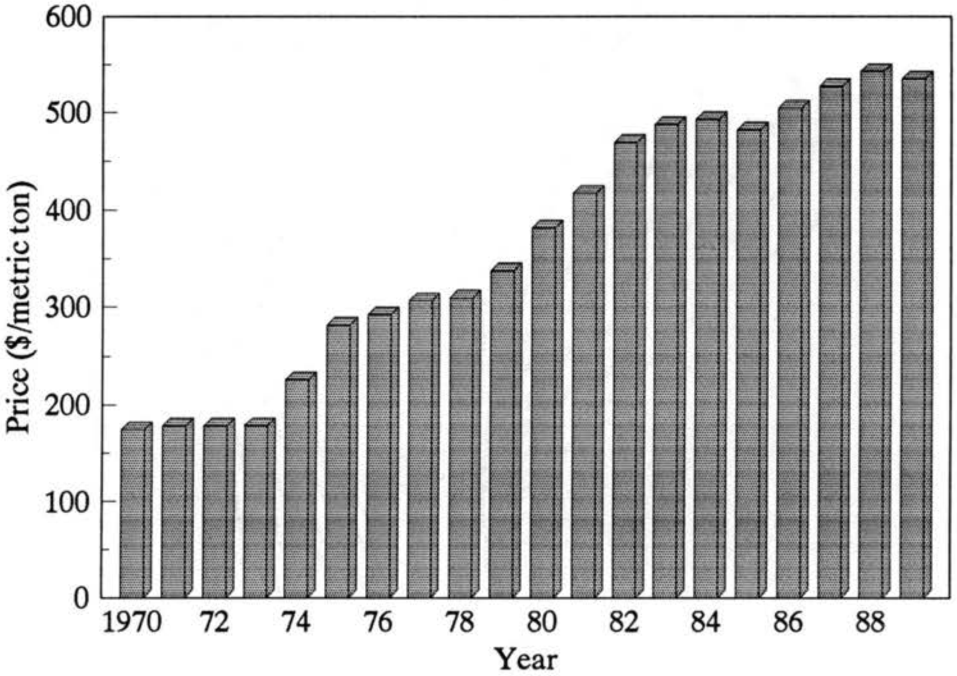


Figure 4.2. U.S. Newsprint Price (1982 dollars), 1970-89

increase during the same time period. Approximately 71 percent of domestically consumed newsprint was from imported sources in 1989 (see table 4.1). The increase in domestic newsprint consumption occured at much higher rate than domestic newsprint production. The consequence is that the market price has been pushed upward to a higher level over more than two decades. This trend can be illustrated by a demand-supply model in figure 4.3 where the initial equilibrium point is at the intersection of initial demand (d') and supply (s') with p' and q' as market clearing price and quantity. If the demand shifts upwards at faster rate than supply, the new equilibrium is reached at the intersection of the new demand (d") and supply (s") curves. The new market clearing price (p") and quantity (q") are higher than the initial equilibrium price (p') and quantity (q').

Economic theory suggests that the shift in demand is determined by variables such as income, prices of closely related goods, consumers' tastes and preferences, and/or consumers' expectations. The variables affecting the shift in newsprint demand through time also significantly affect equilibrium quantities of newsprint consumed and supplied at a particular time period. Thus, the demand for newsprint at a particular time can be empirically estimated with multiple regression because we are able to observe the equilibrium quantities of newsprint supplied and demanded over time. Udell (1981) estimated the U.S. newsprint consumption with

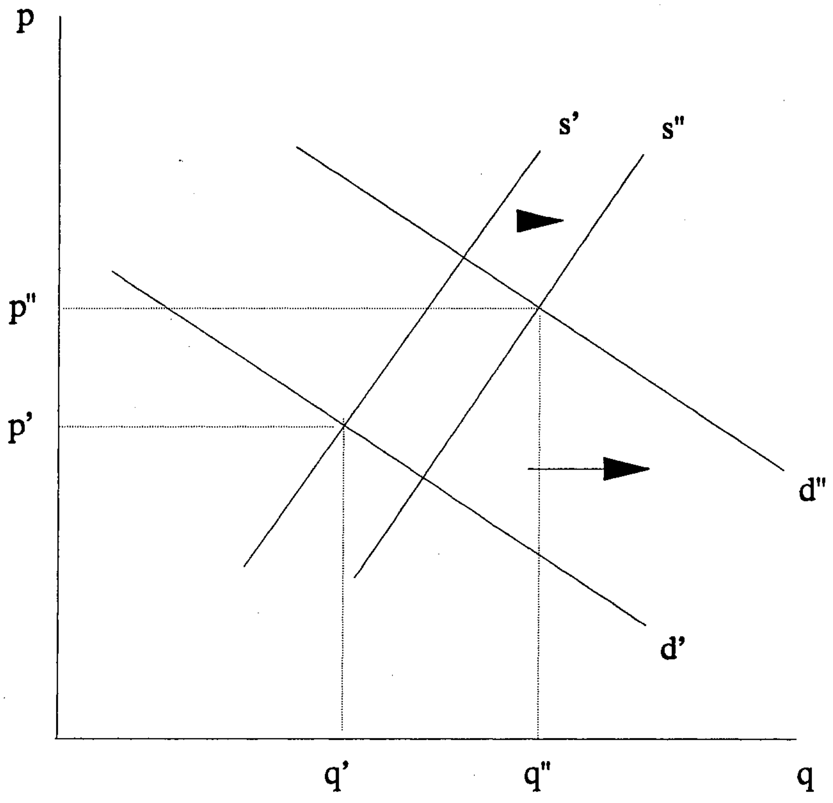


Figure 4.3. An Illustration of Changes of Demand and Supply of Newsprint Over Time

variables such as proportion of adult readers (ages 18 to 64) in the population, gross national product (GNP) and projects that the U.S. newsprint consumption will be around 15.5 million metric tons by the year 2000.

Potential Acreage Requirement of Kenaf Fiber

Kenaf fiber has been tested by most commercial pulping processes as well as processes yet to be adopted by a mill. Conventional technologies such as chemical processes (e.g., kraft, sulfite, and soda) or modified thermo-mechanical (CTMP) processes can be used to pulp kenaf without any problems. Thus, potential acreage requirement of kenaf fiber in a specific region is mainly determined by a mill's location and processing capacity.

A mill's location is the most important factor determining whether or not kenaf will be competitive with other fiber sources. Mills located in forested areas are usually assured of relatively cheap and abundant wood supplies. Thus, kenaf may not be competitive in areas where wood chips are abundant and prices are low. As kenaf is a bulky product, mills should be located close to the production areas so that kenaf can be transported to mills at low costs. If mills locate too far from the production areas, the cost of transporting kenaf to mills can be prohibitive. In this study, we only consider those mills that are located in the possible kenaf production regions.

Estimates of the potential acreage required for kenaf from these three possible production regions are based on the 1986 Post's Pulp and Paper Directory survey data (KI Report, 1986). A total of 88 mills in the potential kenaf production region were included in the estimation of potential demand for kenaf fiber (table 4.2). Each mill was selected for consideration based on location and process technology. Mills indicating kraft, semi-chemical, TMP, sulfite, flax, bagasse, and refiner mechanical process (RMP) capacity were generally selected unless their locations are too far from the production sites.

Although most mills produce more than one end product, the available data generally doesn't separate capacity by product. Therefore, each mill was identified by its principal end-product(s). More importantly, the mill's kenaf-adaptable process capacity was determined. The daily capacity was first converted to annual capacity by multiplying tons/day by 355 days. Potential annual fiber demand was computed by multiplying pulp capacity by a factor of 2 for chemical processes or 1.3 for CTMP processes (KI report, 1986). These factors are suggested by the manufacturers. The estimates are in dry tons per year.

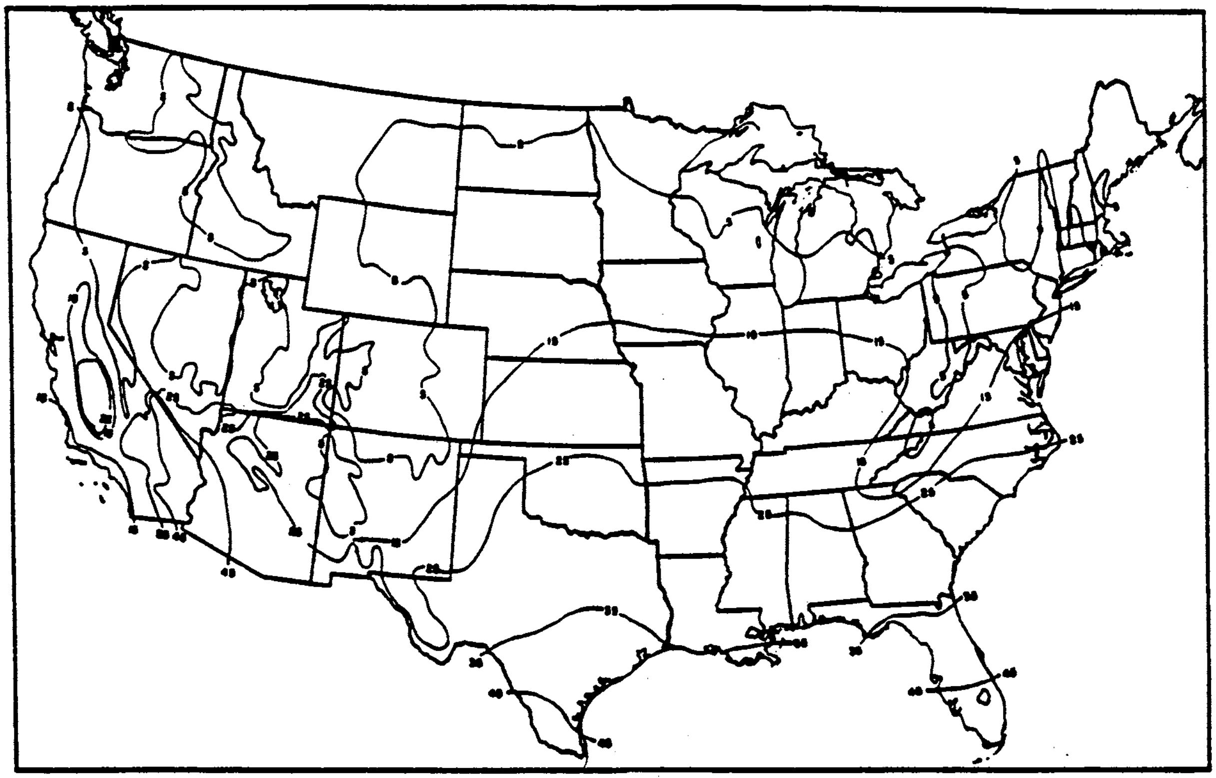
Kenaf yields are assumed to vary with the mill's location, ranging from a low of 6 dry tons to a high of 8 tons. The assumed yield levels are adjusted based on Higgins (figure 4.4). The potential annual demands are then divided by the assumed yield level to estimate potential acreage requirements if the mill were to meet all of its

TABLE 4.2

PAPER MILLS LOCATED IN POTENTIAL KENAF PRODUCTION REGIONS, 1986

State	Mills	Largest	Smallest	Average
		-------	*(1,000 tons/year)*	-------
Atlantic South:				
N Carolina	5	1,420	178	816
S Carolina	6	1,729	199	905
Virginia	5	1,384	97	683
South Central:				
Arkansas	7	1,065	213	661
Louisiana	12	1,456	142	831
Oklahoma	1	1,420	1,420	1,420
Texas	7	1,100	284	705
Southeast:				
Alabama	14	1,456	256	794
Florida	9	1,207	320	876
Georgia	15	2,024	44	774
Mississippi	7	1,388	23	628
Total	88	2,024	23	783

Source: Kenaf International Report, 1986, p.4.



Conversion*

mton/ha	ston/acre
45	20
35	16
25	11
15	7
5	2

Adapted from: Higgins, J.J. "Kenaf Leaf Development and Stem Height: Index of Crop Yield in the U.S." Bul. 1477, ARS/USDA, Washington, D.C., February, 1974.

Figure 4.4. Estimated Kenaf Stem Yield (Mton/ha.) for the United States

fiber demands from kenaf. As kenaf is an annual crop, this information is given in acres/year. However, it is very unlikely that any existing pulp mill will convert completely to kenaf as its only fiber source. We assume that most mills will use kenaf to the extent that it enhances product quality, is competitive with existing fiber, and the supply is both dependable and consistent. For some mills, this may mean that less than 10 percent of its fiber will come from kenaf. Other mills may find both fiber and manufacturing savings from a higher usage of kenaf, especially if kenaf contributes to improved product quality. The latter is the main long term consideration as most fiber savings will likely disappear over time.

All projections as to potential kenaf demand at this time are mostly speculation. Therefore, an arbitrary 25 percent of current potential fiber demand was assumed. Thus, a factor of 0.25 was used to compute the acreage. This estimated acreage was then used to compute potential crop values (table 4.3). Crop value is acres times yield times a price of $55.00/delivered dry ton. This price level represents the current average price for a ton of dry wood chips in most of the regions although chip prices may vary considerably from mill to mill. Actual kenaf prices will initially be a function of comparable wood chip prices. Current chip prices and estimated average yields may make kenaf competitive with most crops for land.

TABLE 4.3

PROJECTED KENAF ACRES AND ANNUAL VALUES BASED ON EXISTING PAPER MILLS' CAPACITIES

State	Mills	Acres	Annual Values
Atlantic South:			
N Carolina	5	145,004	$ 55,826,540
S Carolina	6	194,008	74,693,080
Virginia	5	134,099	44,252,670
Subtotal	16	473,910	$174,772,290
South Central:			
Arkansas	7	147,176	$ 63,138,504
Louisiana	12	311,773	137,180,120
Oklahoma	1	50,714	19,524,890
Texas	7	154,203	67,849,320
Subtotal	23	663,867	$287,692,834
Southeast:			
Alabama	14	372,664	$153,723,900
Florida	9	246,392	108,412,480
Georgia	15	389,629	160,721,962
Mississippi	7	137,373	60,444,120
Subtotal	45	1,146,059	$483,302,462
Total	88	2,283,836	$945,767,586

Poultry Market

Kenaf woody core represents a potential source for use as poultry litter, and tests have shown that it compares favorably to woody chips which are getting more expensive (Masud et al., 1991). Potential demand for kenaf from the poultry industry is determined by the level of poultry supply which is driven by consumer demand for poultry meat in the U.S. each year. Domestic demand for poultry meat has shifted upward since the late 1970s. During 1980 to 1991, per capita consumption of poultry meat has increased by almost 50 percent which may be a result of the change in dietary patterns, awareness of safe and healthy food in American society. Broiler production increased by nearly 75 percent (table 4.4), and the turkey production also increased by more than 70 percent during the same time period.

Total number of broilers and turkeys produced in the U.S. by leading states are reported in table 4.5, obtained from Agricultural Statistics published by the United States Department of Agriculture (USDA). The major broiler production areas are: northwestern Arkansas, northern Georgia, northern Alabama, central Mississippi, eastern Texas, and the Delaware (Delaware, Maryland and Virginia) Peninsula, North Carolina, and central California. In 1991, there were about 6.2 billion broilers and 285 million turkeys on U.S. farms.

TABLE 4.4

BROILER PRODUCTION, VALUES, AND PER CAPITA CONSUMPTION IN THE U.S., 1980-90

Year	Commercial broiler production	Value of production	Per capita consumption
	1,000	*1,000 dollars*	*pounds*
1980	3,963,211	4,302,818	50.5
1981	4,147,521	4,699,379	52.0
1982	4,148,970	4,502,214	53.3
1983	4,183,660	4,872,707	54.1
1984	4,283,020	6,020,066	56.0
1985	4,469,578	5,668,272	58.3
1986	4,648,520	6,784,088	59.7
1987	5,003,560	6,177,127	63.6
1988	5,237,901	7,435,105	65.5
1989	5,516,521	8,777,668	69.2
1990	5,864,150	8,365,470	72.2
1991	6,138,350	8,385,284	75.6

Source: Agricultural Statistics, 1992, p.341.

TABLE 4.5

LEADING BROILER PRODUCTION STATES IN THE U.S., 1991

State Ranked	Number(million)	% of U.S.
1. Arkansas	980.20	15.97
2. Alabama	875.30	14.26
3. Georgia	867.30	14.13
4. N. Carolina	546.80	8.91
5. Mississippi	456.50	7.44
6. Texas	340.20	5.54
7. Maryland	268.80	4.38
8. California	240.00	3.91
9. Delaware	236.50	3.85
10. Virginia	218.70	3.56
U.S. total	6,138.35	100.00

Source: Agricultural Statistics, 1992, p.337.

Potential Acreage Requirement of Kenaf Poultry Litter

The thick inner core of kenaf stem is a potential source for poultry litter. Poultry farms may be able to reduce costs by substituting kenaf chips for wood chips which are assumed to be more expensive. Because paper mills only use kenaf's bast fiber for producing newsprint, the remaining inner core is left unused and can be used as poultry bedding material. Approximately 70 percent of the broilers produced in the United States are from those states where kenaf can be feasibly produced to manufacture newsprint. Therefore, the economic analysis of supply of kenaf as a poultry litter focuses on the states where the paper mills are also located. The following states are included: Alabama, Arkansas, Georgia, Mississippi, North Carolina, Texas and Virginia.

The estimated kenaf litter requirements per broiler and per turkey are 0.03125 cubic feet (cu.ft.) and 0.375 cu.ft. per year, respectively (Hyatt, 1991). Using these conversion rates, the total litter requirements for the U.S. broiler and turkey production would be 192 million cu.ft. and 107 million cu.ft., respectively in 1991. A total of 299 million cu.ft. of poultry litter would require kenaf acreage in the range of 74,000 to 270,000. Potential litter requirements by the leading poultry producing states included in the study were also calculated. The results are reported in table 4.6.

Kenaf acreages required to satisfy the 1991 poultry

TABLE 4.6

ESTIMATED ANNUAL AMOUNT OF TOTAL KENAF LITTER REQUIREMENTS BY THE SELECTED LEADING POULTRY PRODUCTION STATES AND THE U.S., 1991

States	Broiler	Turkey	Total
	-------- *million cubic feet* -------		
Arkansas	30.63	9.00	39.63
Alabama	27.35	na[a]	27.35
Georgia	27.10	0.71	27.81
N. Carolina	17.09	21.75	38.84
Mississippi	14.27	na	14.27
Texas	10.63	na	10.63
California	7.50	10.88	18.38
Virginia	6.83	1.54	8.37
U.S. total	191.82	106.88	298.70

[a] na: not available.

litter demand in the leading poultry producing states and the U.S. were estimated assuming kenaf core is the only source for the poultry litter market (table 4.7). Kenaf core yield ranges from 55 to 65 percent of total stem yield. Therefore, kenaf acreages were estimated for three levels of core yield, i.e., 55, 60, and 65 percent of total yield at 6.5 tons per acre. Of cource, kenaf stem yield varies from state to state. The yield level of 6.5 tons per acre is the average across the study regions.

Because kenaf core is very light, a 40,000 ton capacity trailer would only carry about 15,000 tons of kenaf core material (Masud et al., 1991). Thus, the transportation cost can be very high if poultry firms are located too far away from the production areas. Therefore, the areas where poultry farms are located within short distance are suggested for commercially supplying kenaf core.

Forage Market

The forage market can be analyzed from a different perspective. Forage is produced as an input to raise livestock on farms. The supply of forage may not be market driven in which demand is the pulling source for the product. Because the primary users of forage are livestock producers, the most important reason for harvesting and/or purchasing forage is to feed livestock on farms (e.g., approximately 82 percent of hay produced in the U.S. was directly consumed on farms). Therefore, analysis of the

TABLE 4.7

ESTIMATED KENAF ACRES REQUIRED FOR POULTRY LITTER AT VARIOUS LEVELS OF CORE YIELD IN SELECTED LEADING POULTRY PRODUCTION STATES, 1991

States	55% Core	60% Core	65% Core
		acres	
Arkansas	27,713	25,404	23,450
Alabama	19,126	17,532	16,183
Georgia	19,448	17,827	16,456
N. Carolina	27,161	24,897	22,982
Mississippi	9,979	9,147	8,444
Texas	7,434	6,814	6,290
California	12,853	11,782	10,876
Virginia	5,853	5,365	4,953
Subtotal	129,566	118,769	109,633
U.S. Total	208,881	191,474	176,746

potential market for kenaf forage should focuse on analyzing the potential economic benefits to be gained by livestock producers from their farming activities. If kenaf forage has advantages to offer farmers with good quality forage, but lower costs than other types of forages, farmers will be willing to consider using kenaf forage which may increase farm incomes.

Kenaf has been identified as having the physical characteristics which may provide an alternative to summer fallowing wheat lands in the Southern Plains. Leaves are high in protein (20-30 percent) and are very digestible (greater than 65 percent total digestible nutrients) by ruminants. Kenaf forage can be cubed, baled, or stored using silage methods. The choice of harvesting methods depend on local weather conditions, equipment availability, and processing capabilities.

The physical characteristics of kenaf enable farmers to incorporate the crop into the present farm enterprises where farmers produce winter wheat and raise cattle. Farmers plant winter wheat in early fall and harvest in late spring. During period of November to February, cattle are allowed to graze on wheat pasture. However, between late spring and early fall, the soil is clean tilled to conserve soil moisture and break weed and disease cycles. Thus, while the land resource is fully utilized during the cattle grazing and wheat production cycle, it is left unused during the remainder of the year. Kenaf is economically feasible to be integrated into the winter wheat-stocker cattle farm enterprises. Three consecutive year period field experiments at Oklahoma State University have shown that under favorable weather conditions (i.e., hot and humid weather), good quality kenaf forage can be produced.

Farmers whose enterprises include wheat and stocker cattle would like to see economic profits generated by integrating kenaf forage into their enterprises. For comparison, we developed two types of enterprise budgets including winter wheat-stocker and winter wheat-kenaf-stocker based on the data from the field experiment and production conditions in Southwestern Oklahoma. Kenaf price is hypothesized at $43.20 per ton, which is equivalent to the current estimated market value for non-legume hay. Kenaf was directly seeded on wheat stubble following the wheat harvest at a rate of 10 lbs. per acre. No pre-plant herbicide was applied (no herbicide has been cleared for kenaf yet). Kenaf forage was harvested with ordinary forage cutting equipment, wind-rowed and baled. The harvest of kenaf forage was assumed to follow multiple harvesting times practice. The first cutting would usually occur between 45-50 day growth period, yielding 2.2 tons of kenaf forage per acre. A second cutting would occur just prior to fall planting of winter wheat. We assumed that the interval between the two cuttings is around 20 days, yielding an additional 1 ton of kenaf forage per acre. However, the length of the second growth period varies depending upon the remaining soil moisture, the actual wheat harvest date in the spring and planting date in the fall. After the second cutting, the kenaf stubble is sprayed with paraquat to prevent new growth. While no-till drilling of wheat on kenaf stubble is technically possible, conventional tillage practices are assumed. Stocker cattle are placed on field the first week in November and require two weeks of supplemental feeding during the winter months. Wheat returns above all costs except overhead, risk, land and management were estimated at -$12.78 per acre, assuming a 30 bushel yield and a $3.00 national season average price (table 4.8). Net returns for the wheat enterprise will increase with commodity program participation by approximately $25.00 per acre. Stocker cattle returns for the current year were estimated at $42.90 per head with a stocking rate of 0.356 head per acre, a 135 day grazing period, and a price of $89.10 per cwt (table 4.10). Thus, the stocker return is estimated at $15.27 with a stocking rate of one head per acre, yielding a total return for the wheat-stocker enterprise of -$0.21 per acre without government payments and $25.29 with government payments.

Net returns for the wheat-kenaf double crop were estimated at -$3.23 per acre without government payments and $22.27 with government payments. Thus, addition of kenaf to the wheat-stocker enterprise yields a net return of $15.75 per acre without government payments and $41.25 with government payments (table 4.11). The net gain was

TABLE 4.8

WHEAT FOR GRAIN, DRYLAND BUDGET PER ACRE, SOUTHWESTERB-CENTRAL OKLAHOMA, 1991

Operating Inputs	Units	Price	Quantity	Value
Wheat Seed	bu.	4.50	1.00	4.50
18-46-0 Fert.	cwt.	11.00	1.00	11.00
Nitrogen (N)	lbs.	0.16	70.00	11.20
Insecticide	acre	4.50	0.50	2.25
rntfertsprd	acre	2.00	1.00	2.00
Annual Oper. Cap.	dol.	0.12	21.52	2.58
Labor Charges	hr.	4.50	3.34	15.02
Mach., Fuel, Lube and Repairs	acre			26.38
Total Operating Cost				74.93
Total Fixed Costs (machinery & equipment)				47.07
Production Wheat	bu.	3.00	30.00	90.00
Small Grain Pasture	aums.	21.35	0.90	19.22
Total Receipts				109.21
Returns above all cost except overhead, etc.				-12.78

TABLE 4.9

STOCKER STEERS ON WINTER WHEAT PASTURE COST/RETURNS PER HEAD, 100 OR MORE HEAD SPRING CALVES HEAD 135 DAYS, SOUTHWESTERN-CENTRAL OKLAHOMA, 1991[a]

Operating Inputs	Units	Price	Quantity	Value
Str Calves (4-5)	cwt.	93.12	4.37	406.93
Non-legume Hay	lbs.	0.03	386.00	11.58
Sm Grain Pasture	aums.	21.35	2.53	54.02
Salt and Minerals	lbs.	0.14	7.46	1.04
Mktg. Chrg.	cwt.	1.72	6.79	11.68
Vet Service	hd.	9.00	1.00	9.00
Vet-Med-LS Supp	hd.	2.08	1.00	2.08
Custom Hauling	cwt.	0.35	11.16	3.91
Annual Oper. Cap.	dol.	0.12	151.55	18.57
Machinery Labor	hr.	4.50	1.26	5.68
Equipment Labor	hr.	4.50	0.08	0.36
Livestock Labor	hr.	4.50	1.61	7.24
Machinery Fuel, Lubeand Repairs	dol.			7.88
Equipment Fuel, Lube and Repairs	dol.			0.85
Total Operating Cost				540.82
Total Fixed Costs (machinery & equipment)				9.14
Production Steers (600-700)	cwt.	89.10	6.65	592.86
Returns above all costs except overhead, risk, management, and land				42.90

[a] AV Net Gain 1.79/day. 2% Death Loss. 3% Shrink Off Cattle Wts. Steers conditioned and fed Hay 1st 15 days assumes 2 lbs. of hay/day for 120 days.

TABLE 4.10

WHEAT-KENAF-DOUBLE CROP, DRYLAND BUDGET, SOUTHWESTERN-CENTRAL OKLAHOMA, 1991

Operating Inputs	Units	Price	Quantity	Value
Kenaf Seed	lbs.	2.00	10.00	20.00
Wheat Seed	bu.	1.00	4.50	4.50
18-46-0 Fert	cwt.	1.00	11.00	11.00
Nitrogen (N)	lbs.	0.16	150.00	24.00
Phosph (P_2O_5)	lbs.	0.16	37.00	5.92
Potash (K_2O)	lbs.	0.09	98.00	8.82
Herb	acre	24.35	1.00	24.35
Insecticide	acre	4.50	1.50	6.75
Baling Wire	roll	33.00	0.25	8.25
Rntfertspdr	acre	2.00	2.00	4.00
Annual Oper. Cap.	dol.	0.12	22.03	2.70
Labor Changes	hr.	4.50	5.36	24.10
Mach., Fuel, Lube and Repairs	acre			37.89
Total Operating Cost				182.28
Total Fixed Cost (machinery & equipment)				68.41
Forage	tons	43.20	3.20	138.24
Wheat	bu.	3.00	30.00	90.00
Sm Gr Past	aums	21.35	0.90	19.22
Total Receipts				247.46
Returns Above all cost except overhead, etc.				-3.23

TABLE 4.11

COMPARATIVE SUMMARY OF COSTS AND RETURNS BY ENTERPRISE, SOUTHWESTERN-CENTRAL OKLAHOMA, 1991[a]

Operating Inputs	Wheat-Stockers	Wheat-Kenaf-Stockers	Difference
Wheat Seed	4.50	4.50	0.00
Kenaf Seed	0.00	20.00	20.00
18-46-0	11.00	11.00	0.00
Nitrogen (N)	11.20	24.00	12.80
Phosph (P_2O_5)	0.00	5.92	5.92
Potash (K_2O)	0.00	8.82	8.82
Herbicide	0.00	22.85	22.85
Insecticide	4.50	4.50	0.00
Baling Wire	0.00	8.25	8.25
RntFertSpdr	2.00	4.00	2.00
Ann Op Capital	9.21	9.34	0.13
Steer Calves (4-5)	144.76	144.76	0.00
Non Legume Hay	4.12	4.12	0.00
Sm Grain Pasture	19.22	19.22	0.00
Salt & Mineral	0.37	0.37	0.00
Marketing Charge	4.15	4.15	0.00
Vet	3.20	3.20	0.00
Vet-Med-Supplies	0.74	0.74	0.00
Custom Haul	1.39	1.39	0.00
Labor	15.02	24.10	9.08
Machine Labor	2.02	2.02	0.00
Equipment Labor	0.13	0.13	0.00
Livestock Labor	2.58	2.58	0.00
Mach Fuel, Lube, and Repairs	29.18	40.69	11.51
Equip Fuel, Lube, and Repairs	0.30	0.30	0.00
Total Operating Cost	269.59	370.95	101.36
Fixed Cost	50.32	71.66	21.34
Total Cost	319.91	442.61	122.70
Production			
Production Wheat	90.00	90.00	0.00
Kenaf Forage	0.00	138.24	138.24
Sm Grain Pasture	19.22	19.22	0.00
Production Steers	210.90	210.90	0.00
Government Payments	25.50	25.50	0.00
Total Receipts	345.62	483.86	192.00
Returns	25.71	41.25	16.24

[a] The values are on per acre basis.

estimated at $15.95 per acre.

Summary

Three major markets have been identified as the major potential markets for commercial kenaf production. Potential demand for kenaf pulp, poultry litter, and economic benefits from producing kenaf forage on farms are the economic rationale for integrating kenaf into the present farm enterprises. Farm supply of kenaf should focus on three major markets, i.e., newsprint and paper mills, poultry farms, and livestock farms, where consistent demand would result in acceptable prices and fair returns.

CHAPTER V

ANALYTICAL MODEL

Introduction

This chapter develops the empirical analytical model used to project the available kenaf acreage in the potential production regions. The empirical analytical model employed in this study draws heavily on the theories of quadratic programming and retains the technical features of these types of models discussed in Chapter III. In addition to some conventional technical assumptions associated with mathematical programming models, additional specific assumptions are included to assist in aligning the model to the kenaf supply which must be consistent with the current market and production situations.

The objective of the analytical model is to provide valuable information about potential production capacities and returns of kenaf fiber and forage to producers and manufacturers. The model should have at least the following features (a) it must adequately represent producers' production alternatives and practices and project supply under the given conditions in the short run and the long run, and (b) the model should reflect the risky situation that farmers may face if kenaf is commercially produced.

Commercial production of kenaf is risky containing various factors. Kenaf is a new crop to farmers, production system and cultural practice are unknown. Kenaf products are not yet established in the market, therefore, producers and consumers will have to jointly determine the acceptable price level which may make returns variable. However, kenaf will more likely be supplied on contract basis where the price may be known to producers prior to planting. This reduces risk associated with price variability. In addition, only a limited set of pesticides have been cleared for kenaf. The model should, therefore, incorporate some measure of risk into farmers' decision making.

Model Specification

Crop response function can be derived from either positive models (i.e., econometric estimation) or normative models (i.e., mathematical programming). Applications of econometric models are usually restricted by data availability. Mathematical programming models can be very useful in deriving the supply function for a particular crop. Such models can also handle risk at the individual farm level if each farmer is assumed to operate in a competitive environment according to the *E,V* decision criterion.

Let us define

$\hat{p} = n \times 1$ vector of anticipated product prices

$M = n \times n$ diagonal matrix of expected enterprise yields with jth diagonal element m_j

$x = n \times 1$ vector of enterprise levels

$y = n \times 1$ vector of total outputs calculated by Mx

$c = n \times 1$ vector of known unit costs

$b = k \times 1$ vector of resource constraints

$A = k \times n$ matrix of input coefficients with elements a_{ij}

$N = n \times n$ diagonal matrix of stochastic yields with jth diagonal element $m_j + \epsilon_j$ (ϵ_j is the stochastic term)

ϕ = the risk aversion coefficient of the representative farmer

$\lambda = k \times 1$ vector of Langrangian multipliers.

Then the deterministic programming model for a representative farm can then be written as

$$\begin{aligned} &\textit{maximize} && \pi = \hat{p}^T y - c^T x \\ &\textit{Subject to} && -b + Ax \leq 0 \\ & && \hat{p},\ y,\ x,\ c \geq 0 \end{aligned} \tag{5.1}$$

where the supscript T denotes the transpose.

As kenaf is a new crop, we assume that the risk of producing kenaf comes from possible yield variability. And the risk associated with other crops on farms are assumed to be confined to yields and prices. We further assume that the representative farmer is risk averse, and his behavior conforms to a single period *E-V* specification. Assuming the representative farmer has the utility function as

where U is the utility and R is the net return; and K is

$$U(R) = K - e^{-\phi R} \tag{5.2}$$

constant. Suppose that R is normally distributed, then the expected utility function is

$$E[U(R)] = \int_{-\infty}^{\infty} [K - \exp(-\phi R)] \exp[-(R-\mu)^2/2\sigma^2]\, dR \tag{5.3}$$

The maximization of this function yields

$$E(U^*) = \mu - \frac{\phi}{2}\sigma^2 \tag{5.4}$$

Expressing the system (5.1) in terms of utility function, we have

$$\begin{array}{ll} \textit{maximize} & u = E(p^T y) - c^T x - \frac{1}{2}\phi V(p^T y) \\ \textit{subject to} & -b + Ax \le 0 \\ & p,\ y,\ x,\ c \ge 0 \end{array} \tag{5.5}$$

where E and V denote the expectation and variance operators, respectively.

Under perfect competition, individual farmers do not expect their outputs to have any effect on the market. Therefore, the following assumptions can be made:

(A.1) $E(\epsilon_j) = 0$, *or* $E(m_j + \epsilon_j) = m_j$

(A.2) $V(m_j + \epsilon_j) = \sigma_{mj}^2$

(A.3) $E(p_j) = \hat{p}_j$

(A.4) $V(p_j) = \sigma_{pj}^2$

(A.5) $cov(p_i p_j) = \sigma_{ij}^p;\quad cov[(m_i + \epsilon_i)(m_j + \epsilon_j)] = \sigma_{ij}^m \quad \forall$

$$\text{(A.6)}\qquad \begin{aligned} cov(p_j y_i) &= E\{[p_j-\hat{p}_j]\,[(m_i+\epsilon_i)-m_i]\,x_i\} \\ &= x_i cov[p_j,(m_i+\epsilon_i)] = 0 \end{aligned} \qquad \forall\ i$$

With this set of assumptions, the components of the system (5.5) can be evaluated in more detail as follows:

$$E(p^T y) = E(p^T Nx) = \hat{p}^T Mx \tag{5.6}$$

$$\begin{aligned} V(p^T y) &= E[(p^T Nx - E(p^T Nx))(p^T Nx - E(p^T Nx))^T] \\ &= E[(p^T Nx - \hat{p}^T Mx)(p^T Nx - \hat{p}^T Mx)^T] \\ &= x^T\{E[(p^T N - \hat{p}^T M)(p^T N - \hat{p}^T M)^T]\}x \end{aligned} \tag{5.7}$$

where we can define

$$E[(p^T N - \hat{p}^T M)(p^T N - \hat{p}^T M)^T] = \Omega \tag{5.8}$$

and Ω is an $n \times n$ variance-covariance matrix with diagonal elements

$$\begin{aligned} \omega_{jj} &= V[p_j(m_j+\epsilon_j)] \\ &= E[p_j^2(m_j+\epsilon_j)^2] - \hat{p}_j^2 m_j^2 \\ &= E[p_j^2]\,E[(m_j+\epsilon_j)^2] - \hat{p}_j^2 m_j^2 \\ &= [\sigma_{pj}^2 + \hat{p}_j^2]\,[\sigma_{mj}^2 + m_j^2] - \hat{p}_j^2 m_j^2 \\ &= \sigma_{pj}^2 E[(m_j+\epsilon_j)^2] + \hat{p}_j^2 \sigma_{mj}^2 \end{aligned} \tag{5.9}$$

and off-diagonal elements

$$\begin{aligned} \omega_{ij} &= cov[p_i(m_i+\epsilon_i),\,p_j(m_j+\epsilon_j)] \\ &= E[p_i p_j(m_i+\epsilon_i)(m_j+\epsilon_j)] \\ &\quad - E[p_i(m_i+\epsilon_i)]\,E[p_j(m_j+\epsilon_j)] \\ &= E[p_i p_j]\,E[(m_i+\epsilon_i)(m_j+\epsilon_j)] - \hat{p}_i\hat{p}_j m_i m_j \\ &= E[p_i p_j]\{E[(m_i+\epsilon_i)(m_j+\epsilon_j)] - m_i m_j\} \\ &\quad + m_i m_j\{E[p_i p_j] - \hat{p}_i\hat{p}_j\} \\ &= [\sigma_{ij}^p + \hat{p}_i\hat{p}_j]\,\sigma_{ij}^m + m_i m_j \sigma_{ij}^p \end{aligned} \tag{5.10}$$

Then the objective function of the system (5.5) becomes

$$maximize \qquad u = \hat{p}^T Mx - c^T x - \frac{1}{2}\phi(x^T \Omega x) \tag{5.11}$$

and Ω is positive semidefinite. The Lagrangian function for equation (5.11) is

$$L = \hat{p}^T M x - c^T x - \frac{1}{2}\phi(x^T \Omega x) + \lambda^T (Ax - b) \qquad (5.12)$$

The Kuhn-Tucker conditions for the optimum require that

$$\begin{aligned} \nabla f(x^*) + \mu^T \nabla h(x^*) + \lambda^T \nabla g(x^*) &= 0 \\ \lambda^T g(x^*) &= 0 \\ \textit{where } h(x*) = 0, \textit{ and } g(x^*) &\le 0 \end{aligned} \qquad (5.13)$$

In our case, we obtain the following assuming active constraints:

$$\begin{aligned} \hat{p}^T M - c^T - \phi x^T \Omega - \lambda^T A &= 0 \\ Ax - b &= 0 \end{aligned} \qquad (5.14)$$

The first equation of (5.14) can be rearranged so that we can interpret this condition economically. Taking the partial derivative of the Lagrangian function with respect to x_j, rearranging terms and dividing by m_j on both sides, we obtain

$$\hat{p}_j = \frac{1}{m_j}\left[c_j + \phi \sum_i \omega_{ji} x_i + \sum_k \lambda_k a_{kj}\right] \qquad (5.15)$$

This condition differs from the deterministic model where market price should equal marginal cost. The right hand side (RHS) of equation (5.15) consists of three components: the expected own marginal cost per unit of output c_j/m_j; the expected opportunity costs of the resources as reflected in the dual values $\frac{1}{m_j}\sum_k \lambda_k a_{kj}$; and a marginal risk factor $\frac{1}{m_j}(\phi \sum_i \omega_{ji} x_i)$. The condition stated by equation (5.15) is theoretically and intuitively appealing because the risk term is just an added cost, or the additional return expected by a risk averse farmer as compensation for taking risk.

The other important conditions for the optimum are the complementary slackness conditions which state that

$$x\frac{\partial L}{\partial x} = 0, \text{ and } \lambda\frac{\partial L}{\partial \lambda} = 0. \tag{5.16}$$

The economic interpretation for these conditions is as follows: Taking the *j*th output, the first term implies that if the sum of all cost components going into the production of one more unit of x_j exceeds the expected return, then this product should not be produced. The second term implies that if the resource is not fully exhausted, then its shadow price must be zero.

The RHS of equation (5.15) represents the individual farm's short run supply function, which establishes a relationship between the farmer's decision on levels of enterprises and his expectations about yields, prices and risk. We may express this relationship as

$$x_j = f(M, \hat{p}, \Omega) \tag{5.17}$$

Multiplying this by the mean yield m_j, we obtain the following function which can be expressed as a conditional expected supply function:

$$E(y_j|x_j) = m_j x_j = m_j f(M, \hat{p}, \Omega) \tag{5.18}$$

The "conditional" is based on what the farmer has determined to set the level of enterprise given his subjective anticipations. This supply function differs from a true statistical relation which is estimated with objective data and establishes an *ex post* relationship.

Aggregation and Market Equilibrium

So far we have developed the short run supply function for a risk averse farmer. By summing over all the individual expected supply functions, we can obtain an aggregate conditional expected supply function which can be used in market equilibrium analysis. Let X, Y, W, C, $\overline{P}$, and Ψ be the aggregates of x, y, M, c, $\hat{p}$, and Ω, then aggregate conditional expected supply for *j*th product can be written as

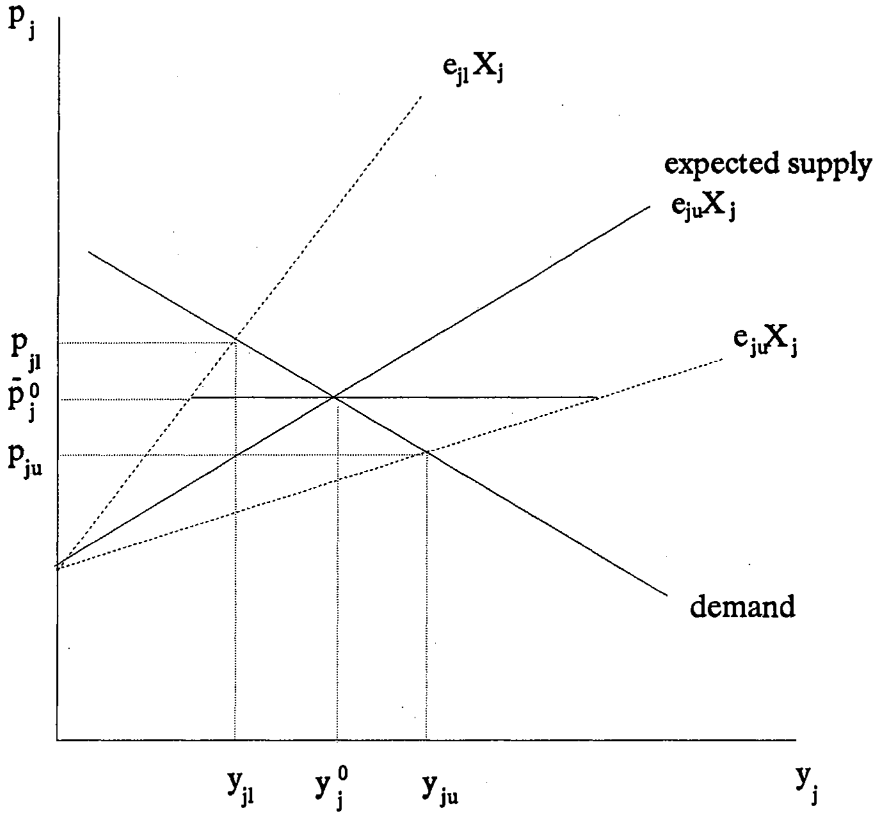
$$E(Y_j|X_j) = w_j g(W, \overline{P}, \Psi) \qquad (5.19)$$

The actual supply may differ from expected supply because of the stochastic nature of yield. Therefore, we can express the actual conditional supply function as

$$Y_j|X_j = e_j X_j = e_j g(W, \overline{P}, \Psi) \qquad (5.20)$$

where $e_j = w_j + \epsilon_j$, and $E(e_j) = w_j$. The actual supply is stochastic with e_j and differs from expected supply. The relationship between expected and actual supply and the effect on market prices are portrayed in figure 5.1.

Suppose that the expected yield, W, and the variance-covariance matrix, Ψ, are fixed, then the expected aggregate



adapted from: P.B.R. Hazell and P.L. Scandizzo. "Competitive Demand Structures under Risk in Agricultural Linear Programming Models", Amer. J. Agr. Econ., 56(1974):235-44.

Figure 5.1. Market Equilibrium under Aggregate Expected Supply

supply is determined by the market price $\overline{P}$ only. For simplicity, we also assume that all farms face the same average costs, and the supply and demand functions are linear. Under these assumptions, the expected supply curve $w_j X_j$ is fixed, but the actual supply curve shifts between the range $e_{ju} X_j$ and $e_{jl} X_j$. If the expected market price is $\overline{P}_j^0$, farmers will plan to produce output at Y_j^0 . Because yields are stochastic, the actual output varies over the range of Y_{jl} and Y_{ju}. If we assume no storage, market price also becomes stochastic ranging over P_{jl} and P_{ju} depending upon elasticity of demand.

The equilibrium solution under this market structure, where yields and prices are simultaneously stochastic, is not trivial. Although the competitive equilibrium can be sought if we view this market as stabilizing in its price distribution, the problem is that this distribution does depend on farmers' forecasting behavior about $\overline{P}$, W, and Ψ. Therefore, the following appropriate assumptions will be necessary to allow us to derive an equilibrium solution:

(A.7) W and Ψ are fixed.

(A.8) The enterprise level X_j is a liner function in expected price $\overline{P}_j$ of the form $X_j = \gamma \overline{P}_j$, where γ is some appropriate function of expected yield W and Ψ. By assumption (A.7), γ is constant. Actual supply in year t can be expressed as $Y_{jt} = \gamma e_{jt} \overline{P}_{jt}$.

(A.9) Demand in year t is $D_{jt}=\alpha-\beta P_{jt}$.

(A.10) Each year farmers form expected price forecasts using a weighted average of past prices, that is, $\bar{P}_{jt}=\sum_{i=1}^{s}\theta_i P_{jt-i}$, *and* $\sum_{i=1}^{s}\theta_i=1$.

(A.11) The yield of jth output in year t is uncorrelated with its past values, that is, $Cov(e_{jt},e_{jt-1})=0,\ \forall\ t$.

If the market clearing condition holds implying that $Y_{jt}=D_{jt}$, we may obtain the market clearing price ignoring jth output as

$$\begin{aligned} P_t &= \frac{1}{\beta}(\alpha-\gamma e_t\bar{P}_t) \\ &= \frac{1}{\beta}(\alpha-\gamma e_t\sum_{i=1}^{s}\theta_i P_{t-i}) \end{aligned} \tag{5.21}$$

Taking expectation yields

$$\begin{aligned} E(P_t) &= E[\frac{1}{\beta}(\alpha-\gamma e_t\sum_{i=1}^{s}\theta_i P_{t-i})] \\ &= \frac{1}{\beta}[\alpha-\gamma w\sum_{i=1}^{s}\theta_i E(P_{t-i})] \end{aligned} \tag{5.22}$$

If convergence exits, we can obtain the solution for the expected price as

$$\lim_{t\to\infty} E(P_t) = \frac{\alpha}{\beta+\gamma w} \tag{5.23}$$

This solution is homogeneous for any weights θ_i as long as the condition $\sum_{i=1}^{s}\theta_i = 1$ holds.

The market equilibrium price can be solved if demand equals expected supply, or actual supply is identical to expected supply. Let P^* be the market equilibrium price, then the equilibrium condition for the market where actual supply equals demand is

$$\gamma w P^* = \alpha - \beta P^* \tag{5.24}$$

solving for P^*, we obtain

$$P^* = \frac{\alpha}{\beta + \gamma w} \tag{5.25}$$

which is identical to equation (5.23). Thus, we can conclude that the learning model using probability distributions and the assumption about price formation lead to the same equilibrium solution. Therefore, we may hypothesize that the market price equals the expected price.

Aggregation of Individual Farms

This section develops assumptions which are implied in the aggregation of Ω to Ψ and ϕ to Φ. Assuming two inputs are used in production and they are denoted respectively by x_1 and x_2, then we can write the variance-covariance matrix as

$$\phi(x^T\Omega x) = \phi[x_1\ x_2]\begin{bmatrix}\omega_{11} & \omega_{12}\\ \omega_{21} & \omega_{22}\end{bmatrix}\begin{bmatrix}x_1\\ x_2\end{bmatrix} \tag{5.26}$$

If there are k number of farms, we can aggregate equation

(5.26) as

$$\Phi(X^T\Psi X) = \phi_1\left([x_1\ x_2]\begin{bmatrix}\omega_{11} & \omega_{12}\\ \omega_{21} & \omega_{22}\end{bmatrix}\begin{bmatrix}x_1\\ x_2\end{bmatrix}\right) + \dots + \phi_k\left([x_1\ x_2]\begin{bmatrix}\omega_{11} & \omega_{12}\\ \omega_{21} & \omega_{22}\end{bmatrix}\begin{bmatrix}x_1\\ x_2\end{bmatrix}\right) \tag{5.27}$$

Let k=2, and assuming two farms are identical, we have

$$\begin{aligned}\Phi(X^T\Psi X) &= \phi_1\left([x_1\ x_2]\begin{bmatrix}\omega_{11} & \omega_{12}\\ \omega_{21} & \omega_{22}\end{bmatrix}\begin{bmatrix}x_1\\ x_2\end{bmatrix}\right)\\ &\quad + \phi_2\left([x_1\ x_2]\begin{bmatrix}\omega_{11} & \omega_{12}\\ \omega_{21} & \omega_{22}\end{bmatrix}\begin{bmatrix}x_1\\ x_2\end{bmatrix}\right)\\ &= \phi_1(\omega_{11}x_1^2 + 2\omega_{12}x_1x_2 + \omega_{22}x_2^2)\\ &\quad + \phi_2(\omega_{11}x_1^2 + 2\omega_{12}x_1x_2 + \omega_{22}x_2^2)\\ &= 2\phi(\omega_{11}x_1^2 + 2\omega_{12}x_1x_2 + \omega_{22}x_2^2)\end{aligned} \tag{5.28}$$

where $\phi_1 = \phi_2$

Aggregating the above, we obtain

$$\Phi(X^T\psi X) = \sum_{k=1}^{2}\phi_k(x_k^T\Omega x_k) \tag{5.29}$$

If all farms are homogenous implying that Ψ=Ω, we have

$$\begin{aligned}\sum_k \phi_k(x_k^T\Omega x_k) &= K\phi(x_k^T\Omega x_k)\\ &= \Phi(Kx^T\Omega Kx)\\ &= \Phi(X^T\Psi X)\end{aligned} \tag{5.30}$$

where $X = Kx = \sum_k x_k$

The complete aggregate model becomes

$$\begin{aligned} &\underset{x}{\mathit{maximize}} && U = P^T W X - C^T X - \frac{1}{2}\Phi\,(X^T \Psi X) \\ &\mathit{subject\ to} && -b^{*} + A^{*} X \le 0 \\ & && P,\ W,\ X,\ C \ge 0 \end{aligned} \tag{5.31}$$

where b* and A* are respectively the aggregation of b and A. Equation (5.31) is the general result from aggregating equation (5.11).

Summary

This chapter developed an analytical QP model to be used to estimate potential farm supply of kenaf. The objective of the model is defined to maximize the expected utility associated with the maximization of expected returns and minimization of variances of returns of growing a set of crops on farms. The model is based on the *E-V* principle and draws heavily on the theoretical models developed by Markowitz (1952) and Freund (1956). Methods developed by Hazell and Scandizzo (1974) for solving equilibrium prices and quantities under uncertain situations were adopted in the model development. The likely risk associated with integrating kenaf into the current farm enterprises is assumed to be probable yield variations due to weather, production location, unacquainted with the crop, and other uncontrollable factors which may significantly affect the expected returns and aggregate supply of kenaf.

CHAPTER VI

MODEL STRUCTURE AND DATA

Introduction

This chapter describes the structure of the model used in the economic analysis of potential kenaf acreage in the study areas. First, the data needed for the analytical QP model developed in the previous chapter are discussed followed by the data collection process. The data collection procedure including the data sources, the problems encountered in the data collection phase, and the adjustments of the original data for each of the proposed potential kenaf markets (i.e., newsprint, poultry litter, and forage) are discussed. A method for detrending kenaf yield is developed. Also, the production characteristics and the major crops in each of the potential kenaf production regions are analyzed. Secondly, the structure of the analytical model is presented in detail. The activities included in the model and properties of the variance-covariance matrices are discussed. Finally, the problem of aggregating the microsystem model is addressed and discussed.

The Data Requirements

The analytical QP model developed in the previous chapter, i.e., system (5.31), requires the expected gross or net returns and the corresponding variances and covariances of the enterprises included in a farm's operation. However, obtaining the data for the QP model requires the subjective information from the individual farms. In most cases, such data are extremely difficult to obtain because the variances and covariances are rarely specified, even though we sometimes are able to obtain the expected returns of the enterprises from the individual farm operators. Therefore, these data are usually estimated with the observed time series or cross-sectional data. The estimated values are sometimes adjusted in accordance with available subjective information.

The sample variance-covariance can be estimated with

$$\sum_{i=1}^{n} \sum_{j=1}^{n} x_i x_j \left[\frac{1}{T-1} \sum_{t=1}^{T} (z_{ti} - \overline{z}_i)(z_{tj} - \overline{z}_j) \right] \tag{6.1}$$

where x_i and x_j denote respectively the *i*th and *j*th enterprise level, t=1 to T denotes the T observations in a random sample of gross or net returns, and $\overline{z}_i$ is the sample mean returns for the *i*th activity. Summing over t, we obtain

$$\frac{1}{T-1}\sum_{t-1}^{T}\left[\sum_{i=1}^{n} z_{ti}x_i - \sum_{i=1}^{n}\overline{z}_i x_i\right]^2 \tag{6.2}$$

Using these two equations, we can calculate the income variance either from the individual activity gross return distributions, equation (6.1), or from the total gross return distribution, equation (6.2). In this study, we used equation (6.1) to obtain the variance-covariance matrix.

Data Source

Chapter IV identified the potential producing regions for commercial kenaf production for the markets of newsprint, poultry litter and forage. Attempts were made to collect data about the major crops from these three regions. The agricultural extension services of all states in these three regions generate crop and livestock budgets. However, finding a set of complete enterprise budgets over a longer time period as required by the QP model was not possible. To date, the most complete set of budgets was found to be the USDA's cost-of-production (COP) data series which provide continuous observations from 1975 to date. In addition, the data set of Farm Cost and Return Survey (FCRS) conducted over the study areas over the periods of 1979 to 1981, and 1989 to 1991 is used in conjunction with the COP data series. Eleven major field crops are included, with costs of production at both the national and regional level.

There are some advantages as well as disadvantages for using this data set. One of the biggest advantages is that yields are calculated based on planted acres and thus reflect risk better than yields calculated on harvested acres. However, the regional enterprise budgets have to be disaggregated into state level budgets since the original data are either the aggregate regional or the aggregate national enterprise budgets. Certain assumptions are needed so that the disaggregation bias can be minimized.

Information on the characteristics of farm operators including farm size and the production inputs, and the major crops and the planted acreage in each state of the study areas were collected from the 1987 Census of Agriculture, United States Department of Commerce, and the 1990 Agricultural Statistics, United States Department of Agriculture (see tables 6.1-6.3).

Data Adjustments

The data period included in this study is from 1981 to 1989. State level enterprise budgets for the major crops in the study areas were collected from the FCRS data set. Yield and cost of production variations for the major crops in each state for the time period of 1981 to 1989 were extrapolated against the COP data series.

Since there are no time series data available on kenaf yields for the time period included in the study. A method is developed here in order to effectively detrend the kenaf yields. The variation of kenaf yields is assumed to be closely related to those crops of the same growing season,

TABLE 6.1

NUMBER OF CROP FARMS, AVAILABLE CROP ACREAGE, AND INPUT COSTS OF THE STUDY AREAS, 1987

State	No. of farms	Available crop acres	Average per farm	Input costs per farm[a]
		------- *acres*	-------	*dollars*
N. Carolina	54,972	5,716,256	104	24,356
S. Carolina	18,578	2,686,117	145	23,614
Virginia	41,491	4,363,106	105	16,771
Alabama	37,148	4,496,607	121	17,461
Florida	29,386	3,790,599	129	77,784
Georgia	37,689	5,780,330	153	29,605
Mississippi	29,785	6,747,639	227	29,576
Arkansas	40,536	9,950,401	246	28,427
Louisiana	23,273	5,562,736	239	31,628
Oklahoma	55,783	14,443,459	259	18,018
Texas	147,174	35,610,951	242	24,284

Source: 1987 Census of Agriculture, U.S. Department of Commerce.

[a] Include expenses on seeds, commercial fertilizer, agricultural chemicals, petroleum products, electricity, hired farm labor, contract labor, repair and maintenance, customwork, machine hire, and rental of machinery and equipment, interest, cash rent, and property taxes paid.

TABLE 6.2

MAJOR CROPS AND THE HARVESTED ACRES IN THE STUDY AREAS, 1987

	State[a]										
Crop	NC	SC	VA	AL	FL	GA	MS	AR	LA	OK	TX
	millions of acres										
Corn	1.10	0.31	0.34	0.24	0.10	0.55	0.12	-	-	-	1.20
Cotton	0.10	0.12	-	0.35	-	0.23	1.03	0.50	0.59	0.36	4.30
Hay (all)	0.50	0.23	1.08	0.65	0.28	0.54	0.56	0.90	0.34	1.92	3.30
Orchards	-	0.05	0.03	-	0.76	-	-	-	-	-	-
Peanuts	0.10	-	-	0.21	-	0.56	-	-	-	0.09	-
Rice	-	-	-	-	-	-	0.20	1.00	0.42	-	0.30
Sorghum	-	-	-	-	-	-	0.11	0.30	0.12	0.34	2.70
Soybeans	1.30	0.60	0.46	0.58	0.09	0.76	2.01	3.20	1.54	0.23	0.20
Sugarcane	-	-	-	-	0.40	-	-	-	0.26	-	-
Tobacco	0.20	0.04	0.05	-	-	-	-	-	-	-	-
Vegetables	-	-	-	-	0.31	-	-	-	-	-	-
Wheat	0.40	0.21	0.19	0.16	-	0.42	0.28	0.90	0.15	4.28	3.60
Other	0.08	0.02	0.27	0.06	0.30	0.24	0.11	0.10	0.17	0.11	0.93

Source: 1987 Census of Agriculture, U.S. Department of Commerce.

[a] NC, North Carolina; SC, South Carolina; VA, Virginia; AL, Alabama; FL, Florida; GA, Georgia; MS, Mississippi; AR, Arkansas; LA, Louisiana; OK, Oklahoma; TX, Texas.

TABLE 6.3

MAJOR CROPS AND THE PERCENTAGE OF TOTAL HARVESTED ACREAGE IN THE STUDY AREAS, 1987

	State[a]										
Crop	NC	SC	VA	AL	FL	GA	MS	AR	LA	OK	TX
	percent										
Corn	29.1	19.6	14.2	10.5	4.3	16.6	2.8	-	-	-	7.3
Cotton	2.6	7.3	-	15.5	-	7.0	24.6	6.2	16.4	4.9	26.0
Hay (all)	13.2	14.6	44.6	29.0	12.5	16.3	13.7	12.3	9.5	26.2	20.0
Orchards	-	3.2	1.4	-	34.0	-	-	-	-	-	-
Peanuts	2.6	-	-	9.3	-	17.0	-	-	-	1.2	-
Rice	-	-	-	-	-	-	4.6	15.4	11.6	-	1.8
Sorghum	-	-	-	-	-	-	2.6	3.1	3.4	4.6	16.3
Soybeans	34.4	37.7	19.1	25.8	4.0	23.0	47.0	49.2	42.8	3.1	1.2
Sugarcane	-	-	-	-	18.0	-	-	-	7.3	-	-
Tobacco	5.3	2.7	1.8	-	-	-	-	-	-	-	-
Vegetables	-	-	-	-	13.9	-	-	-	-	-	-
Wheat	10.6	13.5	7.8	7.0	-	12.6	6.6	12.3	4.2	58.4	21.8
Other	2.1	1.5	11.0	2.9	13.4	7.4	0	1.5	4.8	1.5	5.6

Source, 1987 Census of Agriculture, U.S. Department of Commerce.

[a] NC, North Carolina; SC, South Carolina; VA, Virginia; AL, Alabama; FL, Florida; GA, Georgia; MS, Mississippi; AR, Arkansas; LA, Louisiana; OK, Oklahoma; TX, Texas.

e.g., cotton, corn, sorghum and soybeans. A regression of observed cotton yields per planted acre against corn yields, sorghum yields and soybeans yields was conducted for each state. The fitted values from the regression were used to construct the yield index assuming 1989 equals 1. Kenaf yields were adjusted according to the yield index. This method allows us to effectively project the kenaf yields because crop yields are largely influenced by the weather, and the cotton, corn, sorghum and soybeans yields would capture large scale weather effects common to regions where kenaf can be grown. Since three types of kenaf products, i.e., pulp, poultry litter, and forage, are considered in this study, three base yield levels were assumed respectively. The base yield level of kenaf supplying pulp is assumed at 6 tons per acre based on the observed kenaf yields from both Mississippi and Texas in 1989. The base yield level of kenaf supplying poultry litter (i.e., kenaf core) is equivalent to 60 percent of the total yield per acre. The per acre yield of kenaf forage was based on the observed yield level in Oklahoma and was assumed at 3.2 tons per acre. The base yield levels of three types of kenaf products for the other states included in the study were adjusted according to Higgins (see figure 4.4), respectively.

Enterprises Included in the Model

This study deals with introducing kenaf as a viable cash crop into the regional economy, thus kenaf has to compete with the existing major cash crops grown in the identified potential production regions. Therefore, only crop enterprises were included in the model. Although livestock production is very important for some states (e.g., Oklahoma and Texas), it actually competes very little, if at all, with cash crops as well as kenaf production enterprises.

Selection of crop activities included in the model is based on the relative importance of the crop in the state economy and its growing season. Including perennial tree crops in the model is not practical because of the nature of these crops and long term associated investments.

Nine crops were included in the model. These crops are the row crops corn, cotton, grain sorghum, kenaf, peanuts, rice, soybeans, sugarcane, and wheat. Not all of these crops are grown in every state included in the study. Sugarcane is planted only in Florida and Louisiana. Rice is produced in Arkansas, Louisiana, Mississippi and Texas. A total of 65 crop production activities were included in the model.

Kenaf supplying for the different markets is handled by solving the model under different levels of returns and production costs. Kenaf supplying pulp, poultry litter and forage are considered in the analysis. Transportation costs were included in the model for the activities of kenaf pulp and poultry litter. A 50 mile radius supply zones was assumed for both kenaf pulp and poultry litter. Longer distance hauling prohibits commercial kenaf supply because kenaf pulp and poultry litter are both bulky products. No transportation cost was included for the activity of kenaf forage assuming that kenaf forage is directly consumed on farms where it is produced.

Structure of the Model

The aggregate regional model consists of three regional sub-models (say, REGION01, REGION02, and REGION03) containing all 11 states. Model REGION01 consists of the states in the Atlantic South: North Carolina, South Carolina, and Virginia; model REGION02 consists of the states in the Southeast: Alabama, Florida, Georgia, and Mississippi; and model REGION03 consists of the states in the South Central: Arkansas, Louisiana, Oklahoma, and Texas. The data of each state are linked in block diagonal form and are integrated into the regional model. Total activity level for each enterprise is the summation over all three regional models. Each of the regional sub-models can be solved separately if the risk aversion coefficients vary from region to region. The structure of the model is described in table 6.4.

The objective of the model is defined to maximize the total aggregate expected utility subject to the resource constraints as described in system (5.31). The data used in the regional models were calculated on a per acre basis.

TABLE 6.4

MATRIX OF THE AGGREGATE REGIONAL QUADRATIC PROGRAMMING MODEL

Columns Titles	Region 1 activities	Region 2 activities	Region 3 activities	Selling activities	RHS[a]
Objective function	$-c_1 \dots -c_n$	$-c_1 \dots -c_n$	$-c_1 \dots -c_n$	$p_{11} \dots p_{kn}$	(Max)
Capital constraints	Planting and harvesting coefficients	Planting and harvesting coefficients	Planting and harvesting coefficients		≤ 285,059 ≤ 0 . . . ≤ 0
Land	1 . . . 1	1 . . . 1	1 . . . 1		≤ 1,037
Yields matrix	(-) . . . (-)	(-) . . . (-)	(-) . . . (-)	1 1 . 1	≤ 0 . . ≤ 0
Covariance matrix	covariances of gross margins of activities	covariances of gross margins of activities	covariances of gross margins of activities		≥ 0 . . . ≥ 0
Additional constraints					≥ 0 ≤ 0

[a] RHS = Right-hand side.

The title row contains acronyms for each activity. Each crop enterprise was divided into planting and harvesting activities, and marketing activity. Average production variable costs (1981-1989) were entered under the planting and harvesting activities. Average prices for all the crops included in the model were entered under the marketing activity. The inclusion of sales as separate activities allows the model to generate different results under different scenarios (i.e., different price levels). Following the production and sales activities are the variance-covariance matrices of all the enterprises linked in block diagonal form. All the prices and production costs were deflated by the GNP deflator (1982=100).

This set up allows the addition of more regions following the same pattern as described above. Total production and sales activities are summed over all regions. The model can be run as an LP by simply assigning zero to the risk aversion coefficient ($\Phi = 0$).

Resource and Technology Matrix

The greatest problem is lack of information. Attempts were made to include as much information as possible. Due to the data limitation, certain assumptions about technology and resource constraints were made.

Land is defined as the 1987 total cropland planted to the major crops in each state on a per farm basis. Land committed to produce hay in all the states and vegetables and fruits in some states are not subtracted since no specific information on land utilization is available.

Following the land constraint is the technology matrix. Technology here refers to technical inputs used in the crops productions, such as equipment, labor, capital, etc. The technology matrix should contain information which reflect the real world situations as closely as possible. However, in constructing the model, neither were the data on the number, size, and age of crop production equipments nor the data on labor input and field days available. Therefore, restrictions on machine field hours, labor field hours were ignored. The only technical restriction placed in the model is the capital. Availability of capital for crop production was based on 1987 farm production expenses excluding expenses on livestock and poultry productions. Average variable cost (1981-1989) of producing each crop was entered into the model and assumed to vary with yield. Fixed costs were subtracted from the total costs, and they do not enter into the decision of what to plant.

The Yield Matrix

The crop yield matrix is needed to transfer the production activities to sales activities. The crops' yields entered into the model are the average for the time period of 1981-1989. It can be argued that farmers make production plans based on the expected yields of the planted crops. We assume that

$$Y_t \sim [\overline{Y}, \sigma^2] \qquad (6.3)$$

where Y_t is the yield of a crop at time t, and $\overline{Y}$ is the sample mean. Thus the expected value of Y_t is given by

$$E[Y_t] = \overline{Y} \qquad (6.4)$$

Trend in crops' yields may alter farmers' expectations. Trend in crops' yields was tested by linear regression analysis where the time trend variable (1981=1) was regressed against the observed crop yields for the time period of 1981-1989. If the null hypothesis (i.e., the coefficient associated with the trend variable, say H_0: $\alpha=0$) can not be rejected, the sample average is used as the expected yield. Otherwise, the expected yield for a particular crop is the average of adjusted yields, i.e., the yield at time $t+1$ is an extrapolation of the yield at time t. The null hypothesis can not rejected in all cases at the 10 percent significance level.

The Variance-Covariance Matrix

Variance-covariance is essential in risk programming analysis. Heady (1952) points out that covariance relationships (particularly when negative) are fundamental for effective diversification among farm enterprises as a means of hedging against uncertainty. Specifically, the variance-covariance matrix was calculated from the crop gross margins per acre for the time period of 1981-1989.

The gross margins are the product of prices and yields less fixed costs. When computing the variance-covariance of the gross margins, special attention was paid to the yield variability resulting from trend. Chen (1971) argues that farmers may anticipate yield variability resulting from trend. Thus if a trend is obvious in a series of historical gross margins, the historical gross margins must be adjusted for trend in determining their sample variance. Since no evidence of significant trend was found in the sample yield series of the crops (from the linear regression analysis) included in the model, the standard formula (i.e., equation (6.1)) was used to compute the variance-covariance of the crop gross margins.

The variance-covariance matrices for the 11 states are lined up in block diagonal form in the aggregate regional model. Model REGION01 contains three variance-covariance matrices, and models REGION02 and REGION03 each contains four variance-covariance matrices, respectively (see Appendix A).

Additional Constraints

The aggregate regional model as well as the national model can be run as an LP with or without risk. However, due to the nature of the data used in the model, aggregation bias may be present which may result in solutions too far away from reality. In some cases, we may have to impose additional constraints so that the aggregation bias can be minimized. This can be easily done by the addition of constraining equations into the model. For instance, it may become necessary to limit the acreage planted to certain crops in some states or to force the production of other crops into the solution depending upon the relative importance of the crop in the state agricultural economy.

The Problem of Aggregation Bias

Aggregation or generalization of individual economic units in a set will incur some bias because the individual economic units in the set may not be homogeneous. For instance, if the individual economic units in a set respond differently to changes of economic stimuli, the estimates of aggregate output for the whole set will be biased.

Aggregation bias may be a severe problem in mathematical programming models. Aggregation problems may exist in the objective function, the technology and resource constraint matrices or both.

If the objective function of the mathematical programming model is defined to optimize the gross returns of production activities, differences in price expectations among individual producers can cause biased aggregate output. Pope (1981) defines the bias associated with a strictly concave supply function to be negative. However, methods for estimating the magnitude of such bias are not readily available. Aggregation bias associated with differences in price expectations can be minimized if we assume that producers' price expectations are the same for all producers in a region. This assumption can be justified by the rational expectations hypothesis (see Muth, 1961).

The aggregation problems associated with technology and resource constraint matrices have been studied widely in practical works. Perfect aggregation conditions for linear programming models have been developed by Day (1963); Miller (1966); and Oguchi and Guccione (1977). Perfect aggregation conditions for quadratic programming models are also available for empirical research (Oguchi and Guccione, 1979; and Paris, 1980). Perfect aggregation conditions in mathematical programming models may be defined as conditions which are sufficient to aggregate individual farms so that a representative farm may be used to estimate the aggregate behavior of all the farms without bias. In other words, a set of activities appearing in the optimal solution of the aggregate model also appears in the optimal solutions of the individual models and are actually the summation over all the optimal solutions of the individual models.

This study adopts the method developed by Oguchi and Guccione (1977) for perfect aggregation conditions of quadratic programming models. Specifically, the following conditions are assumed:

$$\Omega^* = \sum_{i=1}^{n} \mu_i \Omega_i, \quad A^* = \sum_{i=1}^{n} \lambda_i A_i, \quad \text{and} \quad b^* = \sum_{i=1}^{n} b_i \qquad (6.5)$$

where Ω_i is the known variance-covariance matrix, A_i and b_i are the technology and resource constraints matrices for the

ith firm. Ω^*, A^*, and b^* are the aggregation notations. λ_i and μ_i are the arbitrary weights which must satisfy that

$$\mu_i, \lambda_i \geq 0, \quad \sum_{i=1}^{n} \mu_i = \sum_{i=1}^{n} \lambda_i = 1 \qquad (6.6)$$

The perfect aggregation conditions for the above system require that all the technology matrix are equal across individual firms. In other words, if $A_i = A$, $b_i = b$ $(i=1, \ldots, n)$, then $A^* = A$ and $b^* = nb$.

Summary

This chapter discussed the structure of the model and the data collection procedure. A method of detrending kenaf yield was proposed and the results were used in the model. The problem of aggregation bias was discussed, appropriate conditions were assumed in order to minimize the aggregation bias.

CHAPTER VII

RESULTS AND DISCUSSIONS

Introduction

This chapter presents the results of the aggregate QP model. First, the approach taken to calibrate the model is discussed followed by the discussions of the problem of selecting values for the risk aversion coefficient. The results of the models are presented and analyzed in the last section.

Model Calibration

Economic models are constructed based on the information and data collected from the real world. Solutions obtained from these models should be the true reflection of actuality. Therefore, we must first validate the model solutions before they can be further used to analyze the relevant economic problems. Recall that the 1987 planted acres and production costs of the major cash crops were used to form the resource constraints vectors. The 1987 planted acreage and production levels of the major cash crops in the production regions were used as the basis to make the necessary adjustments of the model solutions.

Since the enterprise budgets used in the model have been aggregated over space and time, the aggregation bias may cause the results to be unrealistic. For instance, the aggregation bias across the production regions may cause very few crops to come into the optimal solutions in which the planted acreage and production levels of these crops may exceed well beyond the actual physical limitations in some regions.

Aggregation across regions obviously has ignored regional variations in terms of environmental conditions. Crops are believed to be grown in the areas where the environmental conditions are most suitable. However, it is impractical to include all the environmental conditions in constraint vectors in the programming model. The enterprise budgets serve to represent the whole region although they are actually only representative of a small part of it.

Likewise, time periods were also aggregated. Special production practices might be adopted within a time interval due to some unpredictable factors, which may contribute to the variations of planted acreage.

The right hand side values used for the land constraint in the model are the actual planted acreages of major crops in each state included in the study in 1987. These values represent the actual cropping patterns and the relative importance of each of the crops in the study areas. Thus, the solutions would be considered satisfactory if they are close to the 1987 base period actual planted acreage. Additional restrictions were introduced into the model to calibrate the unrealistic results. Lower or upper bounds were imposed allowing 15 percent margin from the 1987 planted acreages of the major crops in the study areas. These restrictions are listed in table 7.1.

Corn accounted for more than 10 percent of total planted crop acreage in every state in the Atlantic South region and some states in the Southeast region. Corn production was forced into the solution for North Carolina, South Carolina, Alabama and Texas.

Lower bounds were placed for wheat production in the southern plains (i.e., Oklahoma and Texas). Winter wheat accounted for more than 55 percent and 20 percent of all planted acreages in Oklahoma and Texas, respectively.

Peanuts production was restricted for all the peanuts producing states: North Carolina, Alabama, Georgia and Oklahoma. Soybeans production was restricted for Virginia and Georgia. Production limits were also imposed on sugarcane in Florida and Louisiana.

In the initial run of the model, rice was not selected into the solutions for the rice producing states (Arkansas, Louisiana, Mississippi, and Texas). Because rice may be regarded as a special crop in these states, production was forced into the solutions for Arkansas, Louisiana, and Mississippi.

The Risk Aversion Coefficient

In quadratic risk programming models, the risk aversion

TABLE 7.1

ADDITIONAL CONSTRAINTS PLACED ON THE MODEL

State	Crop	Restriction	Planted Acreage
			1,000 acres
Alabama	Corn	Lower	256
N. Carolina	Corn	Lower	770
S. Carolina	Corn	Lower	223
Texas	Corn	Lower	1,177
Louisiana	Cotton	Lower	512
Oklahoma	Cotton	Upper	502
Texas	Cotton	Lower	3,974
Georgia	Peanuts	Upper	716
N. Carolina	Peanuts	Upper	165
Virginia	Peanuts	Upper	104
Arkansas	Rice	Lower	851
Louisiana	Rice	Lower	349
Mississippi	Rice	Lower	179
Florida	Sugarcane	Upper	441
Louisiana	Sugarcane	Upper	303
Arkansas	Wheat	Lower	526
Georgia	Wheat	Lower	452
Oklahoma	Wheat	Lower	6,136
Texas	Wheat	Lower	5,813

coefficient, also known as the Pratt-Arrow absolute risk aversion coefficient, is the direct representation of risk-averse behavior at the farm level. The values of risk aversion coefficient reflect farmer's risk attitude toward each crop or livestock activity in his farm enterprises. Thus, incorporating different values of risk aversion into the model's solution provides direct information about the effects of different degrees of risk aversion on aggregate supply of major crops in the study areas.

In the literature, numerous methods have been proposed to elicit or estimate the risk aversion coefficients. However, estimation of risk aversion coefficients (Φ, in this case) is always difficult without empirical data. Because the values of risk aversion coefficient reveal whether the decision marker is either almost risk neutral, strongly risk averse, or risk preference, subjective data are essential to draw meaningful implications on the decision maker's risk attitude. Raskin and Cochran (1986) surveyed numerous empirical studies and concluded that upper bounds on almost risk-neutral preferences range from .000001 to .005. They found that most risk aversion coefficients are assumed based either on certainty equivalents or on secondary data from other studies. Wiens (1976) proposed a method using the Kuhn-Tucker condition[1] for approximating

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[1] The Kuhn-Tucker condition in this study is equation (5.14) where we can define $\mu = \hat{p}^T M - c^T$.

the risk aversion coefficient with

$$\Phi^* \approx (\mu_i - A_j^T\theta)/\Omega_i x^*, \quad for\ i=j. \tag{7.1}$$

where Φ^* is the approximation of the true risk aversion coefficient Φ; μ_i is the *i*th crop net return; A_j is the *j*th column of the technology matrix; θ is the vector of approximated lagrangian multipliers; x^* is the vector of actual levels of activities realized on the farm; and Ω_i is the *i*th row of the variance-covariance matrix. Paris (1979), based on Wiens' study, suggested the following formula to approximate the risk aversion coefficient

$$\Phi^* = -\tau(x^{*T}\Omega x^*)^{-1/2} \tag{7.2}$$

where τ is the value of the standardized random variable corresponding to a specified probability β that total revenue will at least cover total costs. Both Wiens' and Paris' methods require specific information about cropping patterns on a farm or in a region. Obviously, they are not applicable in this study since kenaf acreage was not known. Hazell (1982) suggested to use search procedure through postoptimality techniques, i.e., the selection of values of Φ is based on the model solutions which best describe the base-year cropping patterns in the study areas. This method was adopted to derive the supply response of kenaf in this study. The ranges of the values were chosen to be confined to the values in those studies surveyed by Raskin and Cochran (1986).

Solutions and Analyses

The optimal solutions for the aggregate QP model were obtained for different risk aversion values. The model was also solved assuming risk neutrality which is equivalent to LP solution. Kenaf products supplied to the different markets (i.e., kenaf pulp, poultry litter, and forage) were handled by solving the model under different levels of price and production expenses. The cropping patterns in each state were obtained from the optimal solutions, and the regional cropping patterns are the summation over the states in that region.

Kenaf for Pulp

Kenaf supplying pulp was assumed to sell at $49.91 per dry ton (1982 dollars) or $55.00 per dry ton (current dollars). This price level is commonly assumed on the compatible product currently consumed in the pulp industry. Because the optimal solution is obtained on a per farm basis, the aggregate acreage for each crop in a state was computed by summing over all the available crop producing farms in that state. Kenaf supplying pulp is a very bulky product, and transportation cost may be the most constraining factor for producing kenaf in a wide area. Kenaf is more likely going to enjoy access only to local markets. Production areas which are too far (i.e., 50 miles or further) from the local markets (where newsprint or paper mills are located) should not be considered as feasible areas. Therefore, only those counties where newsprint or paper mills are located were used to compute potential kenaf acreages in each state. There are currently 88 mills in the study areas with 16 mills in the Atlantic South region, 27 mills in the South Central region, and 45 mills in the Southeast region (tables 7.2-7.4).

The cropping patterns for all three regions for the different risk aversion values are reported in table 7.5. State cropping patterns for the different risk aversion values are reported in Appendix B (tables B1-B11). Kenaf produced to supply pulp was selected as a feasible crop in most of the states at all the risk aversion levels. When risk neutrality is assumed (LP solution), kenaf was selected as a farm enterprise in only a few states: Florida, Louisiana, Oklahoma, and Texas. Potential acreage for kenaf production in all three regions ranges from 294,000 acres to 738,000 acres depending on farmers' risk attitudes (table 7.6). When the risk aversion coefficient is assumed at 0.0015, 171,000, 374,000 and 193,000 acres of crop land could be planted to kenaf in the Atlantic South, the South Central, and the Southeast regions, respectively. The potential acres committed to kenaf in each state would ensure consistent supply of kenaf fiber source to the local newsprint or paper mills. For example, 22 percent of the processing capacities in the paper mills could be supplied with the fiber source from kenaf in Mississippi. Table 7.7 shows the percentage of fiber demand in the local newsprint

TABLE 7.2

EXISTING PULP AND PAPER MILLS, AND THEIR ESTIMATED POTENTIAL PROCESSING CAPACITY FOR KENAF PULP, ATLANTIC SOUTH REGION, 1986

Company	County	Product	Process	Capacity
				tons/year
North Carolina: 5 Mills				
Champion Int'l	Halifax	Paperboard	Kraft	781,000
Ecusta Corp.	Transylvania	Cigarette	Flax	177,500
Federal Paper	Columbus	Bl. Paperboard	Kraft	1,420,000
Weyerhaeuser Co.	Craven	Mkt. Pulp	Kraft	497,000
Weyerhaeuser Co.	Martin	Container	Kraft,SC	1,207,000
subtotal				4,082,500
South Carolina: 6 Mills				
Bowater Carolin	York	Print Paper	Kraft,TMP	808,880
Int'l Paper	Georgetown	Paperboard	Kraft,SC	1,212,680
Sonoco Products	Darlington	Paperboard	SC	198,800
Stone Container	Florence	Lineboard	Kraft	994,000
Union Camp	Richland	Fine Paper	Kraft	497,000
Westvaco Crop.	Charleston	Lineboard	Kraft	1,728,850
subtotal				5,440,210
Virginia: 5 Mills				
Bear Island	Hanover	Newsprint	TMP	230,750
Chespaeake Corp.	King William	Paperboard	Kraft	994,000
Georgia-Pacific	Greenville	Insulation	TMP	96,915
Sone Container	Prince George	Paper Board	Kraft	710,000
Union Camp	Isle Weight	Fine Paper	Kraft	1,384,500
Subtotal				3,416,165
Total				10,907,210

TABLE 7.3

EXISTING PULP AND PAPER MILLS, AND THEIR ESTIMATED POTENTIAL PROCESSING CAPACITY FOR KENAF PULP, SOUTH CENTRAL REGION, 1986

Company	County	Product	Process	Capacity
				tons/year
Arkansas: 7 Mills				
Arkansas Kraft	Conway	Lineboard	Kraft	568,000
Georgia-Pacific	Ashley	Bl. Paperboard	Kraft	1,065,000
Int'l Paper	Jefferson	Bl. Paperboard	Kraft	847,030
Int'l Paper	Ouachita	Kraft Papers	Kraft	568,710
Mid-America Pack	Jefferson	Kraft Bags	Kraft	213,000
Nekoosa Papers	Little River	Bond Papers	Kraft	994,000
Potlatch Corp.	Desha	Bl. Paperboard	Kraft	372,750
Subtotal				4,628,490
Louisiana: 12 Mills				
Boise Cascade	Beauregard	News, Liner	TMP, Kraft	1,096,800
Celotex Corp.	Jefferson	Insulation Bd	Bagasse	142,000
Crown Zellerbag	W Feliciana	Creping Paper	Kraft	351,450
Crown Zellerbag	Washington	Kraft Bag	Kraft,SC	1,157,300
Georgia-Pacific	E Baton Rouge	Mkt. Pulp	Kraft	912,350
Int'l Paper	Morehouse	Bl. Paperboard	Kraft	852,000
Int'l Paper	Rapides	Container	Kraft	699,350
Int'l Paper	Morehouse	Container Bd	SC	349,320
Int'l Paper	De Soto	Container	Kraft	1,455,500
Manville Forest	Ouachita	Kraft Paper	Kraft	1,185,700
Stone Container	Jackson	Lineboard	Kraft,SC	1,207,000
Willanette Ind.	Natchitoch	Lineboard	Fraft	568,000
Subtotal				9,976,770
Oklahoma: 1 Mill				
Weyerhaeuser Co.	McCurtain	Lineboard	Kraft,SC	1,420,000
Subtotal				1,420,000
Texas: 7 Mills				
Champion Int'l	Angelina	Newsprint	Kraft	284,000
Champion Int'l	Harris	Fine Papers	Kraft	603,500
Champion Int'l	Harris	Newsprint	Kraft,TMP	646,100
Int'l Paper	Bowie	Paperboard	Kraft	986,900
Temple-Eastex	Angelina	Fiberboard	RMP	461,500
Temple-Eastex	Jasper	Paperboard	Kraft	1,100,500
Temple-Eastex	Orange	Lineboard	Kraft	852,000
Subtotal				80,173,760
Total				96,199,020

TABLE 7.4

EXISTING PULP AND PAPER MILLS, AND THEIR ESTIMATED POTENTIAL PROCESSING CAPACITY FOR KENAF PULP, SOUTHEAST REGION, 1986

Company	County	Product	Process	Capacity
				tons/year
Alabama: 14 Mills				
Alabama Kraft	Russell	Lineboard	Kraft	781,000
Alabama River	Monroe	Mkt. Pulp	Kraft	710,000
Allied Paper	Clarke	Bond Papers	Kraft	255,600
Champion Int'l	Lawrance	Kraft Papers	Kraft	987,610
Container Corp.	Escambia	Lineboard	Kraft	947,140
Gulf States	Marengo	Kraft Board	Kraft	355,000
Hammermill	Dallas	Mkt. Pulp	Kraft	788,100
Int'l Paper	Mobile	Kraft Papers	Kraft	770,350
James River	Choctaw	Paperboard	Kraft	710,000
Kimberly-Clark	Talladega	Newsprint	Kraft,TMP	654,265
Macmillan Bloe.	Wilcox	Lineboard	Kraft,SC	1,207,000
Mead Crop.	Jackson	Corrugated	SC	461,500
Scott Paper	Mobile	Kraft Papers	Kraft	1,029,500
Union Camp	Augusta	Lineboard	Kraft	1,455,500
Subtotal				11,112,565
Florida: 9 Mills				
Alton Packaging	Duval	Lineboard	Kraft	539,600
Buckeye Cellul.	Taylor	Mkt. Pulp	Kraft	710,000
Champion Int'l	Escambia	Kraft Board	Kraft	1,107,600
Container Corp.	Nassau	Lineboard	Kraft,SC	1,207,000
Georgia-Pacific	Putnam	Kraft Papers	Kraft	770,350
ITT Rayonier	Nassau	Mkt. Pulp	Sulfite	319,500
Jacksonvill Kraft	Duval	Lineboard	Kraft	994,000
SW Forest Ind.	Bay	Kraft Board	Kraft	1,029,500
St. Joe Paper Co.	Gulf	Lineboard	Kraft	1,207,000
Subtotal				7,884,550

TABLE 7.4

CONTINUED

Company	County	Product	Process	Capacity
				tons/year
Georgia: 15 Mills				
Augusta Newsprint	Richmond	Newsprint	TMP	355,355
Buckeye Cellul.	Macon	Bl. Kraft	Kraft	610,600
Federal Paperboard	Richmond	TMP Pulp	TMP idle	184,600
Federal Paperboard	Richmond	Bl. Paperboard	Kraft	426,000
Georgia Kraft	Floyd	Lineboard	Kraft	1,420,000
Georgia Kraft	Bibb	Lineboard	Kraft	674,500
Gilman Paper Co.	Camden	Kraft Bag, ETC	Kraft	852,000
Great Southern	Early	Lineboard	Kraft,SC	1,611,700
ITT Rayonier	Wayne	Mkt. Pulp	Kraft	497,000
Int. State Paper	Liberty	Lineboard	Kraft	390,500
Mead/Scott	Glynn	Bl. Paperboard	Kraft	1,249,600
Owens-Illinois	Lowndes	Lineboard	Kraft	708,580
Southeast Paper	Laurens	Newsprint	TMP	44,304
Stone Container	Chatnam	Lineboard	Kraft	568,000
Union Camp	Chatnam	Kraft Bag, ETC	Kraft	2,023,500
Subtotal				11,616,239
Mississippi: 7 Mills				
Goergia-Pacific	Lawerence	Paperboard	Kraft	1,388,050
Great N Nekoosa	Perry	Mkt. Pulp	Kraft	710,000
Int'l Paper	Adams	Kraft Pulp	Kraft	783,840
Int'l Paper	Warren	Kraft Board	Kraft	838,510
Int'l Paper	Jackson	Bl. Paperboard	Kraft	532,500
Owens-Corning	Lauderdale	Insulation Bd	RM	23,075
Weyerhaeuser Co.	Lowndes	LWT Coated	TMP	119,990
Subtotal				4,395,965
Total				35,009,319

TABLE 7.5

REGIONAL CROPPING PATTERNS SOLVED FROM THE QP MODEL FOR DIFFERENT RISK AVERSION VALUES, NEWSPRINT MARKET

	Values of Risk Aversion Coefficients (.001)											
Crop	0	0.20	0.50	0.72	0.94	1.20	1.50	1.74	1.85	1.96	3.00	1987 base year values
	1,000 acres											
Corn	2,991	2,991	2,991	2,991	2,991	2,991	2,991	2,991	2,991	2,991	2,991	4,890
Cotton	6,090	6,290	6,299	6,301	6,302	6,279	6,255	6,243	6,238	6,234	6,210	8,101
Peanuts	1,349	1,349	1,349	1,349	1,349	1,349	1,349	1,349	1,349	1,349	1,349	1,197
Rice	1,379	1,379	1,379	1,379	1,379	1,379	1,379	1,379	1,379	1,379	1,379	1,915
Sorghum	4,904	2,796	2,796	2,796	2,796	2,796	2,796	2,942	3,133	3,303	4,000	4,020
Soybeans	9,699	10,152	10,384	10,024	10,356	10,477	10,402	10,098	9,896	9,718	8,655	12,458
Sugarcane	743	743	743	743	743	743	743	743	743	743	743	665
Wheat	17,581	16,225	15,457	15,009	14,447	14,019	13,531	13,457	13,447	13,437	13,154	17,125
Kenaf	5,714	8,525	8,455	9,858	10,087	10,417	11,004	11,248	11,274	11,296	11,969	na[a]

[a] not available.

TABLE 7.6

ESTIMATED REGIONAL POTENTIAL ACREAGE OF KENAF FOR DIFFERENT RISK AVERSION VALUES, NEWSPRINT MARKET

Risk Aversion	Potential Acreage of Kenaf
	1,000 acres
0	294
0.00020	464
0.00050	597
0.00072	647
0.00094	663
0.00120	696
0.00150	738
0.00174	666
0.00185	636
0.00196	608
0.00300	505

TABLE 7.7

PERCENTAGE OF FIBER DEMAND IN THE LOCAL PAPER MILLS SUPPLIED WITH KENAF FIBER FOR DIFFERENT RISK AVERSION VALUES

	Values of Risk Aversion Coefficients (.001)										
State	0	0.20	0.50	0.72	0.94	1.20	1.50	1.74	1.85	1.96	3.00
	percent										
Atlantic South:											
N. Carolina	0	0	7	10	10	10	10	10	11	11	11
S. Carolina	0	3	10	12	12	13	13	14	14	14	14
Virginia	0	0	0	0	0	0	1	2	2	2	3
South Central:											
Arkansas	0	20	20	20	20	20	20	20	20	20	20
Louisiana	15	15	15	15	15	15	16	10	7	5	0
Oklahoma	19	19	0	0	0	0	0	0	0	0	0
Texas	9	9	9	9	9	9	9	9	9	9	9
Southeast:											
Alabama	0	0	0	0	0	1	3	3	3	4	5
Florida	1	1	1	1	1	1	1	1	1	1	1
Georgia	0	2	2	2	2	2	2	2	2	2	2
Mississippi	0	0	14	18	19	21	22	21	20	19	5

or paper mills that could be met with kenaf fiber locally at different risk aversion values in each state.

The aggregate supply of kenaf is significantly affected by farmers' risk attitudes. The results suggest that kenaf may be a low risk crop as the acreage expands when farmers become more risk averse. A high- (low-) risk crop can be defined as one in which acreage decreases (increases) as the level of risk aversion increases. Whereas a risk-neutral crop is unaffected by the risk aversion coefficient. Although the aggregate supply of kenaf at the regional level suggests that kenaf is a low risk crop, state cropping patterns suggest that kenaf may be a high risk crop in some states. The difference lies in the variations of the variance of net returns of kenaf across the states. A low- (high-) risk crop is always associated with small (large) variance of net returns. For example, kenaf was not selected as a feasible crop when the risk aversion coefficient was greater than 0.0002 in Oklahoma.

Aggregate kenaf supply response function, i.e., price and quantity relationship, was generated with the model. Both risk neutral and risk averse cases were considered. The risk aversion coefficient was set at 0.0005 although different risk aversion coefficients could be used. This value was chosen because it corresponds to the solution which best describes the base year crop acreages in the study areas. A kenaf supply response function was generated assuming the demand for kenaf shifts upwards resulting in 50 percent increase in price at 10 percent interval. The supply curve was traced along the equilibrium prices and quantities solved with the model. Figure 7.1 shows different response functions depending on whether the producer is risk neutral or risk averse. Under the risk averse assumption, the supply curve shifts right resulting in larger quantity supplied than under the risk neutral assumption. This is because risk averse farmers would diversify farm enterprises with low risk crops even though their expected returns are slightly lower than some of the crops associated with higher expected returns, but larger variances. Under the risk neutral assumption, a farmer's objective is to maximize the net returns of the crops regardless the variances of net returns of these crops. Crops associated with high net returns are preferred by the risk neutral farmers. A comparison of the two supply curves in figure 7.1 illustrates that the risk neutral producer increases production (expands acreage) at a faster rate than the risk averse producer when the crop's price increases. Unlike the risk neutral producer, whose objective is to maximize net returns, the risk averse producer not only considers the maximization of the expected returns but also the minimization of the variances of returns associated with the crops.

Kenaf supply elasticities were calculated at the mid-points corresponding to the changing prices and quantities (table 7.8). The results suggest that the kenaf supply is

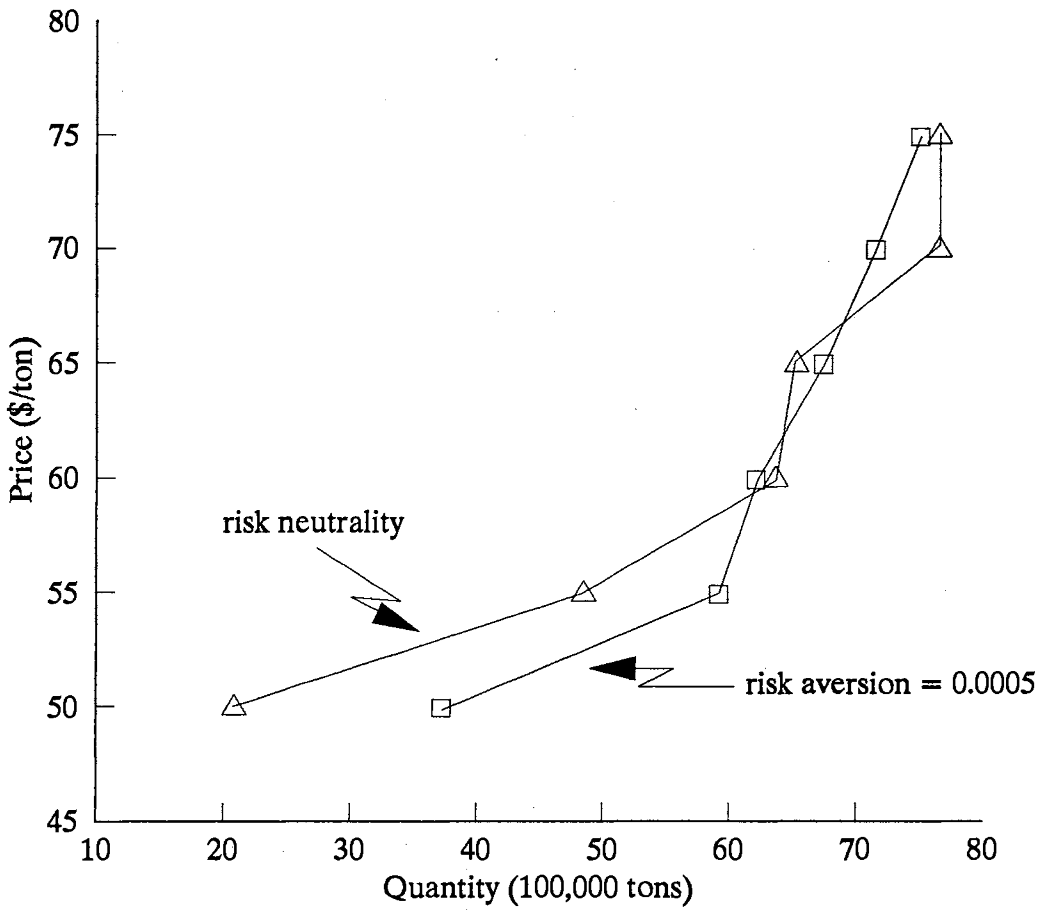

Figure 7.1. Supply Response for Kenaf Under Risk Neutral and Risk Averse Assumptions, Newsprint Market

TABLE 7.8

SUPPLY RESPONSE AND ELASTICITY OF KENAF FOR RISK NEUTRAL AND RISK AVERSE PRODUCERS, NEWSPRINT MARKET

	Risk Neutrality		Risk Aversion	
Price	Quantity	Elasticity	Quantity	Elasticity
$/ton	*mil.tons*		*mil.tons*	
49.91	2.09		3.73	
54.90	4.85	13.23	5.92	5.87
59.89	6.36	3.12	6.21	0.49
64.88	6.53	0.26	6.74	0.85
69.87	7.65	1.72	7.15	0.61
74.87	7.65	0	7.50	0.49

elastic at the initial price change for both risk neutral and risk averse farmers implying both groups of farmers would increase production (expand acreage) more than proportionally to the price increase. Risk averse farmers would increase production less than proportionally to the price increase when the price is above $59.89 (1982 dollars) or $66.00 (current dollars) per dry ton. Kenaf supply becomes extremely inelastic at and above the price of about $75.00 (1982 dollars) or $82.50 (current dollars) per dry ton under the risk neutral assumption.

The acreage distribution for kenaf in the study areas identified by the model provides an explanation to the differences in slopes and elasticities of the supply response functions under risk neutral and risk averse assumptions. When risk neutrality is assumed (table 7.9), at the base price of $49.91 per dry ton, kenaf was selected into the farm enterprises in Florida, Louisiana, Oklahoma, and Texas. As the price increases to $54.90 per dry ton (10 percent higher than the base price level), production is expanded to South Carolina, Alabama, Georgia, and Arkansas resulting in substantial increase in production at the aggregate regional level. When the price reaches as high as $75.00 per dry ton (50 percent higher than the base price level), no further expansion of production could be made due to the resource constraints and bounds imposed upon other crops.

The model identifies a slightly different acreage

TABLE 7.9

KENAF ACREAGE RESPONSE AT DIFFERENT PRICE LEVELS, RISK NEUTRALITY, NEWSPRINT MARKET

	State[a]										
Price	NC	SC	VA	AL	FL	GA	MS	AR	LA	OK	TX
$/ton	*1,000 acres*										
49.91	0.00	0.00	0.00	0.00	10.54	0.00	0.00	0.00	190.58	39.48	54.00
54.90	0.00	185.64	0.00	182.98	10.54	27.43	0.00	117.94	190.58	39.48	54.00
59.89	130.00	185.64	0.00	182.98	10.54	27.43	149.34	117.94	190.58	39.48	54.00
64.88	130.00	185.64	38.87	182.98	10.54	27.43	149.34	117.94	190.58	41.61	54.00
69.87	130.00	185.64	38.87	182.98	36.41	27.43	149.34	117.94	321.07	41.61	54.00
74.87	130.00	185.64	38.87	182.98	36.41	27.43	149.34	117.94	321.07	41.61	54.00

[a] NC, North Carolina; SC, South Carolina; VA, Virginia; AL, Alabama; FL, Florida; GA, Georgia; MS, Mississippi; AR, Arkansas; LA, Louisiana; OK, Oklahoma; TX, Texas.

distribution in the study areas under the risk averse assumption (table 7.10). The empirical results of this study have shown that kenaf is a low risk crop at the aggregate level. Thus, at the base price of $49.91 per dry ton, the crop was selected into the farm enterprises in most of the states except Alabama, Oklahoma, and Virginia. When the price is increased to $54.90 per dry ton (10 percent higher than the base price level), kenaf acreage is expanded into Alabama with about 183,000 acres. As the price increases to $58.89 per dry ton, 22,000 acres of kenaf would be grown in Virginia. We have previously noticed that kenaf may be a high risk crop in Oklahoma, the kenaf acreage distribution also reveals this characteristic. Risk averse farmers in Oklahoma will not be willing to consider planting the crop until the price reaches $64.88 per dry ton (30 percent higher than the base price level). As the price exceeds $64.88 per dry ton, kenaf production is fully expanded to all the 11 states included in the study. The analysis presented above assumed per acre yield for kenaf held constant. If the per acre yield for kenaf could be increased with the same amount of input but improved variety, the potential kenaf acreage equivalent to that when price increases could also be reached in the study areas. For example, risk averse farmers in Oklahoma would consider planting kenaf if the yield is at or above 8 tons per acre.

One important factor that must be noted here is that the kenaf supply response was generated assuming all other

TABLE 7.10

KENAF ACREAGE RESPONSE AT DIFFERENT PRICE LEVELS, RISK AVERSION = 0.0005, NEWSPRINT MARKET

	State[a]										
Price	NC	SC	VA	AL	FL	GA	MS	AR	LA	OK	TX
$/ton	*1,000 acres*										
49.91	39.52	79.24	0.00	0.00	10.54	27.43	77.92	117.94	190.58	0.00	54.00
54.90	106.47	185.64	0.00	182.98	10.54	27.43	133.78	117.94	190.58	0.00	54.00
59.89	130.00	185.64	22.13	182.98	10.54	27.43	149.34	117.94	190.58	0.00	54.00
64.88	130.00	185.64	38.87	182.98	10.54	27.43	149.34	117.94	221.17	39.48	54.00
69.87	130.00	185.64	38.87	182.98	36.41	27.43	149.34	117.94	253.74	39.48	54.00
74.87	130.00	185.64	38.87	182.98	36.41	27.43	149.34	117.94	301.98	39.48	54.00

[a] NC, North Carolina; SC, South Carolina; VA, Virginia; AL, Alabama; FL, Florida; GA, Georgia; MS, Mississippi; AR, Arkansas; LA, Louisiana; OK, Oklahoma; TX, Texas.

crops' prices constant. As the kenaf price increases, the crop becomes more profitable than other crops in a state where the resources committed to those crops flow into kenaf production. However, this situation is very rare in actuality. Thus, real impacts of price increase on production expansions may be slightly different from what the model predicted.

Competing Crops

The empirical results demonstrate that kenaf supplying pulp is very competitive with the existing cash crops in the study areas. As the newsprint and paper mills begin to use more and more kenaf fiber, stronger demand for kenaf fiber from the mills is likely expected in the future. Kenaf will replace those crops with low net returns and/or high variability in net returns. Crops which would likely be replaced by kenaf are corn and cotton in most of the states in the study areas. Although high variability in net returns is found with rice, only limited portion of rice land could be devoted to kenaf production due to the distinctive features of the crop. Once kenaf has well established its production bases and marketing channels, it would more likely compete with crops with high net returns and/or low variability in net returns for resources in the future. Based on the results of this study, major crops which are competitive with kenaf are peanuts and soybeans. Peanuts is identified by the model as a major competitor of kenaf in Georgia, North Carolina, and Virginia while soybeans competes with kenaf in every state in the study areas. Figure 7.2 shows how soybeans production (acreage) responds to increases in kenaf price at the regional level under risk neutral and risk averse assumptions, respectively. The relationship between kenaf acreage and soybeans price may bear some analogy to the relationship between soybeans acreage and kenaf price as depicted in figure 7.2.

Kenaf for Poultry Litter

Analysis of potential acreage of kenaf grown for the poultry litter market is carried out similarly to that for the newsprint market. The delivered price for kenaf core is assumed at $0.32 (1982 dollars) or $0.35 (current dollars) per cubic foot. This price level is based on the price of wood chips currently used as litter material for poultry nationwide. Kenaf core yield was set at 60 percent of the total yield expressed in terms of cubic feet per acre (1 cubic foot is equivalent to 5 pounds). The transportation costs for kenaf core used in the model were based on the estimates obtained by Masud et al., 1990 since the data for different states are not available.

Because kenaf core is very light, a 40 foot trailer with a capacity of about 40,000 pounds would carry only about 15,000 pounds or 3,000 cubic feet (Masud et al., 1990). Thus, long distance hauling would make kenaf

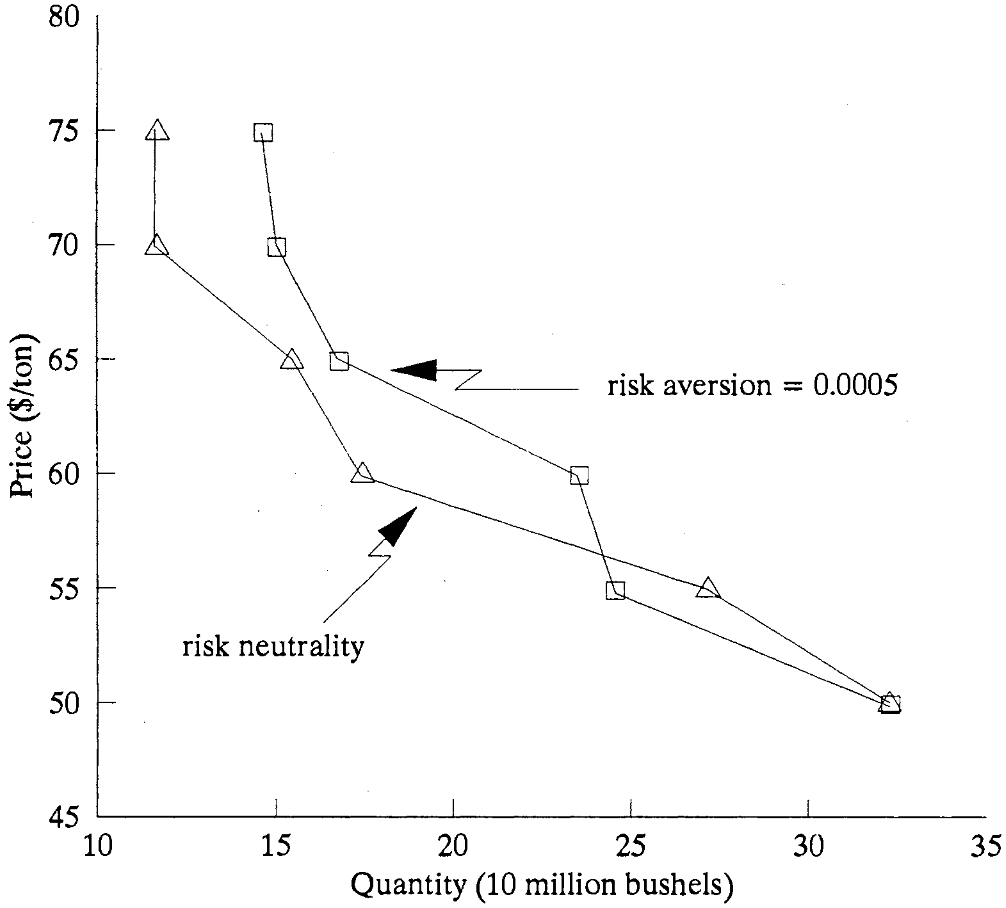

Figure 7.2. Supply Response of Soybeans to Kenaf Price Under Risk Neutral and Risk Averse Assumptions, Newsprint Market

commercially supply poultry litter non-profitable as transportation costs exceed returns. Musad et al. suggest that kenaf produced for poultry litter within 100 miles of poultry farms may keep transportation costs within a feasible range. Commercial production of kenaf poultry litter should be restricted to places where poultry litter is demanded locally. However, counties with few poultry farms should not be considered as potential production areas for commercial kenaf production supplying poultry litter. Obviously, economies of scale may make kenaf production non-competitive with the existing cash crops. Thus, only counties with 200 or more poultry farms are used to compute the aggregate acreage supply of kenaf core in each state in the study areas. There were 6 counties in North Carolina, one county in Virginia, 2 counties in Alabama, 3 counties in Georgia, 2 counties in Mississippi, 7 counties in Arkansas, and 7 counties in Texas where poultry farms were found to exceed 200 based on 1987 Census of Agriculture.

The cropping patterns generated by the model for all three regions at the different risk aversion values are reported in table 7.11. State cropping patterns for the different risk aversion values are reported in Appendix tables B12-B22. Regional cropping patterns of the major cash crops included in the model for kenaf supplying poultry litter are similar to that described in the solutions for kenaf supplying pulp. Kenaf produced to supply poultry litter was selected as a feasible crop in 5 of the 7 states

TABLE 7.11

REGIONAL CROPPING PATTERNS SOLVED FROM THE QP MODEL FOR DIFFERENT RISK AVERSION VALUES, POULTRY LITTER MARKET

	Values of Risk Aversion Coefficients (.001)											
Crop	0	0.20	0.50	0.72	0.94	1.20	1.50	1.74	1.85	1.96	3.00	1987 base year values
	1,000 acres											
Corn	2,991	2,991	2,991	2,991	2,991	2,991	2,991	2,991	2,991	2,991	2,991	4,890
Cotton	6,090	6,398	6,370	6,394	6,357	6,354	6,354	6,337	6,330	6,323	6,283	8,101
Peanuts	1,349	1,349	1,349	1,349	1,349	1,349	1,349	1,349	1,349	1,349	1,349	1,197
Rice	1,379	1,379	1,379	1,379	1,379	1,379	1,379	1,379	1,379	1,379	1,379	1,915
Sorghum	4,904	4,123	3,211	3,210	2,829	2,796	3,342	3,501	3,501	3,613	4,010	4,020
Soybeans	9,699	10,855	11,322	11,534	11,526	11,145	10,696	10,220	10,024	9,849	8,736	12,458
Sugarcane	743	743	743	743	743	743	743	743	743	743	743	665
Wheat	17,581	16,225	15,457	14,919	14,442	14,083	13,709	13,553	13,509	13,509	13,186	17,125
Kenaf	5,714	6,387	7,628	7,931	8,834	9,610	9,887	10,377	10,624	10,694	11,773	na[a]

[a] not available.

when the risk aversion coefficient is at or above 0.0005. However, only one state (Texas) entered the solution when risk neutrality is assumed (LP solution). The aggregate supply of kenaf for poultry litter is also significantly affected by farmers' risk attitudes (table 7.12). The results demonstrate that kenaf is a low risk crop as the acreage expands when farmers become more risk averse. Aggregate acreage for kenaf production increases from 141,000 acres to 708,000 acres as the risk aversion coefficient increases. When the risk aversion coefficient is assumed at 0.00174, 683,000 acres of crop land could be planted to kenaf in the three regions with kenaf as a feasible crop in every state. The potential acres committed to kenaf in each state would provide local poultry farms sufficient poultry litter materials at prices below wood chips. The amount of acreage devoted to kenaf for poultry litter at $\Phi = 0.003$ is sufficient to guarantee the poultry production centers in each of the states in the study areas an abundant supply of kenaf poultry litter (see table 7.13).

An aggregate supply response function for kenaf as a source of poultry litter was generated. Methods and assumptions are similar with that used in generating supply response function for kenaf supplying pulp. Figure 7.3 shows the supply response functions under risk neutral and risk averse assumptions, respectively. Figure 7.3 clearly resembles the features of the supply response functions depicted in figure 7.1. A comparison of the two supply

TABLE 7.12

ESTIMATED REGIONAL POTENTIAL ACREAGE OF KENAF FOR DIFFERENT RISK AVERSION VALUES, POULTRY LITTER MARKET

Risk Aversion	Potential Acreage of Kenaf
	1,000 acres
0	141
0.00020	275
0.00050	561
0.00072	594
0.00094	638
0.00120	652
0.00150	665
0.00174	683
0.00185	690
0.00196	696
0.00300	708

TABLE 7.13

PERCENTAGE OF LITTER DEMAND IN THE POULTRY FARMS SUPPLIED WITH KENAF CORE FOR DIFFERENT RISK AVERSION VALUES

	Values of Risk Aversion Coefficients (.001)										
State	0	0.20	0.50	0.72	0.94	1.20	1.50	1.74	1.85	1.96	3.00
	----------	----------	----------	----------	----------	*percent*	----------	----------	----------	----------	----------
Alabama	0	0	0	0	0	0	0	39	56	72	100
Arkansas	0	100	100	100	100	100	100	100	100	100	100
Georgia	0	0	44	72	89	89	89	89	89	89	89
Mississippi	0	0	100	100	100	100	100	100	100	100	100
N. Carolina	0	0	100	100	100	100	100	100	100	100	100
Texas	100	100	100	100	100	100	100	100	100	100	100
Virginia	0	0	0	0	0	0	99	100	100	100	100

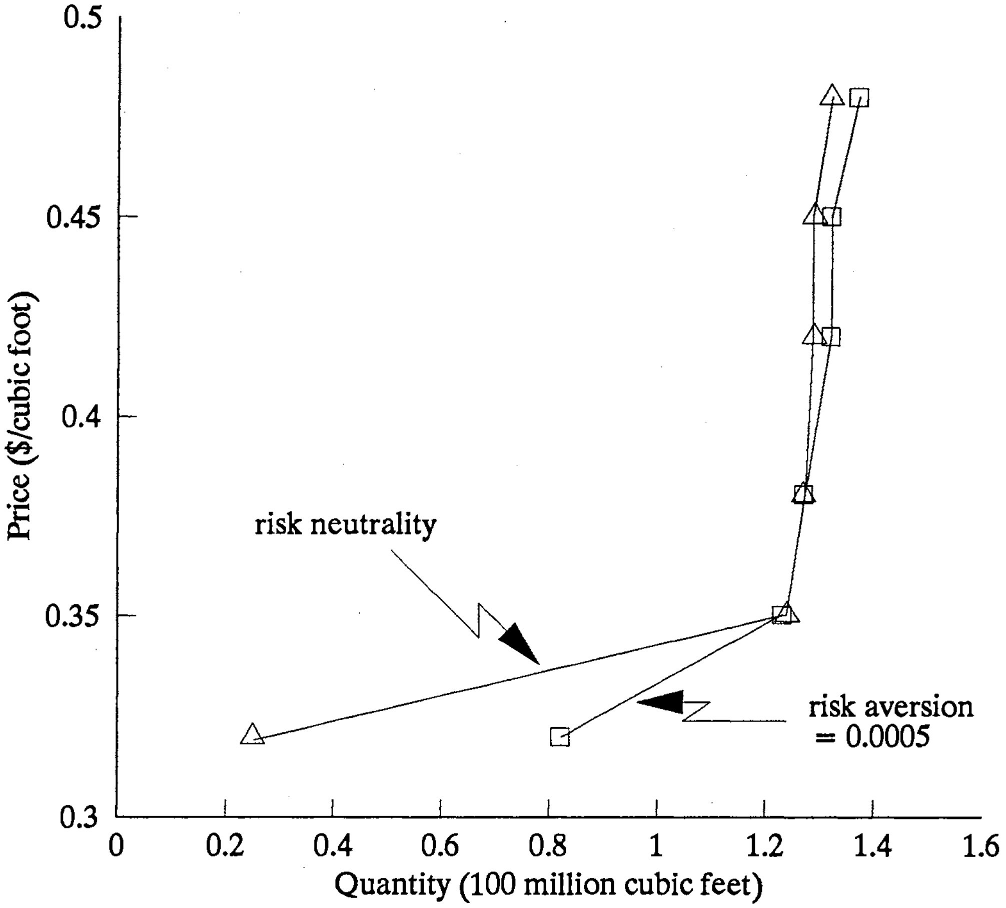

Figure 7.3. Supply Response for Kenaf Under Risk Neutral and Risk Averse Assumptions, Poultry Litter Market

curves in figure 7.3 shows that the model generates a flatter supply curve under the risk neutral assumption than that under the risk averse assumption when the price is increased by 10 percent from the base price of $0.32 per cubic foot. This substantial increase in production (expansion in acreage) may be a result of kenaf becoming more profitable relative to other crops at the new price level. Risk neutral farmers may replace a large amount of crop land with kenaf in order to maximize net returns.

Kenaf supply elasticities were calculated at the mid-points corresponding to the changing prices and quantities (table 7.14). The results suggest that the kenaf supply is extremely elastic at the initial price change for risk neutral farmers. Risk averse farmers would increase production (expand acreage) more than proportionally to the price increase by 10 percent from the base price level ($0.32 per cubic foot). Both groups of farmers would increase kenaf production less than proportionally to the price increase when the price is at and above $0.38 (1982 dollars) or $0.42 (current dollars) per cubic foot. The price increase from $0.42 (1982 dollars) to $0.45 per cubic foot would not induce any expansion in acreage of kenaf in the study areas.

A look at the acreage distribution for kenaf in the study areas (see tables 7.15-7.16) explains the differences in the supply response function's slope and elasticity changes under risk neutral and risk averse assumptions.

TABLE 7.14

SUPPLY RESPONSE AND ELASTICITY OF KENAF FOR RISK NEUTRAL AND RISK AVERSE PRODUCERS, POULTRY LITTER MARKET

	Risk Neutrality		Risk Aversion	
Price	Quantity	Elasticity	Quantity	Elasticity
$/cu.ft.	*mil. cu.ft.*		*mil. cu.ft.*	
0.32	247		821	
0.35	1,242	40.22	1,225	4.92
0.38	1,269	0.22	1,269	0.36
0.42	1,290	0.16	1,316	0.37
0.45	1,290	0	1,316	0
0.48	1,318	0.21	1,370	0.41

TABLE 7.15

KENAF ACREAGE RESPONSE AT DIFFERENT PRICE LEVELS, RISK NEUTRALITY, POULTRY LITTER MARKET

	State[a]							
Price	NC	SC	VA	AL	GA	MS	AR	TX
$/cu.ft.	*1,000 acres*							
0.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	144.32
0.35	283.77	40.21	0.00	91.33	16.02	42.12	328.79	144.32
0.38	283.77	40.21	28.95	91.33	16.02	42.12	328.79	144.32
0.42	283.77	40.21	50.86	91.33	16.02	42.12	328.79	144.32
0.45	283.77	40.21	50.86	91.33	16.02	42.12	328.79	144.32
0.48	283.77	41.49	50.86	112.51	16.02	42.12	328.79	144.32

[a] NC, North Carolina; SC, South Carolina; VA, Virginia; AL, Alabama; GA, Georgia; MS, Mississippi; AR, Arkansas; TX, Texas.

TABLE 7.16

KENAF ACREAGE RESPONSE AT DIFFERENT PRICE LEVELS, RISK AVERSION = 0.0005, POULTRY LITTER MARKET

	State[a]							
Price	NC	SC	VA	AL	GA	MS	AR	TX
$/cu.ft.	*1,000 acres*							
0.32	269.33	10.50	0.00	0.00	8.50	42.12	315.75	144.32
0.35	269.33	40.21	0.00	91.33	16.02	42.12	328.79	144.32
0.38	283.77	40.21	28.95	91.33	16.02	42.12	328.79	144.32
0.42	283.77	40.21	50.86	91.33	16.02	42.12	347.38	144.32
0.45	283.77	40.21	50.86	91.33	16.02	42.12	347.38	144.32
0.48	283.77	40.37	50.86	112.51	34.92	44.74	347.38	144.32

[a] NC, North Carolina; SC, South Carolina; VA, Virginia; AL, Alabama; GA, Georgia; MS, Mississippi; AR, Arkansas; TX, Texas.

When risk neutrality is assumed, at the base price of $0.32 per cubic foot, kenaf was not selected into the farm enterprises in all the states except Texas. As the price increases by 10 percent from the base price level, production is expanded to the other 7 states except Virginia, contributing to the substantial increase in production at the aggregate regional level, and causing a flat supply curve for this price range.

The acreage distribution for kenaf in the study areas identified by the model under the risk averse assumption is slightly different from that under the risk neutral assumption. Because kenaf has been identified as a low risk crop, risk averse farmers in most of the states (except Alabama and Virginia) choose kenaf as a feasible crop to diversify their farm enterprises when the price is even as low as $0.32 per cubic foot. As the price increased to $0.35 per cubic foot (10 percent higher than the base price level), kenaf acreage is expanded into Alabama with about 91,000 acres which results in only small increase in production at the aggregate level, i.e., the supply elasticity is much smaller than that under the risk neutral assumption. As the price continues to increase to $0.38 per cubic foot (20 percent higher than the base price level), kenaf production is expanded into every state with about 29,000 acres of kenaf grown in Virginia.

Competing Crops

Kenaf produced to supply litter materials to the local poultry farms represents a potential alternative crop for crop farmers to diversify their enterprises. Although the per acre net returns of producing kenaf poultry litter is slightly lower than some of the cash crops currently grown on farms in the study areas, it still attracts farmers who are risk averse, and maximize the expected utility in terms of the maximization of expected net returns and minimization of variability in net returns of the crops on farms. Thus, kenaf would replace those crops associated with high variability in net returns (e.g., corn and cotton) on farms where the operators are risk averse. The empirical results demonstrate that kenaf producing for the poultry litter market is not competitive with the existing cash crops on farms where the operators are risk neutral.

At the base price of $0.32 per cubic foot for kenaf core, acreages devoted to kenaf identified by the model would allow poultry production centers to achieve 100 percent self sufficiency for litter materials locally in almost every state. Crops with high net returns and/or low variability in net returns are not expected to compete with kenaf for land and capital resources in the near future.

Kenaf for Forage

Kenaf was assumed to sell at $40.84 (1982 dollars) or $45.00 (current dollars) per ton, which is equivalent to the current estimated market value for non-legume hay. Kenaf forage can be supplied in any form (e.g., round baled, square cubed, etc.) common to the region. Therefore, no specification of a potential supply zone is needed when aggregating the farm level kenaf forage production into state level production as the transportation cost may not be a constraining factor for producing kenaf forage on farms in an entire state.

The optimal cropping patterns generated with the model for different risk aversion values are reported in table 7.15. State cropping patterns for the different risk aversion values are reported in Appendix tables B23-B33. Regional cropping patterns of the major cash crops included in the model for kenaf supplying forage are similar to that described in the solutions for kenaf supplying pulp and poultry litter. Table 7.17 shows that kenaf was selected only when Φ is at and above 0.00072. Farmers who are risk neutral or almost risk neutral would not choose kenaf forage as a potential cash crop grown on farms. This may be due to the low net returns of kenaf forage relative to other cash crops grown on farms. However, farmers whose risk attitudes may be defined as medium to strongly risk averse would consider growing kenaf forage as an alternative to diversify enterprises on farms. Aggregate acreage for kenaf forage expands from 994,000 acres to 7.2 million acres as the risk aversion coefficient increases from 0.00072 to 0.00196.

Farmers in different states differ in their decisions

TABLE 7.17

REGIONAL CROPPING PATTERNS SOLVED FROM THE QP MODEL FOR DIFFERENT RISK AVERSION VALUES FOR THE KENAF'S FORAGE MARKET

	Values of Risk Aversion Coefficients (.001)											
Crop	0	0.20	0.50	0.72	0.94	1.20	1.50	1.74	1.85	1.96	3.00	1987 base year values
	1,000 acres											
Corn	2,991	2,991	2,991	2,991	2,991	2,991	2,991	3,050	3,056	3,062	3,095	4,890
Cotton	6,090	6,562	6,991	7,107	7,002	6,858	6,799	6,766	6,742	6,712	6,536	8,101
Peanuts	1,349	1,349	1,349	1,349	1,349	1,349	1,349	1,349	1,349	1,349	1,349	1,197
Rice	1,379	1,379	1,379	1,379	1,379	1,379	1,379	1,379	1,379	1,379	1,379	1,915
Sorghum	4,904	4,632	4,213	4,156	3,331	3,534	3,746	3,852	3,889	3,921	4,153	4,020
Soybeans	13,270	16,490	16,904	16,910	16,230	15,747	15,192	13,446	12,506	11,843	9,529	12,458
Sugarcane	743	743	743	743	743	743	743	743	743	743	743	665
Wheat	19,645	16,225	15,802	14,742	14,179	13,779	13,696	13,621	13,569	13,522	13,180	17,125
Kenaf	0	0	0	994	2,726	3,991	4,476	6,166	7,052	7,173	6,770	na[a]

[a] not available.

on growing kenaf forage on farms with respect to the degree of risk aversion. When the risk aversion coefficient is assumed at 0.00072, risk averse farmers in only two states (Louisiana and Mississippi) replace some of their soybeans acres with 395,000 and 559,000 acres of kenaf forage, respectively. Arkansas farmers shift some of the cotton and grain sorghum acreage to grow kenaf forage at $\Phi = 0.00094$. The kenaf acreage continues to expand in these three states as the farmers are assumed to become more risk averse. When the risk aversion coefficient exceeds 0.00174, kenaf forage was integrated into the farm enterprises in Georgia (34,000 acres), Texas (1.4 million acres), and Virginia (37,000 acres). When Φ is at 0.00185 and 0.00196, about 50,000 acres and 129,000 acres of land would be used for growing kenaf forage in South Carolina and North Carolina, respectively while acreage diverted to grow kenaf forage continues to expand in those states where kenaf forage is already an economically feasible crop.

Forage is produced as an input to raise livestock on farms. The supply of forage is mostly to meet on-farm feed requirements rather than producing for the cash market (e.g., commercial forage suppliers) in which consumer's demand may be the pulling source for the product. An empirical study shows that approximately 82 percent of hay produced in the U.S. was directly consumed on farms where it was produced (see Stephens and Westhoff, 1989). Therefore, analysis of supply of kenaf forage should focus on the potential economic gains by livestock producers who would be the primary users of kenaf forage.

The empirical results of this study show that kenaf forage can be economically integrated into the farm enterprises of risk averse farmers in 8 of the 11 states included in this study. At the different values for the risk aversion coefficient, aggregate acreage for kenaf forage ranges from 994,000 to 7.4 million acres resulting in about 2 million to 14.8 million tons of kenaf forage (assuming a average of 2 tons/acre) available to the regional forage market. Additional forage supplied from kenaf would adversely affect the price of non-legume hay currently consumed in the regional market. Total hay production in the southern 11 states included in this study was roughly 27.5 million tons of which 25 million tons (91 percent) was non-legume hay in 1991. The availability of kenaf forage (ranging from 2 million to 14.8 million tons) for the regional forage market would consequently shift the hay supply curve to the right resulting in lower equilibrium price for the non-legume hay assuming the demand curve holds at the current position. The magnitude of such a impact on the hay price can be assessed using a regional price elasticity for hay (-.351) estimated by Zhang and Dicks (1992). Table 7.18 shows the percentage of possible hay price decrease resulted from the additional kenaf forage introduced into the regional hay market for different levels of risk aversion coefficient assumed in the model. For

TABLE 7.18

IMPACTS OF ADDITIONAL KENAF FORAGE ON REGIONAL HAY PRICE FOR DIFFERENT RISK AVERSION VALUES ASSUMING AVERAGE KENAF FORAGE YIELD AT 2 TONS PER ACRE FOR THE REGION

Risk Aversion	Aggregate Supply	Change in Price
	1,000 tons	*percent*
0	0	0
0.00020	0	0
0.00050	0	0
0.00072	1,988	-2.5
0.00094	5,452	-6.9
0.00120	7,982	-10.2
0.00150	8,952	-11.4
0.00174	12,332	-15.7
0.00185	14,104	-18.0
0.00196	14,346	-18.3
0.00300	13,400	-17.1

example, an additional 8.9 million tons (4.5 million acres) of kenaf forage would reduce price of hay by approximately 11.4 percent, from $58.45 per ton to $51.79 per ton in 1991. In addition, livestock producers would be able to reduce feed costs in the short run.

Summary

This chapter empirically estimated the potential of kenaf acreage produced for three different markets of kenaf products in the U.S. using the aggregate regional QP model developed in chapter V. The supply functions of kenaf produced to supply pulp and poultry litter were generated respectively from the optimal solutions of the model when the price or demand for kenaf is assumed to shift upwards. Individual farmers' risk attitudes significantly affect the kenaf supply. Different risk attitudes resulted in completely different supply response behaviors for kenaf.

The empirical results obtained from the model demonstrated that kenaf could be economically integrated into the present farm enterprises in the southern regions in the U.S. The potential of kenaf acreage produced for three markets would range from 435,000 to 8.2 million acres in the southern 11 states depending upon farmers' risk attitudes. Kenaf would likely replace those crops which are vulnerable to price volatility (e.g., corn, cotton, sorghum, wheat) in the near future. The results showed that the present demand for kenaf fiber in the local newsprint and/or paper mills could be partially satisfied with locally produced kenaf. Poultry production centers in most of the states included in the study could be assured of abundant litter materials from kenaf core. With the introduction of kenaf forage into the regional forage market, hay price would likely decline ranging from 3 percent to 18 percent depending upon crop farmers' risk attitudes in the region. The reduced hay price would benefit livestock producers who are the primary forage consumers in the region.

CHAPTER VIII

SUMMARY AND CONCLUSIONS

This chapter is a summary of the research conducted in this dissertation. First, the economic rationale, objectives are restated followed by a brief discussion of the research methods adopted to implement the analysis. Secondly, a brief summary of the findings about demand and supply of kenaf products are presented. Finally, some concluding comments and thoughts are presented.

Review of the Rationale and Objectives of This Study

Persistently low and unstable agricultural prices and farm incomes have been the symptoms of farm problems in American agriculture. Diversifying farm enterprises enables farmers to reduce economic vulnerability and increase farm incomes. Kenaf may be the alternative crop with economic potentials that farmers could integrate into the present farm enterprises. Information and economic analysis about the potential demand and supply of kenaf are crucial for interactions between processors and producers in order to establish a complete market system for kenaf. Kenaf processors are concerned about dependable supplies while producers require fair returns and low risk. Studies on the demand and supply of kenaf can also provide invaluable information to making proper policies which may lead to the success of this new crop venture.

The purpose of this study was to determine the feasibility of kenaf production for potential markets in various parts of the United States. The specific objectives were:

1. to determine acreage requirements of kenaf supplying pulp, poultry litter, and forage; and
2. to determine potential farm supply of kenaf in the identified production regions.

Review of the Methods Used in This Study

Three types of analytical tools were used to implement the analysis in this study: descriptive, theoretical, and empirical. The theoretical framework for this study drew from Bernoulli's Principle or the expected utility theorem (EU). The empirical aggregate regional QP model was developed based on efficient portfolio theory and concepts (Markowitz 1952; Tobin 1958; Baumol 1963) and maximization of expected utility on farms (Freund 1956; Hazell and Scandizzo 1974).

Potential acreage requirements for three major kenaf products were obtained with the descriptive analysis. Surveys of the newsprint and/or paper mills and poultry farms in the potential kenaf production regions were used to obtain the point estimates of acreage requirements for kenaf bast fiber and inner core. Production budgets were used to compare the net returns of farm enterprises with and without kenaf.

Potential acreage for kenaf produced to supply three separate markets in the southern 11 states included in the study were examined with the aggregate regional QP model. Ten levels of risk aversion values were used in the model. Supply functions for kenaf supplying pulp and poultry litter were obtained with the optimal solutions solved under alternative price levels.

Potential Acreage Requirements for Kenaf

Potential acreage required for kenaf produced to supply pulp was estimated based on a 25 percent conversion rate of processing capacities of the existing newsprint and/or paper mills in the Atlantic South (North Carolina, South Carolina, Virginia), South Central (Arkansas, Louisiana, Oklahoma, Texas), and Southeast (Alabama, Florida, Georgia, Mississippi) regions. A total of 88 mills were included in the estimation with 16 mills in the Atlantic South, 23 mills in the South Central and 45 mills in the Southeast. Each mill was selected for consideration based on location and process technology. Mills indicating kraft, semi-chemical, TMP, sulfite, flax, bagasse, and refiner mechanical process (RMP) capacity were generally selected unless their locations are too far from the production sites. Total acreage was estimated at 1.2 millions acres with acreage ranging from 50,714 acres in Oklahoma to 389,629 acres in Georgia.

Potential acreage required for kenaf produced to supply poultry litter was estimated assuming poultry farms in major poultry production states would replace wood chips and/or saw dust with kenaf inner core for litter materials. Approximately 70 percent of the broiler supplied in the U.S. are from those states where kenaf can be feasibly produced to manufacture newsprint. Therefore, the economic analysis of supply of kenaf as a poultry litter focused on the states where the paper mills were also located. The following states were included: Alabama, Arkansas, Georgia, Mississippi, North Carolina, Texas and Virginia. The estimated kenaf litter requirements per broiler and per turkey were 0.03125 cu.ft. and 0.375 cu.ft. per year, respectively. Using these conversion rates, the total litter requirements for the U.S. broiler and turkey production would be 192 million cu.ft. and 107 million cu.ft., respectively in 1991. A total of 299 million cu.ft of poultry litter would require kenaf acreage in the range of 74,000 to 270,000. Kenaf acreages required to satisfy the 1991 poultry litter demand in the leading poultry producing states and the U.S. were estimated assuming kenaf core was the only source for the poultry litter market. Kenaf core yield was assumed ranging from 55 to 65 percent of total stem yield, and kenaf acreages were estimated for three levels of core yield, i.e., 55, 60, and 65 percent of total average yield at 6.5 tons per acre across the study regions.

No specific point estimation of potential acreage requirement for kenaf forage was obtained. The analysis of the potential market for kenaf forage focused on the potential economic benefits to be gained by livestock producers from integrating kenaf forage into their farming activities. Kenaf has been identified as having the physical characteristics which may provide an alternative to summer fallowing wheat lands in the Southern Plains and other regions. The physical characteristics of kenaf would enable farmers to incorporate the crop into the present farm enterprises where farmers produced winter wheat and raise cattle. Two types of enterprise budgets including winter wheat-stocker and winter wheat-kenaf-stocker based on the data from the field experiment and production conditions in Southwestern Oklahoma were used to compare net returns of farm enterprises. The net return for the wheat-stocker enterprise was -$0.21 per acre without government payments and $25.29 with government payments. The addition of kenaf to the wheat-stocker enterprise generated a net return of $15.75 per acre without government payments and $41.25 with government payments. The net gain was estimated at $15.95 per acre.

Economic Analysis of Potential Supply of Kenaf

The first portion dealt with the newsprint market where kenaf bast fiber was assumed to sell at $49.91 per dry ton (1982 dollars) or $55.00 per dry ton (current dollars). Kenaf produced to supply pulp was selected as a feasible crop in most of the states at all the risk aversion levels. When risk neutrality is assumed (LP solution), kenaf was selected as a farm enterprise in only a few states: Florida, Louisiana, Oklahoma, and Texas. Potential acreage for kenaf production in all three regions ranged from 294,000 acres to 738,000 acres depending on farmers' risk attitudes. When the risk aversion coefficient was assumed at 0.0015, 171,000, 374,000 and 193,000 acres of crop land could be planted to kenaf in the Atlantic South, the South Central, and the Southeast regions, respectively. The potential acres committed to kenaf in each state would ensure consistent supply of kenaf fiber source to the local newsprint or paper mills. Various levels of percentage of fiber demand in the local newsprint or paper mills that could be met with kenaf fiber locally were estimated at different risk aversion values in each state, they ranged from 1 to 24 percent depending on farmers' risk attitudes.

The aggregate supply of kenaf was significantly affected by farmers' risk attitudes. The results suggested that kenaf might be a low risk crop in most states included in the study as the acreage expanded when farmers become more risk averse. However, the empirical results also suggested that kenaf might be a high risk crop in Oklahoma.

Aggregate kenaf supply response function, i.e., price and quantity relationship, was generated with the model. Both risk neutral and risk averse cases were considered. Under the risk averse assumption, the supply curve shifts right resulting in larger quantity supplied than under the risk neutral assumption.

The second portion dealt with the input market for poultry production where kenaf was sold as litter materials at \$0.32 (1982 dollars) or \$0.35 (current dollars) per cubic foot. Kenaf core yield was set at 60 percent of the total yield expressed in terms of cubic feet per acre (1 cubic foot is equivalent to 5 pounds). Counties with 200 or more poultry farms were used to compute the aggregate acreage supply of kenaf core in each state in the study areas. Kenaf produced to supply poultry litter was selected as a feasible crop in 5 of the 7 states when the risk aversion coefficient was at or above 0.0005. However, only one state (Texas) entered the solution when risk neutrality is assumed (LP solution). The aggregate supply of kenaf for poultry litter was also significantly affected by farmers' risk attitudes. Aggregate acreage for kenaf production increased from 141,000 acres to 708,000 acres as the risk aversion coefficient increased. When the risk aversion coefficient was assumed at 0.00174, 683,000 acres of crop land could be planted to kenaf in the three regions with kenaf as a feasible crop in every state. The potential acres committed to kenaf in each state would provide local poultry farms sufficient poultry litter materials at prices below wood chips. The amount of acreage devoted to kenaf for poultry litter at $\Phi = 0.003$ was sufficient to guarantee the poultry production centers in each of the states in the study areas an abundant supply of kenaf poultry litter.

An aggregate supply response function for kenaf as a source of poultry litter was generated. Results of the estimated kenaf supply elasticities suggested that the kenaf supply was extremely elastic at the initial price change for risk neutral farmers. Both groups of farmers would increase kenaf production less than proportionally to the price increase when the price was at and above $0.38 (1982 dollars) or $0.42 (current dollars) per cubic foot. The price increased from $0.42 (1982 dollars) to $0.45 per cubic foot would not induce any expansion in acreage of kenaf in the study areas.

The last portion dealt with forage market where kenaf would be produced to substitute some types of non-legume hay on farms. Kenaf was assumed to sell at $40.84 (1982 dollars) or $45.00 (current dollars) per ton. since kenaf forage could be supplied in any form (e.g., round baled, square cubed, etc.) common to the region, no specification of a potential supply zone was assumed. The empirical results showed that kenaf was selected as a feasible crop into the farm enterprises only when Φ was at and above 0.00072. Farmers who were risk neutral or almost risk neutral would not choose kenaf forage as a potential cash crop grown on farms. However, farmers whose risk attitudes may be defined as medium to strongly risk averse would consider growing kenaf forage as an alternative to diversify enterprises on farms. Aggregate acreage for kenaf forage expanded from 994,000 acres to 7.2 million acres as the risk aversion coefficient increased from 0.00072 to 0.00196.

Potential economic impacts on the regional forage market was assessed. The availability of kenaf forage (ranging from 2 million to 14.8 million tons) for the regional forage market would consequently shift the hay supply curve to the right resulting in lower equilibrium price for the non-legume hay assuming the demand curve holds at the current position. With the introduction of kenaf forage into the regional forage market, hay price would likely decline ranging from 3 percent to 18 percent depending upon crop farmers' risk attitudes in the region. The reduced hay price would benefit livestock producers who are the primary forage consumers in the region.

Concluding Comments

This study examined the economic feasibility of potential of U.S. kenaf markets. Three major kenaf products were considered in the analysis, i.e., pulp, poultry litter, and forage. The analysis presented in this study contains numerous assumptions on kenaf due to limited data availability. Relaxing some of the assumptions (i.e., yield and/or price levels of kenaf) may alter the results obtained in this study. However, the estimates presented represent a best approximation based upon the available data on kenaf. Further research are needed in order to provide more and accurate information about this new crop venture. Future research should also focus on the likely economic impacts on the major cash crops (i.e., corn, cotton, sorghum, wheat) as kenaf is becoming an economically viable crop in the regional farm economy.

The empirical results obtained from the model demonstrated that kenaf could be economically integrated into the present farm enterprises in the southern regions in the U.S. The potential of kenaf acreage produced for three markets would range from 435,000 to 8.2 million acres in the southern 11 states depending upon farmers' risk attitudes. Kenaf would likely replace those crops which are vulnerable to price volatility (e.g., corn, cotton, sorghum, wheat) in the near future. The study showed that the present demand for kenaf fiber in the local newsprint and/or paper mills could be partially satisfied with locally produced kenaf. Poultry production centers in most of the states included in the study could be assured of abundant litter materials from kenaf core. With the introduction of kenaf forage into the regional forage market, hay price would likely decline in the region.

The study suggests that incorporation of risk into the programming model is important to study new crop venture in the farm economy. Comparisons of model solutions at different risk aversion levels clearly suggest that risk can significantly affect farmer's planting decisions on kenaf. Assuming risk neutral (LP solutions) may lead to unrealistic estimations of kenaf supply.

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APPENDIXES

APPENDIX A

VARIANCE-COVARIANCE TABLES

TABLE A1

VARIANCE-COVARIANCE MATRIX, ATLANTIC-SOUTH REGION, 1981-89. NEWSPRINT MARKET

	NCCO	NCWT	NCSY	NCCT	NCPT	NCKF	SCCO	SCWT	SCSY	SCCT	SCKF	VACO	VAWT	VASY	VAPT	VAKF
NCCO	1109	725	313	485	-1487	119	0	0	0	0	0	0	0	0	0	0
NCWT	725	1440	637	-346	336	-109	0	0	0	0	0	0	0	0	0	0
NCSY	313	637	468	-386	-381	-132	0	0	0	0	0	0	0	0	0	0
NCCT	485	-346	-386	3152	-200	900	0	0	0	0	0	0	0	0	0	0
NCPT	-1487	336	-381	-200	10476	679	0	0	0	0	0	0	0	0	0	0
NCKF	119	-109	-132	900	679	394	0	0	0	0	0	0	0	0	0	0
SCCO	0	0	0	0	0	0	882	579	282	530	110	0	0	0	0	0
SCWT	0	0	0	0	0	0	579	1183	576	-322	-68	0	0	0	0	0
SCSY	0	0	0	0	0	0	282	576	432	-355	-97	0	0	0	0	0
SCCT	0	0	0	0	0	0	530	-322	-355	3515	801	0	0	0	0	0
SCKF	0	0	0	0	0	0	110	-68	-97	801	265	0	0	0	0	0
VACO	0	0	0	0	0	0	0	0	0	0	0	1365	823	417	-1599	189
VAWT	0	0	0	0	0	0	0	0	0	0	0	823	1564	784	340	104
VASY	0	0	0	0	0	0	0	0	0	0	0	417	784	584	-424	57
VAPT	0	0	0	0	0	0	0	0	0	0	0	-1599	340	-424	10476	339
VAKF	0	0	0	0	0	0	0	0	0	0	0	189	104	57	339	146

[a] NC, North Carolina; SC, South Carolina; VA, Virginia.
[b] CO, Corn; CT, Cotton; KF, Kenaf; PT, Peanuts; SY, Soybean; WT, Wheat.

TABLE A2

VARIANCE-COVARIANCE MATRIX, SOUTHEAST REGION, 1981-89. NEWSPRINT MARKET

	ALCO	ALWT	ALSY	ALCT	ALPT	ALKF	GACO	GAWT	GASY	GACT	GAPT	GAKF
ALCO	1113	466	341	4	331	14	0	0	0	0	0	0
ALWT	466	758	522	-200	410	-116	0	0	0	0	0	0
ALSY	341	522	508	-168	147	-119	0	0	0	0	0	0
ALCT	4	-200	-168	3702	-478	175	0	0	0	0	0	0
ALPT	331	410	147	-478	2687	416	0	0	0	0	0	0
ALKF	14	-116	-119	175	416	203	0	0	0	0	0	0
GACO	0	0	0	0	0	0	1087	542	282	540	292	150
GAWT	0	0	0	0	0	0	542	924	529	-348	524	-82
GASY	0	0	0	0	0	0	282	529	478	-419	38	-122
GACT	0	0	0	0	0	0	540	-348	-419	3397	1007	888
GAPT	0	0	0	0	0	0	292	524	38	1007	2687	474
GAKF	0	0	0	0	0	0	150	-82	-122	888	474	355

	FLCO	FLSY	FLSU	FLKF	MSCO	MSWT	MSSY	MSCT	MSRI	MSSG	MSKF
FLCO	1127	309	263	189	0	0	0	0	0	0	0
FLSY	309	485	273	-148	0	0	0	0	0	0	0
FLSU	263	273	984	87	0	0	0	0	0	0	0
FLKF	189	-148	87	490	0	0	0	0	0	0	0
MSCO	0	0	0	0	1008	478	641	318	1588	276	136
MSWT	0	0	0	0	478	700	598	-237	1055	366	-13
MSSY	0	0	0	0	641	598	1381	98	881	567	-37
MSCT	0	0	0	0	318	-237	98	4756	-355	-354	421
MSRI	0	0	0	0	1588	1055	881	-355	5926	1173	375
MSSG	0	0	0	0	276	366	567	-354	1173	438	46
MSKF	0	0	0	0	136	-13	-37	421	375	46	267

[a] AL, Alabama; FL, Florida; GA, Georgia; MS, Mississippi.

[b] CO, Corn; CT, Cotton; KF, Kenaf; PT, Peanuts; RI, Rice; SG, Sorghum; SU, Sugarcane; SY, Soybean; WT, Wheat.

TABLE A3

VARIANCE-COVARIANCE MATRIX, SOUTH-CENTRAL REGION, 1981-89. NEWSPRINT MARKET

	ARSY	ARWT	ARRI	ARCT	ARSG	ARKF	LASY	LAWT	LARI	LACT	LASG	LASU	LAKF
ARSY	1042	484	676	30	548	-66	0	0	0	0	0	0	0
ARWT	484	697	931	-218	460	-11	0	0	0	0	0	0	0
ARRI	676	931	6193	-260	1531	438	0	0	0	0	0	0	0
ARCT	30	-218	-260	4148	-352	392	0	0	0	0	0	0	0
ARSG	548	460	1531	-352	726	82	0	0	0	0	0	0	0
ARKF	-66	-11	438	392	82	267	0	0	0	0	0	0	0
LASY	0	0	0	0	0	0	1155	421	674	56	438	-534	85
LAWT	0	0	0	0	0	0	421	441	1027	-182	250	-125	-64
LARI	0	0	0	0	0	0	674	1027	5888	-593	994	-2182	402
LACT	0	0	0	0	0	0	56	-182	-593	4316	402	-328	1667
LASG	0	0	0	0	0	0	438	250	994	402	319	382	-400
LASU	0	0	0	0	0	0	-534	-125	-2182	-328	382	4311	111
LAKF	0	0	0	0	0	0	85	-64	402	1667	-400	111	429

	OKSY	OKWT	OKSG	OKCT	OKPT	OKKF	TXCO	TXWT	TXSY	TXCT	TXRI	TXSG	TXKF
OKSY	162	-2136	425	3992	353	-60	0	0	0	0	0	0	0
OKWT	-2136	1922	6	-8842	-2150	-138	0	0	0	0	0	0	0
OKSG	425	6	384	224	-207	-70	0	0	0	0	0	0	0
OKCT	3992	-8842	224	6161	851	79	0	0	0	0	0	0	0
OKPT	353	-2150	-207	851	1062	-59	0	0	0	0	0	0	0
OKKF	-60	-138	-70	79	-59	190	0	0	0	0	0	0	0
TXCO	0	0	0	0	0	0	675	799	207	-270	1428	577	-156
TXWT	0	0	0	0	0	0	799	1806	416	-232	2190	809	-113
TXSY	0	0	0	0	0	0	207	416	212	-147	423	248	-99
TXCT	0	0	0	0	0	0	-270	-232	-147	8266	-3202	-911	10
TXRI	0	0	0	0	0	0	1428	2190	423	-3202	5888	1447	33
TXSG	0	0	0	0	0	0	577	809	248	-911	1447	613	-87
TXKF	0	0	0	0	0	0	-156	-113	-99	10	33	-87	258

[a] AR, Arkansas; LA, Louisiana; OK, Oklahoma; TX, Texas.

[b] CO, Corn; CT, Cotton; KF, Kenaf; PT, Peanuts; RI, Rice; SG, Sorghum; SU, Sugarcane; SY, Soybean; WT, Wheat.

TABLE A4

VARIANCE-COVARIANCE MATRIX, ATLANTIC-SOUTH REGION, 1981-89. POULTRY LITTER MARKET

	NCCO	NCWT	NCSY	NCCT	NCPT	NCKF	SCCO	SCWT	SCSY	SCCT	SCKF	VACO	VAWT	VASY	VAPT	VAKF
NCCO	1109	725	313	485	-1487	109	0	0	0	0	0	0	0	0	0	0
NCWT	725	1440	637	-346	336	-99	0	0	0	0	0	0	0	0	0	0
NCSY	313	637	468	-386	-381	-120	0	0	0	0	0	0	0	0	0	0
NCCT	485	-346	-386	3152	-200	821	0	0	0	0	0	0	0	0	0	0
NCPT	-1487	336	-381	-200	10476	619	0	0	0	0	0	0	0	0	0	0
NCKF	109	-99	-120	821	619	328	0	0	0	0	0	0	0	0	0	0
SCCO	0	0	0	0	0	0	882	579	282	530	100	0	0	0	0	0
SCWT	0	0	0	0	0	0	579	1183	576	-322	-62	0	0	0	0	0
SCSY	0	0	0	0	0	0	282	576	432	-355	-89	0	0	0	0	0
SCCT	0	0	0	0	0	0	530	-322	-355	3515	730	0	0	0	0	0
SCKF	0	0	0	0	0	0	100	-62	-89	730	220	0	0	0	0	0
VACO	0	0	0	0	0	0	0	0	0	0	0	1365	823	417	-1599	172
VAWT	0	0	0	0	0	0	0	0	0	0	0	823	1564	784	340	95
VASY	0	0	0	0	0	0	0	0	0	0	0	417	784	584	-424	52
VAPT	0	0	0	0	0	0	0	0	0	0	0	-1599	340	-424	10476	309
VAKF	0	0	0	0	0	0	0	0	0	0	0	172	95	52	309	122

[a] NC, North Carolina; SC, South Carolina; VA, Virginia.

[b] CO, Corn; CT, Cotton; KF, Kenaf; PT, Peanuts; SY, Soybean; WT, Wheat.

TABLE A5

VARIANCE-COVARIANCE MATRIX, SOUTHEAST REGION, 1981-89. POULTRY LITTER MARKET

	ALCO	ALWT	ALSY	ALCT	ALPT	ALKF	GACO	GAWT	GASY	GACT	GAPT	GAKF
ALCO	1113	466	341	4	331	13	0	0	0	0	0	0
ALWT	466	758	522	-200	410	-106	0	0	0	0	0	0
ALSY	341	522	508	-168	147	-108	0	0	0	0	0	0
ALCT	4	-200	-168	3702	-478	160	0	0	0	0	0	0
ALPT	331	410	147	-478	2687	379	0	0	0	0	0	0
ALKF	13	-106	-108	160	379	168	0	0	0	0	0	0
GACO	0	0	0	0	0	0	1087	542	282	540	292	136
GAWT	0	0	0	0	0	0	542	924	529	-348	524	-75
GASY	0	0	0	0	0	0	282	529	478	-419	38	-111
GACT	0	0	0	0	0	0	540	-348	-419	3397	1007	810
GAPT	0	0	0	0	0	0	292	524	38	1007	2687	432
GAKF	0	0	0	0	0	0	136	-75	-111	810	432	295

	MSCO	MSWT	MSSY	MSCT	MSRI	MSSG	MSKF
MSCO	1008	478	641	318	1588	276	124
MSWT	478	700	598	-237	1055	366	-12
MSSY	641	598	1381	98	881	567	-34
MSCT	318	-237	98	4756	-355	-354	384
MSRI	1588	1055	881	-355	5926	1173	342
MSSG	276	366	567	-354	1173	438	42
MSKF	124	-12	-34	384	342	42	222

[a] AL, Alabama; FL, Florida; GA, Georgia; MS, Mississippi.

[b] CO, Corn; CT, Cotton; KF, Kenaf; PT, Peanuts; RI, Rice; SG, Sorghum; SU, Sugarcane; SY, Soybean; WT, Wheat.

TABLE A6

VARIANCE-COVARIANCE MATRIX, SOUTH-CENTRAL REGION, 1981-89. POULTRY LITTER MARKET

	ARSY	ARWT	ARRI	ARCT	ARSG	ARKF	TXCO	TXWT	TXSY	TXCT	TXRI	TXSG	TXKF
ARSY	1042	484	676	30	548	-60	0	0	0	0	0	0	0
ARWT	484	697	931	-218	460	-10	0	0	0	0	0	0	0
ARRI	676	931	6193	-260	1531	399	0	0	0	0	0	0	0
ARCT	30	-218	-260	4148	-352	357	0	0	0	0	0	0	0
ARSG	548	460	1531	-352	726	75	0	0	0	0	0	0	0
ARKF	-60	-10	399	357	75	222	0	0	0	0	0	0	0
TXCO	0	0	0	0	0	0	675	799	207	-270	1428	577	-142
TXWT	0	0	0	0	0	0	799	1806	416	-232	2190	809	-103
TXSY	0	0	0	0	0	0	207	416	212	-147	423	248	-90
TXCT	0	0	0	0	0	0	-270	-232	-147	8266	-3202	-911	9
TXRI	0	0	0	0	0	0	1428	2190	423	-3202	5888	1447	30
TXSG	0	0	0	0	0	0	577	809	248	-911	1447	613	-79
TXKF	0	0	0	0	0	0	-142	-103	-90	9	30	-79	215

[a] AR, Arkansas; TX, Texas.

[b] CO, Corn; CT, Cotton; KF, Kenaf; RI, Rice; SG, Sorghum; SY, Soybean; WT, Wheat.

TABLE A7

VARIANCE-COVARIANCE MATRIX, ATLANTIC-SOUTH REGION, 1981-89. FORAGE MARKET

	NCCO	NCWT	NCSY	NCCT	NCPT	NCKF	SCCO	SCWT	SCSY	SCCT	SCKF	VACO	VAWT	VASY	VAPT	VAKF
NCCO	1109	725	313	485	-1487	29	0	0	0	0	0	0	0	0	0	0
NCWT	725	1440	637	-346	336	-27	0	0	0	0	0	0	0	0	0	0
NCSY	313	637	468	-386	-381	-32	0	0	0	0	0	0	0	0	0	0
NCCT	485	-346	-386	3152	-200	221	0	0	0	0	0	0	0	0	0	0
NCPT	-1487	336	-381	-200	10476	167	0	0	0	0	0	0	0	0	0	0
NCKF	29	-27	-32	221	167	24	0	0	0	0	0	0	0	0	0	0
SCCO	0	0	0	0	0	0	882	579	282	530	27	0	0	0	0	0
SCWT	0	0	0	0	0	0	579	1183	576	-322	-17	0	0	0	0	0
SCSY	0	0	0	0	0	0	282	576	432	-355	-24	0	0	0	0	0
SCCT	0	0	0	0	0	0	530	-322	-355	3515	196	0	0	0	0	0
SCKF	0	0	0	0	0	0	27	-17	-24	196	16	0	0	0	0	0
VACO	0	0	0	0	0	0	0	0	0	0	0	1365	823	417	-1599	56
VAWT	0	0	0	0	0	0	0	0	0	0	0	823	1564	784	340	31
VASY	0	0	0	0	0	0	0	0	0	0	0	417	784	584	-424	17
VAPT	0	0	0	0	0	0	0	0	0	0	0	-1599	340	-424	10476	100
VAKF	0	0	0	0	0	0	0	0	0	0	0	56	31	17	100	13

[a] NC, North Carolina; SC, South Carolina; VA, Virginia.

[b] CO, Corn; CT, Cotton; KF, Kenaf; PT, Peanuts; SY, Soybean; WT, Wheat.

TABLE A8

VARIANCE-COVARIANCE MATRIX, SOUTHEAST REGION, 1981-89. NEWSPRINT MARKET

	ALCO	ALWT	ALSY	ALCT	ALPT	ALKF	GACO	GAWT	GASY	GACT	GAPT	GAKF
ALCO	1113	466	341	4	331	3	0	0	0	0	0	0
ALWT	466	758	522	-200	410	-29	0	0	0	0	0	0
ALSY	341	522	508	-168	147	-29	0	0	0	0	0	0
ALCT	4	-200	-168	3702	-478	43	0	0	0	0	0	0
ALPT	331	410	147	-478	2687	102	0	0	0	0	0	0
ALKF	3	-29	-29	43	102	12	0	0	0	0	0	0
GACO	0	0	0	0	0	0	1087	542	282	540	292	37
GAWT	0	0	0	0	0	0	542	924	529	-348	524	-20
GASY	0	0	0	0	0	0	282	529	478	-419	38	-30
GACT	0	0	0	0	0	0	540	-348	-419	3397	1007	218
GAPT	0	0	0	0	0	0	292	524	38	1007	2687	116
GAKF	0	0	0	0	0	0	37	-20	-30	218	116	21

	FLCO	FLSY	FLSU	FLKF	MSCO	MSWT	MSSY	MSCT	MSRI	MSSG	MSKF
FLCO	1127	309	263	56	0	0	0	0	0	0	0
FLSY	309	485	273	-44	0	0	0	0	0	0	0
FLSU	263	273	984	26	0	0	0	0	0	0	0
FLKF	56	-44	26	44	0	0	0	0	0	0	0
MSCO	0	0	0	0	1008	478	641	318	1588	276	33
MSWT	0	0	0	0	478	700	598	-237	1055	366	-3
MSSY	0	0	0	0	641	598	1381	98	881	567	-9
MSCT	0	0	0	0	318	-237	98	4756	-355	-354	103
MSRI	0	0	0	0	1588	1055	881	-355	5926	1173	92
MSSG	0	0	0	0	276	366	567	-354	1173	438	11
MSKF	0	0	0	0	33	-3	-9	103	92	11	16

[a] AL, Alabama; FL, Florida; GA, Georgia; MS, Mississippi.

[b] CO, Corn; CT, Cotton; KF, Kenaf; PT, Peanuts; RI, Rice; SG, Sorghum; SU, Sugarcane; SY, Soybean; WT, Wheat.

TABLE A9

VARIANCE-COVARIANCE MATRIX, SOUTH-CENTRAL REGION, 1981-89. NEWSPRINT MARKET

	ARSY	ARWT	ARRI	ARCT	ARSG	ARKF	LASY	LAWT	LARI	LACT	LASG	LASU	LAKF
ARSY	1042	484	676	30	548	-16	0	0	0	0	0	0	0
ARWT	484	697	931	-218	460	-3	0	0	0	0	0	0	0
ARRI	676	931	6193	-260	1531	107	0	0	0	0	0	0	0
ARCT	30	-218	-260	4148	-352	96	0	0	0	0	0	0	0
ARSG	548	460	1531	-352	726	20	0	0	0	0	0	0	0
ARKF	-16	-3	107	96	20	16	0	0	0	0	0	0	0
LASY	0	0	0	0	0	0	1155	421	674	56	438	-534	22
LAWT	0	0	0	0	0	0	421	441	1027	-182	250	-125	-17
LARI	0	0	0	0	0	0	674	1027	5888	-593	994	-2182	105
LACT	0	0	0	0	0	0	56	-182	-593	4316	402	-328	382
LASG	0	0	0	0	0	0	438	250	994	402	319	382	111
LASU	0	0	0	0	0	0	-534	-125	-2182	-328	382	4311	29
LAKF	0	0	0	0	0	0	22	-17	105	382	111	29	29

	OKSY	OKWT	OKSG	OKCT	OKPT	OKKF	TXCO	TXWT	TXSY	TXCT	TXRI	TXSG	TXKF
OKSY	162	-2136	425	3992	353	-11	0	0	0	0	0	0	0
OKWT	-2136	1922	6	-8842	-2150	-42	0	0	0	0	0	0	0
OKSG	425	6	384	224	-207	-16	0	0	0	0	0	0	0
OKCT	3992	-8842	224	6161	851	34	0	0	0	0	0	0	0
OKPT	353	-2150	-207	851	1062	-13	0	0	0	0	0	0	0
OKKF	-11	-42	-16	34	-13	11	0	0	0	0	0	0	0
TXCO	0	0	0	0	0	0	675	799	207	-270	1428	577	-43
TXWT	0	0	0	0	0	0	799	1806	416	-232	2190	809	-31
TXSY	0	0	0	0	0	0	207	416	212	-147	423	248	-27
TXCT	0	0	0	0	0	0	-270	-232	-147	8266	-3202	-911	3
TXRI	0	0	0	0	0	0	1428	2190	423	-3202	5888	1447	9
TXSG	0	0	0	0	0	0	577	809	248	-911	1447	613	-24
TXKF	0	0	0	0	0	0	-43	-31	-27	3	9	-24	20

[a] AR, Arkansas; LA, Louisiana; OK, Oklahoma; TX, Texas.

[b] CO, Corn; CT, Cotton; KF, Kenaf; PT, Peanuts; RI, Rice; SG, Sorghum; SU, Sugarcane; SY, Soybean; WT, Wheat.

APPENDIX B

OPTIMAL CROPPING PATTERNS BY STATE

TABLE B1

CROPPING PATTERNS SOLVED FROM THE QP MODEL, RISK NEUTRALITY, NEWSPRINT MARKET, BY STATE

Crop	NC	SC	VA	AL	FL	GA	MS	AR	LA	OK	TX
						1,000 acres					
Corn	770	223	0	256	0	565	na	na	na	na	1,177
Cotton	0	502	na	0	na	0	1,102	0	512	502	3,974
Peanuts	165	na	104	253	na	716	na	na	na	112	na
Rice	na	na	na	na	na	na	179	851	349	na	0
Sorghum	na	na	na	na	na	na	0	2,108	0	0	2,796
Soybeans	0	0	581	1,089	0	1,206	3,247	2,432	1,144	0	0
Sugarcane	na	na	na	na	441	na	na	na	303	na	na
Wheat	2,529	1,356	768	0	0	452	0	527	0	6,136	5,813
Kenaf	0	0	0	0	10	0	0	0	191	39	54

(Column group header: State)

[a] NC, North Carolina; SC, South Carolina; VA, Virginia; AL, Alabama; FL, Florida; GA, Georgia; MS, Mississippi; AR, Arkansas; LA, Louisiana; OK, Oklahoma; TX, Texas.

[b] na: not applicable.

TABLE B2

CROPPING PATTERNS SOLVED FROM THE QP MODEL AT RISK AVERSION COEFFICIENT = 0.00020, NEWSPRINT MARKET, BY STATE

Crop	State										
	NC	SC	VA	AL	FL	GA	MS	AR	LA	OK	TX
	1,000 acres										
Corn	770	223	0	256	0	565	na	na	na	na	1,177
Cotton	0	0	na	200	na	0	1,102	0	512	502	3,974
Peanuts	165	na	104	253	na	716	na	na	na	112	na
Rice	na	na	na	na	na	na	179	851	349	na	0
Sorghum	na	na	na	na	na	na	0	0	0	0	2,796
Soybeans	0	0	581	1,089	0	678	3,247	2,432	1,144	0	0
Sugarcane	na	na	na	na	441	na	na	na	303	na	na
Wheat	2,529	1,356	768	0	0	452	0	527	0	6,136	5,813
Kenaf	0	24	0	0	10	27	0	118	191	39	54

[a] NC, North Carolina; SC, South Carolina; VA, Virginia; AL, Alabama; FL, Florida; GA, Georgia; MS, Mississippi; AR, Arkansas; LA, Louisiana; OK, Oklahoma; TX, Texas.

[b] na: not applicable.

TABLE B3

CROPPING PATTERNS SOLVED FROM THE QP MODEL AT RISK AVERSION COEFFICIENT = 0.00050, NEWSPRINT MARKET, BY STATE

Crop	State										
	NC	SC	VA	AL	FL	GA	MS	AR	LA	OK	TX
	1,000 acres										
Corn	770	223	0	256	0	565	na	na	na	na	1,177
Cotton	0	0	na	210	na	0	1,102	0	512	502	3,974
Peanuts	165	na	104	253	na	716	na	na	na	112	na
Rice	na	na	na	na	na	na	179	851	349	na	0
Sorghum	na	na	na	na	na	na	0	0	0	0	2,796
Soybeans	0	777	581	880	0	678	1,826	2,432	1,144	2,064	0
Sugarcane	na	na	na	na	441	na	na	na	303	na	na
Wheat	1,760	0	768	0	0	452	0	527	0	6,136	5,813
Kenaf	40	79	0	0	10	27	78	118	191	39	54

[a] NC, North Carolina; SC, South Carolina; VA, Virginia; AL, Alabama; FL, Florida; GA, Georgia; MS, Mississippi; AR, Arkansas; LA, Louisiana; OK, Oklahoma; TX, Texas.

[b] na: not applicable.

TABLE B4

CROPPING PATTERNS SOLVED FROM THE QP MODEL AT RISK AVERSION COEFFICIENT = 0.00072, NEWSPRINT MARKET, BY STATE

	State										
Crop	NC	SC	VA	AL	FL	GA	MS	AR	LA	OK	TX
	1,000 acres										
Corn	770	223	0	256	0	565	na	na	na	na	1,177
Cotton	0	0	na	211	na	0	1,102	0	512	502	3,974
Peanuts	165	na	104	253	na	716	na	na	na	112	na
Rice	na	na	na	na	na	na	179	851	349	na	0
Sorghum	na	na	na	na	na	na	0	0	0	0	2,796
Soybeans	62	695	581	878	0	678	1,490	2,432	1,144	2,064	0
Sugarcane	na	na	na	na	441	na	na	na	303	na	na
Wheat	1,312	0	768	0	0	452	0	527	0	6,136	5,813
Kenaf	59	91	0	0	10	27	96	118	191	0	54

[a] NC, North Carolina; SC, South Carolina; VA, Virginia; AL, Alabama; FL, Florida; GA, Georgia; MS, Mississippi; AR, Arkansas; LA, Louisiana; OK, Oklahoma; TX, Texas.

[b] na: not applicable.

TABLE B5

CROPPING PATTERNS SOLVED FROM THE QP MODEL AT RISK AVERSION COEFFICIENT = 0.00094, NEWSPRINT MARKET, BY STATE

	State										
Crop	NC	SC	VA	AL	FL	GA	MS	AR	LA	OK	TX
	1,000 acres										
Corn	770	223	0	256	0	565	na	na	na	na	1,177
Cotton	0	0	na	212	na	0	1,102	0	512	502	3,974
Peanuts	165	na	104	253	na	716	na	na	na	112	na
Rice	na	na	na	na	na	na	179	851	349	na	0
Sorghum	na	na	na	na	na	na	0	0	0	0	2,796
Soybeans	617	651	581	877	0	678	1,311	2,432	1,144	2,064	0
Sugarcane	na	na	na	na	441	na	na	na	303	na	na
Wheat	750	0	768	0	0	452	0	527	0	6,136	5,813
Kenaf	60	96	0	0	10	27	106	118	191	0	54

[a] NC, North Carolina; SC, South Carolina; VA, Virginia; AL, Alabama; FL, Florida; GA, Georgia; MS, Mississippi; AR, Arkansas; LA, Louisiana; OK, Oklahoma; TX, Texas.

[b] na: not applicable.

TABLE B6

CROPPING PATTERNS SOLVED FROM THE QP MODEL AT RISK AVERSION COEFFICIENT = 0.0012, NEWSPRINT MARKET, BY STATE

Crop	State										
	NC	SC	VA	AL	FL	GA	MS	AR	LA	OK	TX
	1,000 acres										
Corn	770	223	0	256	0	565	na	na	na	na	1,177
Cotton	0	0	na	189	na	0	1,102	0	512	502	3,974
Peanuts	165	na	104	253	na	716	na	na	na	112	na
Rice	na	na	na	na	na	na	179	851	349	na	0
Sorghum	na	na	na	na	na	na	0	0	0	0	2,796
Soybeans	1,011	620	581	786	0	678	1,184	2,432	1,120	2,064	0
Sugarcane	na	na	na	na	441	na	na	na	303	na	na
Wheat	352	0	739	0	0	452	0	527	0	6,136	5,813
Kenaf	60	101	1	19	10	27	113	118	192	0	54

[a] NC, North Carolina; SC, South Carolina; VA, Virginia; AL, Alabama; FL, Florida; GA, Georgia; MS, Mississippi; AR, Arkansas; LA, Louisiana; OK, Oklahoma; TX, Texas.

[b] na: not applicable.

TABLE B7

CROPPING PATTERNS SOLVED FROM THE QP MODEL AT RISK AVERSION COEFFICIENT = 0.0015, NEWSPRINT MARKET, BY STATE

	State										
Crop	NC	SC	VA	AL	FL	GA	MS	AR	LA	OK	TX
	1,000 acres										
Corn	770	223	0	256	0	565	na	na	na	na	1,177
Cotton	0	0	na	166	na	0	1,102	0	512	502	3,974
Peanuts	165	na	104	253	na	716	na	na	na	112	na
Rice	na	na	na	na	na	na	179	851	349	na	0
Sorghum	na	na	na	na	na	na	0	0	0	0	2,796
Soybeans	1,295	598	581	699	0	678	1,093	2,432	961	2,064	0
Sugarcane	na	na	na	na	441	na	na	na	303	na	na
Wheat	64	0	539	0	0	452	0	527	0	6,136	5,813
Kenaf	60	104	7	38	10	27	118	118	202	0	54

[a] NC, North Carolina; SC, South Carolina; VA, Virginia; AL, Alabama; FL, Florida; GA, Georgia; MS, Mississippi; AR, Arkansas; LA, Louisiana; OK, Oklahoma; TX, Texas.

[b] na: not applicable.

TABLE B8

CROPPING PATTERNS SOLVED FROM THE QP MODEL AT RISK AVERSION COEFFICIENT = 0.00174, NEWSPRINT MARKET, BY STATE

Crop	State										
	NC	SC	VA	AL	FL	GA	MS	AR	LA	OK	TX
	1,000 acres										
Corn	770	223	0	256	0	565	na	na	na	na	1,177
Cotton	0	0	na	153	na	0	1,102	0	512	502	3,974
Peanuts	165	na	104	253	na	716	na	na	na	112	na
Rice	na	na	na	na	na	na	179	851	349	na	0
Sorghum	na	na	na	na	na	na	146	0	0	0	2,796
Soybeans	1,345	585	581	652	0	678	919	2,432	841	2,064	0
Sugarcane	na	na	na	na	441	na	na	na	303	na	na
Wheat	0	0	429	0	0	452	100	527	0	6,136	5,813
Kenaf	61	106	10	48	10	27	114	118	119	0	54

[a] NC, North Carolina; SC, South Carolina; VA, Virginia; AL, Alabama; FL, Florida; GA, Georgia; MS, Mississippi; AR, Arkansas; LA, Louisiana; OK, Oklahoma; TX, Texas.

[b] na: not applicable.

TABLE B9

CROPPING PATTERNS SOLVED FROM THE QP MODEL AT RISK AVERSION COEFFICIENT = 0.00185, NEWSPRINT MARKET, BY STATE

Crop	NC	SC	VA	AL	FL	GA	MS	AR	LA	OK	TX
	State										
	1,000 acres										
Corn	770	223	0	256	0	565	na	na	na	na	1,177
Cotton	0	0	na	149	na	0	1,102	0	512	502	3,974
Peanuts	165	na	104	253	na	716	na	na	na	112	na
Rice	na	na	na	na	na	na	179	851	349	na	0
Sorghum	na	na	na	na	na	na	337	0	0	0	2,796
Soybeans	1,336	581	581	634	0	678	793	2,432	796	2,064	0
Sugarcane	na	na	na	na	441	na	na	na	303	na	na
Wheat	0	0	388	0	0	452	130	527	0	6,136	5,813
Kenaf	61	106	11	51	10	27	109	118	87	0	54

[a] NC, North Carolina; SC, South Carolina; VA, Virginia; AL, Alabama; FL, Florida; GA, Georgia; MS, Mississippi; AR, Arkansas; LA, Louisiana; OK, Oklahoma; TX, Texas.

[b] na: not applicable.

TABLE B10

CROPPING PATTERNS SOLVED FROM THE QP MODEL AT RISK AVERSION COEFFICIENT = 0.00196, NEWSPRINT MARKET, BY STATE

Crop	State										
	NC	SC	VA	AL	FL	GA	MS	AR	LA	OK	TX
	1,000 acres										
Corn	770	223	0	256	0	565	na	na	na	na	1,177
Cotton	0	0	na	145	na	0	1,102	0	512	502	3,974
Peanuts	165	na	104	253	na	716	na	na	na	112	na
Rice	na	na	na	na	na	na	179	851	349	na	0
Sorghum	na	na	na	na	na	na	506	0	0	0	2,796
Soybeans	1,329	577	581	619	0	678	681	2,432	757	2,064	0
Sugarcane	na	na	na	na	441	na	na	na	303	na	na
Wheat	0	0	351	0	0	452	130	527	0	6,136	5,813
Kenaf	62	107	12	55	10	27	104	118	57	0	54

[a] NC, North Carolina; SC, South Carolina; VA, Virginia; AL, Alabama; FL, Florida; GA, Georgia; MS, Mississippi; AR, Arkansas; LA, Louisiana; OK, Oklahoma; TX, Texas.

[b] na: not applicable.

TABLE B11

CROPPING PATTERNS SOLVED FROM THE QP MODEL AT RISK AVERSION COEFFICIENT = 0.0030, NEWSPRINT MARKET, BY STATE

	State										
Crop	NC	SC	VA	AL	FL	GA	MS	AR	LA	OK	TX
	1,000 acres										
Corn	770	223	0	256	0	565	na	na	na	na	1,177
Cotton	0	0	na	120	na	0	1,102	0	512	502	3,974
Peanuts	165	na	104	253	na	716	na	na	na	112	na
Rice	na	na	na	na	na	na	179	851	349	na	0
Sorghum	na	na	na	na	na	na	1,185	0	0	0	2,796
Soybeans	1,286	553	581	527	0	678	53	2,432	480	2,064	0
Sugarcane	na	na	na	na	441	na	na	na	303	na	na
Wheat	0	0	140	0	0	452	85	527	0	6,136	5,813
Kenaf	64	110	18	74	10	27	30	117	0	0	54

[a] NC, North Carolina; SC, South Carolina; VA, Virginia; AL, Alabama; FL, Florida; GA, Georgia; MS, Mississippi; AR, Arkansas; LA, Louisiana; OK, Oklahoma; TX, Texas.

[b] na: not applicable.

TABLE B12

CROPPING PATTERNS SOLVED FROM THE QP MODEL AT RISK AVERSION COEFFICIENT = 0, POULTRY LITTER MARKET, BY STATE

Price	State						
	NC	VA	AL	GA	MS	AR	TX
	---------------- *1,000 acres* ----------------						
Corn	770	0	256	565	na	na	1,177
Cotton	0	na	0	0	1,102	0	3,974
Peanuts	165	104	253	716	na	na	0
Rice	na	na	na	na	179	851	0
Sorghum	na	na	na	na	0	2,108	2,796
Soybeans	0	581	1,089	1,206	3,247	2,432	0
Wheat	2,529	768	0	452	0	527	5,813
Kenaf	0	0	0	0	0	0	144

[a] NC, North Carolina; SC, South Carolina; VA, Virginia; AL, Alabama; FL, Florida; GA, Georgia; MS, Mississippi; AR, Arkansas; LA, Louisiana; OK, Oklahoma; TX, Texas.

[b] na: not applicable.

TABLE B13

CROPPING PATTERNS SOLVED FROM THE QP MODEL AT RISK AVERSION COEFFICIENT = 0.00020, POULTRY LITTER MARKET, BY STATE

	State						
Price	NC	VA	AL	GA	MS	AR	TX
	----------------- *1,000 acres* ---------------						
Corn	770	0	256	565	na	na	1,177
Cotton	0	na	200	0	1,102	103	3,974
Peanuts	165	104	253	716	na	na	0
Rice	na	na	na	na	179	851	0
Sorghum	na	na	na	na	0	1,327	2,796
Soybeans	0	581	889	1,206	3,247	2,432	0
Wheat	2,529	758	0	452	0	527	5,813
Kenaf	0	0	0	0	0	131	144

[a] NC, North Carolina; SC, South Carolina; VA, Virginia; AL, Alabama; FL, Florida; GA, Georgia; MS, Mississippi; AR, Arkansas; LA, Louisiana; OK, Oklahoma; TX, Texas.

[b] na: not applicable.

TABLE B14

CROPPING PATTERNS SOLVED FROM THE QP MODEL AT RISK AVERSION COEFFICIENT = 0.00050, POULTRY LITTER MARKET, BY STATE

	State						
Price	NC	VA	AL	GA	MS	AR	TX
	1,000 acres						
Corn	770	0	256	565	na	na	1,177
Cotton	0	na	210	0	1,102	71	3,974
Peanuts	165	104	253	716	na	na	0
Rice	na	na	na	na	179	851	0
Sorghum	na	na	na	na	0	415	2,796
Soybeans	0	581	880	926	2,255	2,432	0
Wheat	2,090	768	0	452	0	527	5,813
Kenaf	49	0	0	8	42	317	144

[a] NC, North Carolina; SC, South Carolina; VA, Virginia; AL, Alabama; FL, Florida; GA, Georgia; MS, Mississippi; AR, Arkansas; LA, Louisiana; OK, Oklahoma; TX, Texas.

[b] na: not applicable.

TABLE B15

CROPPING PATTERNS SOLVED FROM THE QP MODEL AT RISK AVERSION COEFFICIENT = 0.00072, POULTRY LITTER MARKET, BY STATE

Price	State						
	NC	VA	AL	GA	MS	AR	TX
	1,000 acres						
Corn	770	0	256	565	na	na	1,177
Cotton	0	na	211	0	1,102	93	3,974
Peanuts	165	104	253	716	na	na	0
Rice	na	na	na	na	179	851	0
Sorghum	na	na	na	na	0	413	2,796
Soybeans	547	581	878	771	2,255	2,432	0
Wheat	1,223	768	0	452	0	527	5,813
Kenaf	85	0	0	13	42	309	144

[a] NC, North Carolina; SC, South Carolina; VA, Virginia; AL, Alabama; FL, Florida; GA, Georgia; MS, Mississippi; AR, Arkansas; LA, Louisiana; OK, Oklahoma; TX, Texas.

[b] na: not applicable.

TABLE B16

CROPPING PATTERNS SOLVED FROM THE QP MODEL AT RISK AVERSION COEFFICIENT = 0.00094, POULTRY LITTER MARKET, BY STATE

	State						
Price	NC	VA	AL	GA	MS	AR	TX
	1,000 acres						
Corn	770	0	256	565	na	na	1,177
Cotton	0	na	212	0	1,102	54	3,974
Peanuts	165	104	253	716	na	na	0
Rice	na	na	na	na	179	851	0
Sorghum	na	na	na	na	0	32	2,796
Soybeans	961	581	877	688	2,011	2,432	0
Wheat	688	768	0	452	57	527	5,813
Kenaf	99	0	0	16	44	339	144

[a] NC, North Carolina; SC, South Carolina; VA, Virginia; AL, Alabama; FL, Florida; GA, Georgia; MS, Mississippi; AR, Arkansas; LA, Louisiana; OK, Oklahoma; TX, Texas.

[b] na: not applicable.

TABLE B17

CROPPING PATTERNS SOLVED FROM THE QP MODEL AT RISK AVERSION COEFFICIENT = 0.0012, POULTRY LITTER MARKET, BY STATE

	State						
Price	NC	VA	AL	GA	MS	AR	TX
	1,000 acres						
Corn	770	0	256	565	na	na	1,177
Cotton	0	na	213	0	1,102	51	3,974
Peanuts	165	104	253	716	na	na	0
Rice	na	na	na	na	179	851	0
Sorghum	na	na	na	na	0	0	2,796
Soybeans	1,254	581	880	678	1,435	2,432	0
Wheat	309	739	0	452	106	527	5,813
Kenaf	108	0	0	16	46	338	144

[a] NC, North Carolina; SC, South Carolina; VA, Virginia; AL, Alabama; FL, Florida; GA, Georgia; MS, Mississippi; AR, Arkansas; LA, Louisiana; OK, Oklahoma; TX, Texas.

[b] na: not applicable.

TABLE B18

CROPPING PATTERNS SOLVED FROM THE QP MODEL AT RISK AVERSION COEFFICIENT = 0.0015, POULTRY LITTER MARKET, BY STATE

Price	State						
	NC	VA	AL	GA	MS	AR	TX
	1,000 acres						
Corn	770	0	256	565	na	na	1,177
Cotton	0	na	214	0	1,102	51	3,974
Peanuts	165	104	253	716	na	na	0
Rice	na	na	na	na	179	851	0
Sorghum	na	na	na	na	545	0	2,796
Soybeans	1,466	581	876	678	987	2,432	0
Wheat	35	631	0	452	114	527	5,813
Kenaf	115	5	0	16	46	338	144

[a] NC, North Carolina; SC, South Carolina; VA, Virginia; AL, Alabama; FL, Florida; GA, Georgia; MS, Mississippi; AR, Arkansas; LA, Louisiana; OK, Oklahoma; TX, Texas.

[b] na: not applicable.

TABLE B19

CROPPING PATTERNS SOLVED FROM THE QP MODEL AT RISK AVERSION COEFFICIENT = 0.00174, POULTRY LITTER MARKET, BY STATE

Price	State						
	NC	VA	AL	GA	MS	AR	TX
	1,000 acres						
Corn	770	0	256	565	na	na	1,177
Cotton	0	na	197	0	1,102	51	3,974
Peanuts	165	104	253	716	na	na	0
Rice	na	na	na	na	179	851	0
Sorghum	na	na	na	na	705	0	2,796
Soybeans	1,450	581	810	678	740	2,432	0
Wheat	0	507	0	452	118	527	5,813
Kenaf	121	10	7	16	46	338	144

[a] NC, North Carolina; SC, South Carolina; VA, Virginia; AL, Alabama; FL, Florida; GA, Georgia; MS, Mississippi; AR, Arkansas; LA, Louisiana; OK, Oklahoma; TX, Texas.

[b] na: not applicable.

TABLE B20

CROPPING PATTERNS SOLVED FROM THE QP MODEL AT RISK AVERSION COEFFICIENT = 0.00185, POULTRY LITTER MARKET, BY STATE

	State						
Price	NC	VA	AL	GA	MS	AR	TX
	1,000 acres						
Corn	770	0	256	565	na	na	1,177
Cotton	0	na	189	0	1,102	51	3,974
Peanuts	165	104	253	716	na	na	0
Rice	na	na	na	na	179	851	0
Sorghum	na	na	na	na	764	0	2,796
Soybeans	1,429	581	780	678	648	2,432	0
Wheat	0	460	0	452	120	527	5,813
Kenaf	123	12	10	16	47	338	144

[a] NC, North Carolina; SC, South Carolina; VA, Virginia; AL, Alabama; FL, Florida; GA, Georgia; MS, Mississippi; AR, Arkansas; LA, Louisiana; OK, Oklahoma; TX, Texas.

[b] na: not applicable.

TABLE B21

CROPPING PATTERNS SOLVED FROM THE QP MODEL AT RISK AVERSION COEFFICIENT = 0.00196, POULTRY LITTER MARKET, BY STATE

	State						
Price	NC	VA	AL	GA	MS	AR	TX
	1,000 acres						
Corn	770	0	256	565	na	na	1,177
Cotton	0	na	189	0	1,102	51	3,974
Peanuts	165	104	253	716	na	na	0
Rice	na	na	na	na	179	851	0
Sorghum	na	na	na	na	817	0	2,796
Soybeans	1,411	581	754	678	566	2,432	0
Wheat	0	419	0	452	121	527	5,813
Kenaf	125	13	13	16	47	338	144

[a] NC, North Carolina; SC, South Carolina; VA, Virginia; AL, Alabama; FL, Florida; GA, Georgia; MS, Mississippi; AR, Arkansas; LA, Louisiana; OK, Oklahoma; TX, Texas.

[b] na: not applicable.

TABLE B22

CROPPING PATTERNS SOLVED FROM THE QP MODEL AT RISK AVERSION COEFFICIENT = 0.0030, POULTRY LITTER MARKET, BY STATE

Price	State						
	NC	VA	AL	GA	MS	AR	TX
	1,000 acres						
Corn	770	0	256	565	na	na	1,177
Cotton	0	na	143	0	1,102	51	3,974
Peanuts	165	104	253	716	na	na	0
Rice	na	na	na	na	179	851	0
Sorghum	na	na	na	na	1,213	0	2,796
Soybeans	1,303	581	601	678	43	2,432	0
Wheat	0	179	0	452	78	527	5,813
Kenaf	138	22	29	16	21	338	144

[a] NC, North Carolina; SC, South Carolina; VA, Virginia; AL, Alabama; FL, Florida; GA, Georgia; MS, Mississippi; AR, Arkansas; LA, Louisiana; OK, Oklahoma; TX, Texas.

[b] na: not applicable.

TABLE B23

CROPPING PATTERNS SOLVED FROM THE QP MODEL AT RISK AVERSION COEFFICIENT = 0, FORAGE MARKET, BY STATE

	State										
Crop	NC	SC	VA	AL	FL	GA	MS	AR	LA	OK	TX
	1,000 acres										
Corn	770	223	0	256	0	565	na	na	na	na	1,177
Cotton	0	0	na	0	na	0	1,102	0	512	502	3,974
Peanuts	165	na	104	253	na	716	na	na	na	112	na
Rice	na	na	na	na	na	na	179	851	349	na	0
Sorghum	na	na	na	na	na	na	0	2,108	0	0	2,796
Soybeans	0	0	581	1,089	176	1,206	3,247	2,432	2,257	0	2,281
Sugarcane	na	na	na	na	441	na	na	na	303	na	na
Wheat	2,529	1,356	768	0	0	452	0	527	0	8,200	5,813
Kenaf	0	0	0	0	0	0	0	0	0	0	0

[a] NC, North Carolina; SC, South Carolina; VA, Virginia; AL, Alabama; FL, Florida; GA, Georgia; MS, Mississippi; AR, Arkansas; LA, Louisiana; OK, Oklahoma; TX, Texas.

[b] na: not applicable.

TABLE B24

CROPPING PATTERNS SOLVED FROM THE QP MODEL AT RISK AVERSION COEFFICIENT = 0.00020, FORAGE MARKET, BY STATE

Crop	State										
	NC	SC	VA	AL	FL	GA	MS	AR	LA	OK	TX
	1,000 acres										
Corn	770	223	0	256	0	565	na	na	na	na	1,177
Cotton	0	0	na	200	na	0	1,102	272	512	502	3,974
Peanuts	165	na	104	253	na	716	na	na	na	112	na
Rice	na	na	na	na	na	na	179	851	349	na	0
Sorghum	na	na	na	na	na	na	0	1,836	0	0	2,796
Soybeans	0	1,356	581	889	176	1,206	3,247	2,432	2,257	2,064	2,281
Sugarcane	na	na	na	na	441	na	na	na	303	na	na
Wheat	2,529	0	768	0	0	452	0	527	0	6,136	5,813
Kenaf	0	0	0	0	0	0	0	0	0	0	0

[a] NC, North Carolina; SC, South Carolina; VA, Virginia; AL, Alabama; FL, Florida; GA, Georgia; MS, Mississippi; AR, Arkansas; LA, Louisiana; OK, Oklahoma; TX, Texas.

[b] na: not applicable.

TABLE B25

CROPPING PATTERNS SOLVED FROM THE QP MODEL AT RISK AVERSION COEFFICIENT = 0.00050, FORAGE MARKET, BY STATE

Crop	State										
	NC	SC	VA	AL	FL	GA	MS	AR	LA	OK	TX
	----	----	----	----	----	*1,000 acres*	----	----	----	----	----
Corn	770	223	0	256	0	565	na	na	na	na	1,177
Cotton	0	0	na	210	na	0	1,102	692	512	502	3,974
Peanuts	165	na	104	253	na	716	na	na	na	112	na
Rice	na	na	na	na	na	na	179	851	349	na	0
Sorghum	na	na	na	na	na	na	0	1,417	0	0	2,796
Soybeans	423	1,356	581	880	176	1,206	3,247	2,432	2,257	2,064	2,281
Sugarcane	na	na	na	na	441	na	na	na	303	na	na
Wheat	2,105	0	768	0	0	452	0	527	0	6,136	5,813
Kenaf	0	0	0	0	0	0	0	0	0	0	0

[a] NC, North Carolina; SC, South Carolina; VA, Virginia; AL, Alabama; FL, Florida; GA, Georgia; MS, Mississippi; AR, Arkansas; LA, Louisiana; OK, Oklahoma; TX, Texas.

[b] na: not applicable.

TABLE B26

CROPPING PATTERNS SOLVED FROM THE QP MODEL AT RISK AVERSION COEFFICIENT = 0.00072, FORAGE MARKET, BY STATE

	State										
Crop	NC	SC	VA	AL	FL	GA	MS	AR	LA	OK	TX
	1,000 acres										
Corn	770	223	0	256	0	565	na	na	na	na	1,177
Cotton	0	30	na	211	na	0	1,102	777	512	502	3,974
Peanuts	165	na	104	253	na	716	na	na	na	112	na
Rice	na	na	na	na	na	na	179	851	349	na	0
Sorghum	na	na	na	na	na	na	28	1,331	0	0	2,796
Soybeans	1,483	1,327	581	878	176	1,206	2,620	2,432	1,863	2,064	2,281
Sugarcane	na	na	na	na	441	na	na	na	303	na	na
Wheat	1,046	0	768	0	0	452	0	527	0	6,136	5,813
Kenaf	0	0	0	0	0	0	559	0	395	0	0

[a] NC, North Carolina; SC, South Carolina; VA, Virginia; AL, Alabama; FL, Florida; GA, Georgia; MS, Mississippi; AR, Arkansas; LA, Louisiana; OK, Oklahoma; TX, Texas.

[b] na: not applicable.

TABLE B27

CROPPING PATTERNS SOLVED FROM THE QP MODEL AT RISK AVERSION COEFFICIENT = 0.00094, FORAGE MARKET, BY STATE

	State										
Crop	NC	SC	VA	AL	FL	GA	MS	AR	LA	OK	TX
						1,000 acres					
Corn	770	223	0	256	0	565	na	na	na	na	1,177
Cotton	0	73	na	212	na	0	1,102	626	512	502	3,974
Peanuts	165	na	104	253	na	716	na	na	na	112	na
Rice	na	na	na	na	na	na	179	851	349	na	0
Sorghum	na	na	na	na	na	na	443	534	0	0	2,796
Soybeans	2,047	1,283	581	877	176	1,206	1,825	2,432	1,459	2,064	2,281
Sugarcane	na	na	na	na	441	na	na	na	303	na	na
Wheat	483	0	768	0	0	452	0	527	0	6,136	5,813
Kenaf	0	0	0	0	0	0	979	949	799	0	0

[a] NC, North Carolina; SC, South Carolina; VA, Virginia; AL, Alabama; FL, Florida; GA, Georgia; MS, Mississippi; AR, Arkansas; LA, Louisiana; OK, Oklahoma; TX, Texas.

[b] na: not applicable.

TABLE B28

CROPPING PATTERNS SOLVED FROM THE QP MODEL AT RISK AVERSION COEFFICIENT = 0.0012, FORAGE MARKET, BY STATE

Crop	State										
	NC	SC	VA	AL	FL	GA	MS	AR	LA	OK	TX
	1,000 acres										
Corn	770	223	0	256	0	565	na	na	na	na	1,177
Cotton	0	105	na	213	na	0	1,102	451	512	502	3,974
Peanuts	165	na	104	253	na	716	na	na	na	112	na
Rice	na	na	na	na	na	na	179	851	349	na	0
Sorghum	na	na	na	na	na	na	737	0	0	0	2,796
Soybeans	2,447	1,252	581	876	176	1,206	1,261	2,432	1,172	2,064	2,281
Sugarcane	na	na	na	na	441	na	na	na	303	na	na
Wheat	83	0	768	0	0	452	0	527	0	6,136	5,813
Kenaf	0	0	0	0	0	0	1,248	1,657	1,085	0	0

[a] NC, North Carolina; SC, South Carolina; VA, Virginia; AL, Alabama; FL, Florida; GA, Georgia; MS, Mississippi; AR, Arkansas; LA, Louisiana; OK, Oklahoma; TX, Texas.

[b] na: not applicable.

TABLE B29

CROPPING PATTERNS SOLVED FROM THE QP MODEL AT RISK AVERSION COEFFICIENT = 0.0015, FORAGE MARKET, BY STATE

	State										
Crop	NC	SC	VA	AL	FL	GA	MS	AR	LA	OK	TX
	1,000 acres										
Corn	770	223	0	256	0	565	na	na	na	na	1,177
Cotton	0	127	na	214	na	0	1,102	368	512	502	3,974
Peanuts	165	na	104	253	na	716	na	na	na	112	na
Rice	na	na	na	na	na	na	179	851	349	na	0
Sorghum	na	na	na	na	na	na	950	0	0	0	2,796
Soybeans	2,529	1,229	581	876	176	1,206	853	2,432	965	2,064	2,281
Sugarcane	na	na	na	na	441	na	na	na	303	na	na
Wheat	0	0	768	0	0	452	0	527	0	6,136	5,813
Kenaf	0	0	0	0	0	0	1,443	1,740	1,293	0	0

[a] NC, North Carolina; SC, South Carolina; VA, Virginia; AL, Alabama; FL, Florida; GA, Georgia; MS, Mississippi; AR, Arkansas; LA, Louisiana; OK, Oklahoma; TX, Texas.

[b] na: not applicable.

TABLE B30

CROPPING PATTERNS SOLVED FROM THE QP MODEL AT RISK AVERSION COEFFICIENT = 0.00174, FORAGE MARKET, BY STATE

Crop	NC	SC	VA	AL	FL	GA	MS	AR	LA	OK	TX
	1,000 acres										
Corn	770	223	59	256	0	565	na	na	na	na	1,177
Cotton	0	140	na	214	na	0	1,102	322	512	502	3,974
Peanuts	165	na	104	253	na	716	na	na	na	112	na
Rice	na	na	na	na	na	na	179	851	349	na	0
Sorghum	na	na	na	na	na	na	1,056	0	0	0	2,796
Soybeans	2,529	1,217	581	876	176	1,173	625	2,432	851	2,064	2,281
Sugarcane	na	na	na	na	441	na	na	na	303	na	na
Wheat	0	0	673	0	0	452	20	527	0	6,136	5,813
Kenaf	0	0	37	0	0	34	1,546	1,786	1,407	0	1,357

[a] NC, North Carolina; SC, South Carolina; VA, Virginia; AL, Alabama; FL, Florida; GA, Georgia; MS, Mississippi; AR, Arkansas; LA, Louisiana; OK, Oklahoma; TX, Texas.

[b] na: not applicable.

TABLE B31

CROPPING PATTERNS SOLVED FROM THE QP MODEL AT RISK AVERSION COEFFICIENT = 0.00185, FORAGE MARKET, BY STATE

	State										
Crop	NC	SC	VA	AL	FL	GA	MS	AR	LA	OK	TX
	1,000 acres										
Corn	770	223	65	256	0	565	na	na	na	na	1,177
Cotton	0	133	na	214	na	0	1,102	305	512	502	3,974
Peanuts	165	na	104	253	na	716	na	na	na	112	na
Rice	na	na	na	na	na	na	179	851	349	na	0
Sorghum	na	na	na	na	na	na	1,092	0	0	0	2,796
Soybeans	2,529	1,173	581	875	176	1,074	539	2,432	808	2,064	256
Sugarcane	na	na	na	na	441	na	na	na	303	na	na
Wheat	0	0	609	0	0	452	31	527	0	6,136	5,813
Kenaf	0	50	94	0	0	132	1,584	1,803	1,364	0	2,025

[a] NC, North Carolina; SC, South Carolina; VA, Virginia; AL, Alabama; FL, Florida; GA, Georgia; MS, Mississippi; AR, Arkansas; LA, Louisiana; OK, Oklahoma; TX, Texas.

[b] na: not applicable.

TABLE B32

CROPPING PATTERNS SOLVED FROM THE QP MODEL AT RISK AVERSION COEFFICIENT = 0.00196, FORAGE MARKET, BY STATE

Crop	State										
	NC	SC	VA	AL	FL	GA	MS	AR	LA	OK	TX
	1,000 acres										
Corn	770	223	71	256	0	565	na	na	na	na	1,177
Cotton	0	118	na	214	na	0	1,102	290	512	502	3,974
Peanuts	165	na	104	253	na	716	na	na	na	112	na
Rice	na	na	na	na	na	na	179	851	349	na	0
Sorghum	na	na	na	na	na	na	1,125	0	0	0	2,796
Soybeans	2,400	1,099	581	875	176	987	463	2,432	766	2,064	0
Sugarcane	na	na	na	na	441	na	na	na	303	na	na
Wheat	0	0	552	0	0	452	41	527	0	6,136	5,813
Kenaf	129	140	145	0	0	219	1,618	1,818	823	0	2,281

[a] NC, North Carolina; SC, South Carolina; VA, Virginia; AL, Alabama; FL, Florida; GA, Georgia; MS, Mississippi; AR, Arkansas; LA, Louisiana; OK, Oklahoma; TX, Texas.

[b] na: not applicable.

TABLE B33

CROPPING PATTERNS SOLVED FROM THE QP MODEL AT RISK AVERSION COEFFICIENT = 0.0030, FORAGE MARKET, BY STATE

	State										
Crop	NC	SC	VA	AL	FL	GA	MS	AR	LA	OK	TX
	1,000 acres										
Corn	770	223	105	256	0	565	na	na	na	na	1,177
Cotton	0	29	na	215	na	0	1,102	202	512	502	3,974
Peanuts	165	na	104	253	na	716	na	na	na	112	na
Rice	na	na	na	na	na	na	179	851	349	na	0
Sorghum	na	na	na	na	na	na	1,357	0	0	0	2,796
Soybeans	1,576	666	581	875	176	678	0	2,432	480	2,064	0
Sugarcane	na	na	na	na	441	na	na	na	303	na	na
Wheat	0	0	221	0	0	452	31	527	0	6,136	5,813
Kenaf	953	660	442	0	0	528	0	1,906	0	0	2,281

[a] NC, North Carolina; SC, South Carolina; VA, Virginia; AL, Alabama; FL, Florida; GA, Georgia; MS, Mississippi; AR, Arkansas; LA, Louisiana; OK, Oklahoma; TX, Texas.

[b] na: not applicable.

VITA 2

Jun Zhang

Candidate for the Degree of

Doctor of Philosophy

Thesis: A STUDY OF ECONOMIC FEASIBILITY OF U.S. KENAF MARKETS

Major Field: Agricultural Economics

Biographical:

Personal Data: Born in Ma Anshan, Anhui Province, P.R. China, September 21, 1962, the son of Mr. Zhengwan Zhang and Mrs. Zhimin Shu.

Education: Received Bachelor of Arts degree in English and American Literatures from Wuhan University in July 1984; received Master of Science degree in Agricultural Economics from Alcorn State University in December 1990; completed requirements for the Doctor of Philosophy degree at Oklahoma State University in May 1994.

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