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A MARKETING STUDY OF FINE WOOD RESIDUE
IN SOUTHERN LOWER MICHIGAN

By

astings

Harley H. Thomas, III

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ABSTRACT

A MARKETING STUDY OF FINE WOOD RESIDUE
IN SOUTHERN LOWER MICHIGAN

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Harley H. Thomas, III

Historically, grade lumber has been the primary product of most hardwood sawmills in Michigan and the utilization of wood residue has amounted to a disposal problem. Consequently, burning residues in the open or in teepee burners or dumping it at the back of the already crowded mill site has been the quick, inexpensive means used to eliminate vast quantities of residue materials from the mill site. Today, new federal and state air pollution legislation is beginning to restrict waste burning. As a result, the production-oriented sawmill operator may be forced to select some alternative in an effort to dispose of wood residues.

Last year (1968), 150 hardwood sawmills in forty-one southern lower Michigan counties alone produced approximately 500,000 tons of wood residue while processing an estimated 171 million board feet of hardwood lumber. It is only reasonable to assume that this great quantity of residue could provide support for even more new industries and serve as the basis for expanding the profit margin of many existing industries.

Currently, a few markets are developing for sawdust and bark where the use of wood residue is considered a natural; such as animal bedding, poultry litter, soil improvement, and mulch. These basically agricultural and horticultural markets have a lot of potential in southern Michigan, but they will not expand to any degree without the aid of product information, advertising, a marketing program, and establishment of a dependable source of supply.

In an effort to stimulate interest in greater wood residue utilization and to compile the necessary facts upon which a residue processing plant could be established, the research study was initiated. The primary portion of the study centered around the development of an original heuristic simulation model which could be used as a management decision-making tool. The simulation is used in determining whether or not it is currently economically feasible for a processing plant to geographically concentrate and process sawdust and bark from hardwood sawmills on a large scale for sale to agricultural and horticultural markets. The secondary portion of the study investigated the present wood disposal situation at the sawmill site and the current use of sawdust and bark products in bulk quantities by dairy farmers, orchard growers and tree nurseries and the sale of packaged bark products by lawn and garden centers.

A field survey was conducted among sawmill operators, at which time general information was gathered and photographic documentation was made of the residue disposal problem. Following the field survey, a mail survey was administered among the majority of sawmill operators to obtain specific wood residue handling and disposal data. To aid in determining the feasibility of a residue processing plant, a simulation model was developed. The model evaluates the potential success of a processing plant which purchases bark and sawdust, provides inbound transportation, processes the raw material and sells the finished product f.o.b. plant in relation to current agricultural and horticultural market opportunities.

Costs in the simulation are evaluated using the cost center concept. The location and size of both raw material supply and market demand surrounding any given processing plant location constitutes a market configuration. Many configurations were evaluated during the research and analysis, with three being included in the study as typical examples supporting the findings.

The findings supported, even though in many cases on a marginal basis, the hypothesis that there presently exist agricultural and horticultural markets for fine sawmill residues, and that transformation of the sawmill residue disposal problem into a source of income through the establishment of a firm to collect, process and market bark and sawdust is economically feasible.

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PART I

UTILIZING WOOD RESIDUES--A PROBLEM AREA

Introduction

More complete utilization of forest resources must be the goal of our forest products industries if they are to maintain favorable economic growth. Because of new restrictions on air pollution, increasing competition from other materials and rising labor and transportation costs, the wood-using industries have begun to scrutinize their costs for possible reductions. Wood residues are one of the prime areas where this can be done.

Sawmills produce wood residue consisting of slabs, edgings, trimmings, sawdust, shavings and bark which accumulate incidental to the manufacturing of lumber. Within the sawmill industry only an average of 57 percent of the log is currently utilized for the primary product, lumber. The remaining 43 percent ends up as sawmill residue. This residue is commonly called wood waste and, by the connotation, unfortunately portrays the erroneous idea of having little value.

There are presently many uses for wood residues, but numerous economic factors impose limitations that frequently make residue utilization unfeasible. Transportation costs and concentration of residues are factors that often cause economic roadblocks to utilization. It is obvious that uses for residues must pay their way or much of the material will continue to remain unused. Once wood residue markets are established as a paying proposition the cost of residue disposal will be transformed into additional income for the sawmill operator. To date very little progress has been made in the development of Michigan markets for wood residue based products.

Statement of the Problem

The successful utilization of any material requires the consideration of many factors. A thorough understanding of the material itself is essential. More specifically in the case of wood residue this includes knowledge about available quantities, species, sawmill location, properties and characteristics of the wood residues themselves. Equally as important, if a marketing program is to be developed, is a knowledge of uses, consumer requirements, markets, processing methods, capital investment, operating costs and returns. Obviously, individual circumstances regarding these factors will largely dictate which uses will be most advantageous.

It is generally accepted that data are available on the quantity of wood residue available in the State of Michigan. To date, most wood residue research efforts have been directed toward improving lumber production and increasing the utilization of coarse sawmill residue (slabs, edging and trim). Out of this research came the wood hog and chipper which have made coarse residue more compatible with fuel requirements and pulp chips, respectively. Converting coarse residue to pulp chips has been progressing very well in Michigan and the economic picture continues to improve.

The fine residues, sawdust and bark, have not been as fortunate as coarse residue in finding adequate markets. Even more than the coarse residues, the fine residues have often been considered over the years as only another disposal problem. At first bark and sawdust were used as fuel or disposed of in a variety of ways. Recently other uses have been developing which continue to make both bark and sawdust more valuable. Some of the first uses were directed toward using sawdust as a floor sweeping compound or charcoal briquets, but limiting factors such as (1) the high bulk of the product, (2) scattered sawmill locations, and (3) small quantities produced at each of the mills have severely limited the growth of such markets.

To most sawmill operators, disposing of hardwood sawdust and bark represents a cost not only in dollars but in valuable space occupied, increased fire risks, insurance problems, and investments tied up in equipment.

The direct costs of disposal alone encourage many operators to look for another way out. These costs range from $0.25 to $0.50 per thousand board feet of lumber produced. At $0.50 per thousand board feet, this amounts to $2,500 per year for a sawmill cutting 20,000 board feet daily. Annual insurance rates may increase as much as eight percent when residues are piled or burned near a mill.

Disposal costs will increase for many operators--especially those nearest to urban areas. New air-pollution codes and strict enforcement of current laws will force some operators to install pollution control devices on their teepee burners or change from burning to dumping.

Currently, a few markets are developing for sawdust and bark where the use of wood residue is considered a natural, such as animal bedding, poultry litter, soil improvement, mulch, and some pressed-wood products. These markets have a lot of potential in southern Michigan, but they will not expand to any degree without the aid of product information, education, a marketing program, and establishment of a dependable source of supply.

The sawmill industry and the individual sawmill owners are typically production oriented rather than market oriented. If they choose not to develop the markets or to show interest in supplying raw material to a processor, one of two things will happen: (1) it is conceivable that an independent operator will initiate a marketing program for sawdust and bark products, concentrating and processing them as necessary, or (2) the sawmills in general will continue to maintain an indifferent attitude and keep the status quo with the residue disposal problem becoming even worse, and a substantial profit opportunity will be overlooked.

Background

Historically, grade lumber has been the primary product of most hardwood sawmills in Michigan and the utilization of wood residue has amounted to a disposal problem. Consequently, burning residues in the open or in teepee burners or dumping it at the back of the already crowded mill site have been the quick, inexpensive means used to eliminate vast quantities of residue materials from the mill site. Today, new federal and state air pollution legislation is beginning to restrict waste burning. As a result, the production-oriented sawmill operator may be forced to select some alternative in an effort to dispose of wood residues.*

*See Glossary for definition.

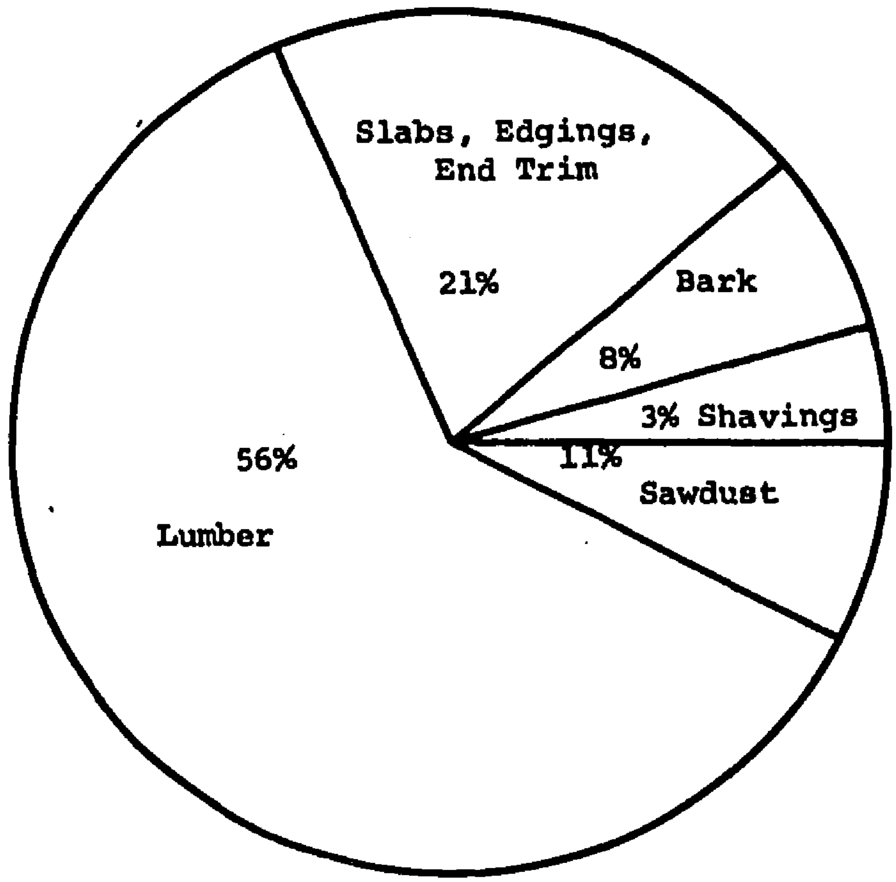
Coarse residues, consisting of slabs, edgings and trimming, constitute 21 percent of the total log volume. Fine residues, bark, sawdust and shavings, constitute 22 percent ofthe total by volume. Figure 1 shows the average percentages of materials that result in the process of converting a log into lumber at the sawmill.

Of these two residue classes, only coarse residue has received the necessary attention from the wood industry to develop adequate processing systems and markets. The reason for this trend is that each individual sawmill in Michigan is relatively small and interested primarily in the production of lumber. Because of this size limitation, sawmill operators have given very little thought to the wood residues that accumulate incidental to the production of lumber other than disposing of them through inexpensive methods.

Last year (1968), 150 hardwood sawmills in forty-one southern lower Michigan counties alone produced approximately 500,000 tons of wood residue while processing an estimated 171 million board feet of hardwood lumber. It is only reasonable to assume that this great quantity of residue could provide support for new industries and serve as the basis for expanding many existing industries.

Current indications are that immediate markets for large quantities of fine sawmill residue do exist and could

Figure 1. Materials Resulting From Sawlog Breakdown



be developed at a reasonable cost (8). Background information from sawmill operations on the west coast reveal that some sawmills have been actively processing wood residues and developing markets for some time. This information is cited in support of the idea that wood residue processing can also be done in Michigan.

From a preliminary investigation, indications were that a reasonable amount of opportunity may exist in Michigan for a firm to become established solely on the processing and marketing of wood residue based products. The proposed firm would purchase and concentrate hardwood bark and sawdust from several sawmills at one or more selected processing locations. The material would then be processed as necessary, scheduled for packaging or sale in bulk, the finished goods stored, and promotion and advertising done according to a basic marketing plan. The end result would be the beginning of a formal utilization program for sawdust and bark that would add to the economic growth of Michigan and effectively utilize our wood resources.

Scope of the Study

The material in the study covers several areas. To describe the scope of the study in the most logical order, the individual parts are discussed in order of presentation. Part

II concerns a review of the literature in two areas: (1) the function of mulches and soil conditioners, the common misconceptions that surround their use, and how crops respond to their use, and (2) simulation as an analytical technique used in management decision making.

Part III concerns the research design portion of the study and is broken down into three phases. Phase I contains the research support data, including study assumptions, definitions, and the adoption of wood residue conversion factors used to compute residue quantities in the study. Phase II details the hardwood sawmill residue survey which is broken down into a field study portion and a mail survey portion. Important information is obtained through the use of both surveys which is in turn used in Phase III.

In each survey the primary purpose was to obtain reasonably accurate information about wood residue quantities produced at each sawmill and associated cost data that would contribute to the development of a realistic residue processing simulation. The processing plant included in the study is a hypothetical one with realistic characteristics. The processing plant functions as the center of the simulation in that all raw materials must be brought to, and processed through, the plant. The cost centers within the processing plant are described and the effect of individual variations are discussed.

Phase III describes the simulation program, the cost center concept, processing plant costs, inputs and outputs of the processing plant, and how the simulation functions as a management decision-making tool for analyzing processing configurations. Three processing configurations are included to show the variety of results obtained from different configurations. Each configuration will have different sawmills supplying the raw material and different counties included in the demand. This is readily done by changing the geographic locations of the processing plant.

Important in each configuration are the markets to be considered for products produced by the processing plant. In the study the markets will be limited to agricultural and horticultural markets since the literature cites these as being the most logical ones at a time when wood residue utilization is just beginning. The dairy industry, the nursery and orchard industry, and the home lawn and garden markets are the only ones included in the study. The lawn and garden market is considered to be a packaged product market; all the others are bulk markets. Estimates of market size are included in the study.

Part IV presents the findings of Phase II, the field and mail survey. Supporting the visual observations made during the field survey is a photographic documentation of wood residue characteristics and sawmill residue disposal methods. Details of the mail survey sent to 106 selected sawmills in lower Michigan describe the methods different sawmills are using to dispose of wood residues and the problems therein. Data which generally point out a lack of interest, on the part of sawmill owners, in wood residue utilization are presented in the form of numerous tables accompanied by brief narrative comments.

Part V discusses the findings of the simulation, described in Phase III, in relation to the hypotheses set forth in Part I. The resulting effect will be to prove or disprove the hypotheses.

Part VI contains the author's summary, conclusions and implications regarding the potential for a wood residue processing plant in Michigan.

Hypotheses

Information about the characteristics of wood residue, the supply and location of raw materials, and the location and potential of markets, is all essential to the intelligent planning of a processing plant which will accumulate and process sawdust and bark into products for selected agricultural and horticultural markets. The method chosen to aid in the evaluation of the basic factors is computer simulation. Ultimately the simulation can process great quantities of data and act as a tool in evaluating the profitability of given market configurations. The simulation will also be able to illustrate the effect on profitability by changing the raw material supply area, raw material costs, competition, inbound transportation, market demand, plant production capacity, processing costs, or price of finished goods.

The thesis of the research study is that there presently exist agricultural and horticultural markets for fine sawmill residues, and that transformation of the sawmill residue disposal problem into a source of income through the establishment of a firm to collect, process, and market the material is economically feasible.

The testable hypotheses are as follows:

H_{o1} Agricultural and horticultural use of sawdust and bark in bulk units dictates a raw material positioned processing unit.

H_{o2} As scale of operations increase, unit costs will decrease up to an optimum size.

H_{o3} The type of raw material used as product input (i.e., sawdust or bark) will influence the location of the processing unit.

The study is formulated to accomplish the following secondary objectives:

1. Evaluate the present sawmill residue utilization situation by both field survey and mail questionnaire.

2. Evaluate current agricultural and horticultural market demand for sawdust and bark.

3. Adopt a set of wood residue conversion factors which reasonably represent the residue produced by hardwood sawmills in southern Michigan.

4. Summarize the functions of bark and sawdust mulches and soil amendments, and the acceptability of their use in relation to the soil.

5. Present photographic documentation of wood residue types and the various methods of handling and disposal used by sawmills.

6. Assemble current wood residue type, volume and location data for use by both producers and potential consumers of sawmill residue in southern lower Michigan.

Methodology

To determine what had been written about the utilization of wood residues, a review of the technical and promotional literature and reports of various individuals, associations, and government agencies was made. This initially involved a thorough search of the Michigan State University and University of Missouri library resources. Two of the most comprehensive wood industry trade journals, The Forest Products Journal and Wood and Wood Products, were extensively researched. Then, to find out what wood residue utilization programs were in progress or had been completed recently, letters were sent to all universities with forestry programs, all U.S.D.A. Agriculture Experiment Stations, all U.S.F.S. Research Stations, the Southern Pine Association, Western Wood

Products Association, and the Forest Products Laboratory in Madison, Wisconsin.

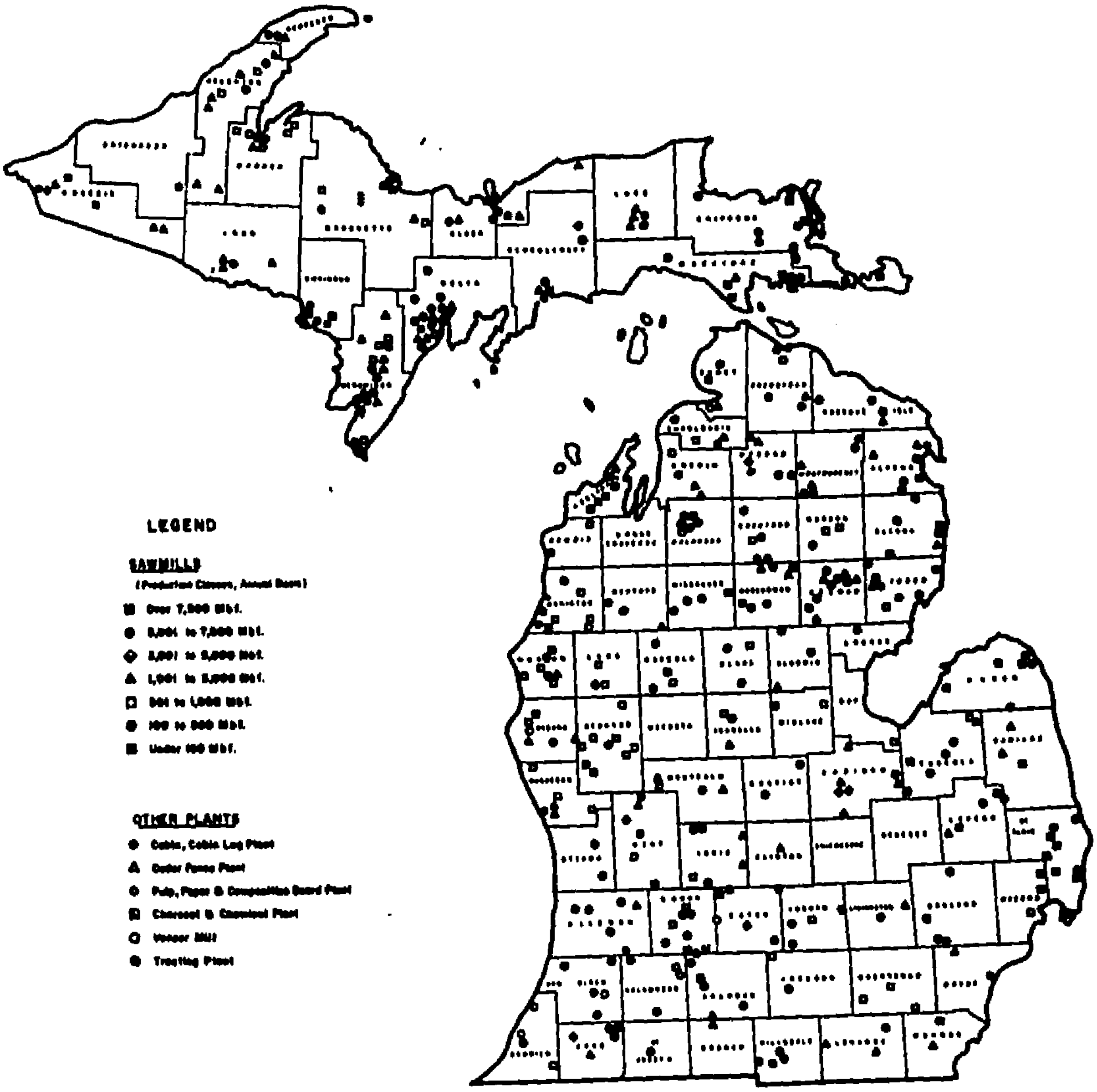
The major objective was to accumulate available research data as background material for this study and to avoid unnecessary duplication of previous research.

Wood residue conversion factor data used to compute quantities of residues produced during sawmilling was secured through library research of wood industry publications. Information about heuristic simulation techniques was likewise obtained from researching the business management and marketing literature and textbooks.

A field survey of hardwood sawmills was designed and completed in the southern forty-one counties of lower Michigan. Only sawmills shown in Figure 2 and listed in the 1968 Directory of Wood Using Plants in Michigan (7) were considered for the sample.

Data collection was done by personal interview and photographic documentation. The survey was designed to better acquaint the author with the actual wood residue problem and to obtain first-hand information about wood residue handling, disposal, and the attitude of sawmill operators toward the local market potential for wood residues. Incorporated into the above survey were planned visits to the most logical markets for wood residues, see Appendix C-3.

Figure 2. **LOCATION OF PRIMARY WOOD USING PLANTS**
-1968-



The mail survey was completed using the mail questionnaire in Appendix A. The mail questionnaire was designed to obtain detailed information about the quantities of wood residues produced by sawmills and how individual mills handle and dispose of sawdust and bark. A sample of 106 sawmills was chosen to receive mail questionnaires.

In the development of an original and highly specialized computer simulation, which has the capability to handle raw material supply data, market demand data, cost center data, and the many control parameters of a bark and sawdust processing plant, several distinct steps were involved. The major steps are outlined on the following two pages. The actual computer program, prepared with the assistance of a professional programmer in the office of Applications Programming of the M.S.U. Computer Center, is included in Appendix D.

Step One: The simulation program designed for this study utilizes a uniform grid system for measuring distances and points. Before the processing plants could be located and the supply data or demand data used as data inputs, the exact location of all 150 operational sawmills and the center point of each county included in the southern Michigan study area were plotted on a grid overlay of a Michigan map.

Step Two: The geographic location of all mills in the study were obtained from a detailed locator card file prepared by the men in M.S.U. Forestry Extension. The four digit coordinates of all 150 sawmills were recorded. These data were stored on punched cards for later use in the actual simulation. They were used in measuring distances and computing transportation costs for various configurations surrounding selected processing plant coordinate points.

Step Three: To determine the quantities of each type wood residue produced by hardwood sawmills, incidental to the production of hardwood lumber, a set of wood residue conversion factors were adopted from previous research. The conversion factors are detailed in Phase I of Part III. These calculations were made for each sawmill using the annual production figures reported on the mail questionnaire. The resultant quantities estimated for each of the 150 sawmills and each of the forty-one counties are shown in Appendix B.

Step Four: Demand data was next to be determined. Total market size and market share estimates for dairy cattle bedding, orchard mulch, nursery mulch, mulches and soil conditioners for the lawn and garden markets in southern Michigan were made and the quantities demanded by each market shown in tons per county, see Table 9.

Step Five: The processing plant is considered to be the center point (hub) of the simulation. The methodology used in this section is focused on material flow through the processing plant and should bring about a better understanding of the operation to the reader. The cost center concept utilized to keep a logical accounting of the various types of costs involved in the total processing plant concept and details of the processing plant activities are shown in Phase III of Part III.

The actual computer simulation program which evaluates the supply and demand relations relative to the cost centers and determines the profitability of selected configurations is shown in Appendix D.

Limitations

The field survey was not restricted by any major limitations, although the ideal situation would have included time during the field survey for on-site measurement of residues produced by each sawmill in the study rather than adopting conversion factors developed elsewhere. However, the author feels that this shortcoming was somewhat offset by knowledge gained during the field survey and cross-checking of mail questionnaire responses.

The basic limitation, with respect to the mail survey, was the difficulty of having all questions in the questionnaire answered completely and determining the accuracy of the answers.

A second limitation resulted from insufficient funds to support a 100 percent survey; therefore, data from over 100 small, but important, E, F and LTF-class sawmills had to be estimated from a random sample of 12.

The mail questionnaire is limited in the amount of information that can be asked at any one time; therefore, much information about the sawmill industry and wood residues remains unknown.

The computer simulation used as an aid in the market analysis is limited, as far as the wood industry is concerned, to rather specific applications. It is designed to include only sawmills as suppliers of wood residue products to one specific type of processing plant. Because of the established logic this part of the program cannot be changed.

Confining the market study to the agricultural and horticultural applications of wood residues also constitutes a limitation. Other industries such as those making floor sweeping compound, charcoal, paper, wood fiber products, pressed wood products and others present additional profitable market opportunities. As the technology is developed and the economic situation becomes increasingly favorable, bark and sawdust will be used as a raw material for more and more products.

The study area included in the simulation was chosen arbitrarily and is limited geographically to the forty-one counties in southern lower Michigan. This area includes all counties within a 100-mile radius of Lansing. Within this area of southern lower Michigan is located over eighty percent of the hardwood growing stock and hardwood sawmills, most of the dairy, nursery, orchard, lawn and garden markets, and over ninety-five percent of the population.

Contributions

Two major contributions of the field survey came out of the opportunity to personally visit fifty sawmills in lower Michigan, exchanging information with the sawmill owners and operators about wood residue utilization technology and potential, and photographing the various wood residue handling systems and methods of disposal. This documentation is available, on a limited basis, in the body of the study. The conversation was, in many cases, the initiation of wood residue utilization awareness, and the photographs are valuable in that they point out the tremendous waste of sawmill residues and help to make the case for increased wood utilization. The bulk of the color slides and black and white photographs were collected for the M.S.U. Forestry Department Extension Staff who will use them to plan future extension programs and research studies of the various sawmill operations.

During the field survey samples of various types of wood residues were collected, photographed and included in the study. In presenting photographs of various residue types is important to present utilization potential because it is now possible for persons not familiar with the sawmill process to compare the physical characteristics of the different residue materials.

The mail survey represents a valuable contribution of new knowledge to the Michigan sawmill industry. Quantities of original data were successfully collected from two-thirds of the hardwood sawmills in southern lower Michigan, including lumber production data, operating days per year, equipment owned by the sawmills, the methods they currently use to dispose of wood residues, amount of residue marketing and advertising done, and the amounts and prices of residues sold.

The data is made available in this report and the new profit opportunity should serve as a stimulus to the sawmill industry to improve wood residue marketing efforts and will also serve as a price and information guide to markets interested in purchasing quantities of residue.

With the initiation of a marketing program for bark and sawdust products the problem of air pollution from the previous burning of these materials by sawmills will be significantly reduced. During this time when much attention is focused on air pollution any method of reducing the problem would be considered a positive contribution.

An original heuristic simulation was developed as a marketing management tool to determine the profitability of wood residue processing on a large scale. The methodology used is not new, but the application of this specific analysis technique to the sawmill industry is considered a significant contribution. The secondary value of this computer simulation comes from the fact that it is not limited to use only in Michigan, but has the potential for broad applications throughout the sawmill industry.

The real value of the simulation comes from its potential value as an aid to management decision making. For example, using this simulation it is possible to determine the quantities of raw materials within a radius of a chosen point, transportation costs to these points can easily be determined, the effect on unit cost can be seen by increases or decreases in raw material cost, transportation rates, or processing costs. Speed and accuracy as well as simultaneous consideration of multiple factors is made possible by using simulation.

Organization

The remaining sections of the study consist of five chapters, each concentrating on a specific aspect of the research. Part II is a review of the literature.

The third Part is a discussion of the research design used in the study. The Part is divided into three phases. Phase I deals with general research support data that are used in the study as a whole. Phase II concentrates on the design of the two hardwood sawmill residue surveys; one a field survey, the other a mail survey. Phase III discusses the design of the simulation and the important factors that are included in the basic simulation system.

Part Four of the dissertation discusses the findings relative to the surveys outlined in Phase II. The discussion centers on the information obtained by the two surveys.

The fifth Part discusses the findings resulting from the computer simulation configuration designed in Phase III.

Part Six presents the conclusions drawn from the results presented in Parts Four and Five. In addition, Part Six discusses the implications of the conclusions and makes suggestions for further research based on the findings of the present study.

PART II

LITERATURE

Introduction

Due to the nature of this study, the literature in a number of areas which relate to the research problem was consulted, but a review of literature for this research study covers only the first two of the following three areas:

1. The heuristic approach to problem solving.
2. The use of fine wood residues in agricultural and horticultural applications.
3. Development and application of wood residue conversion factors.

Research on each of these topics has been conducted independently from each of the others. Of the three basic areas mentioned above, the author does not consider it necessary to duplicate a review of wood residue conversion factors literature for the following reasons.

Only a very few studies have been designed to study wood residue conversion factors. Such studies have often been limited in application to other parts of the United

States and do not apply in this study because of differences in climate, species, soil conditions, and other influences. In most cases the studies were extremely brief in their description of methodology and results; therefore, for the convenience of persons interested in various methods of determining or applying wood residue conversion factors the best articles are footnoted below in order of significance (8) (28) (32) (41) (51).

For purposes of this research study, wood residue conversion factors were adopted from King (32) because of his systematic approach to the problem and study of hardwood species with characteristics similar to those growing in Michigan.

Heuristic Simulation

Very little information is available on the application of heuristic simulation as used in the study because it is an original program; therefore, because there are many who are unfamiliar with heuristics, some of the literature included in this review will discuss heuristics as an approach to problem solving.

Webster's New International Dictionary of the English Language defines the adjective "heuristic" as "serving to discover or reveal." Heuristics, after Newell, Shaw and

Simon (39), are defined as principles or devices that contribute, on the average, to reduction of search in problem-solving activity.

Simon (52) has referred to heuristics as rules of thumb selected on the basis that they will aid in problem solving. In an earlier paper, Simon, in collaboration with Newell and Shaw, used the term "heuristic" to denote "any principle or device that contributes to the reduction in the average search to a solution" (39). Making use of the latter definition, a heuristic program can be defined, after Tonge (56), as a problem-solving program organized around such principles or devices. Simon (52) has distinguished between such programs and algorithms on the basis that only the latter guarantee solution of the problem to a desired degree of accuracy.

Kuehn and Hamburger (33) do not believe that this is the most appropriate way to characterize heuristic programs. They report the existance of many solution procedures, referred to as algorithms, which do not guarantee solutions to a desired degree of accuracy; but rather, as is possible with the heuristic warehouse location program, provide only upper and lower bounds to the solution. An example from Kemeny and Thompson (31) is the fictitious play method for solving matrix games. Furthermore, Courant and Robbins (18) report the definition of algorithm generally used by mathematicians is "a systematic method for computation." Such a definition would include all computer programs.

For purposes of the study, heuristic simulation is considered to be an approach to problem solving where the emphasis is on working toward optimum solutions rather than optimum solutions. Tonge (56) supports this approach by saying heuristic techniques are most often used when the goal is to solve a problem whose solution can be described in terms of acceptability characteristics rather than by optimizing rules.

Bowersox, Smykoy and LaLonde (16) and Reynolds (45) discuss the development of a computer program for a heuristic simulation as a systematic order that closely parallels the thought process of the human mind. This step-like procedure of adding facilities allows managerial review of system development with related explanation of logic at each step. Thus, the solution, once derived, requires little managerial interpretation. Two limitations are also pointed out: First, heuristics does not necessarily result in selection of the best network among those facilities that appear plausible; and, secondly, although managerial intervention eases the process of understanding study results, the possibility of bias remains a constant danger.

Basic applications of the technique are varied. Tonge (55) has prepared a heuristic program to balance production assembly lines in an appliance factory. Clarkson and Meltzer (19) have prepared a heuristic program to simulate investment activity under a trust fund. While no formal results have yet been published, Gere (24) has made several attempts to construct heuristic programs for the job shop scheduling problem. Shycon and Maffei (50) use heuristic simulation techniques in the modeling of warehouse networks because of built-in flexibility which allows for rapid changes as required by new management decisions.

Recent interest in the heuristic approach to problem solving has led to the development of computer programs designed to: compose music (29), play checkers (49), play chess (13) (38), discover proofs for theorems in logic and geometry (40) (23), design electric motors and transformers (27), balance assembly lines (55), and locate warehouses (33).

Of the many applications of heuristics, the one used by management that most closely approximates the processing plant feasibility problem in the study is distribution warehouse location as discussed by Kuehn and Hamburger (33). The processing plant is the "hub" of the simulation and requires an efficient concentration system of raw material supply from many scattered sawmill locations. Similarly, the distribution warehouse is the "hub" of a system, but works in reverse to efficiently distribute goods to many locations.

According to Kuehn and Hamburger (33) the use of heuristics in problem solving has two prime advantages relative to the currently available linear programming formulations and solutions procedures: First, computational simplicity, which results in substantial reductions in solution times and permits the treatment of large-scale problems; Second, flexibility with respect to the underlying cost functions, eliminating the need for restrictive assumptions. It also represents an important extension to the simulation approach to locating warehouses in that it incorporates a systematic procedure designed to generate at least one near-optimal distribution system without reducing flexibility in the modeling of the problem.

Wood Residues as Mulches and Soil Conditioners

It is generally accepted that both bark and sawdust make excellent cattle bedding. Cattle bedding is also the largest current market for these materials. Because extensive use of either material for this purpose currently hinges on the economics of transportation and availability of substitute bedding materials, a review of the literature covering this point is considered unnecessary. Primary emphasis of this portion of the literature review will focus upon bark and sawdust and their relation to the soil as mulches and soil conditioners.

The principal uses of wood residues in agriculture and horticulture are for mulches and soil conditioners (30). Mater reports that both sawdust and bark are widely used for both purposes in some sections of the country (36). Whether employed as mulches or soil conditioners, wood residue, as it decomposes, results in complex transformations of carbon and nitrogen and ultimately supplements the soil humus. The humus, in turn, improves the tilling properties of soil and serves as a reservoir for nitrogen, phosphorous, potassium, sulfur, and other plant nutrients as well as water. The nutrients bound to the humus are slowly released and made available for plant growth by the action of soil organisms.

Benefits of Wood Residues as Mulches and Soil Conditioners

Wood residues are used as soil covers or mulches, or may be mixed with the soil to improve the physical and chemical properties. Dudley and Kelly (20) found that when used as a mulch, water intake is increased, runoff and erosion are decreased, soil temperature is lower, water loss through evaporation is decreased, weeds are controlled to some extent, and it offers a pleasing appearance. In comparison with leaves and straw, Bollen and Glennie (14) found that wood residues are more easily applied, longer lasting, less susceptible to blowing and fire, and more pleasing in appearance.

Dunn and Emery (21) and Wilde (61) reported that when incorporated with the soil, wood residues improve friability and prevent crust formation as effectively as peat moss, improve tilth in fine textured soils as effectively as peat, increase initial infiltration rate, improve aeration, produce more rapid flowering of some plants and lower bulk density of soils. Although increased moisture retention is often given as an advantage of soil amendments, Lunt and Clark (35) state that the incorporation of coarse organic matter in soil decreases rather than increases moisture-holding capacity and that evaporation rates are increased unless a mulch is also used.

In certain cases, Lunt and Clark (35) report that potassium and phosphorus derived from bark appear to make a contribution to plantings for short periods, but, generally, undecomposed sawdust (and bark) would seldom be worth the cost of hauling if its only value was to supply mineral nutrients. Allison and Anderson (1) support this by saying "The principal effect of bark and wood particles on the macro-element nutrition of plantings in soil mixes is that to be expected by diluting the soil with relatively inert materials; in other words, more frequent fertilization is generally required."

Lignin makes up approximately half the weight of bark and a quarter of the weight of wood. It is quite resistant to decomposition. For this reason, it is the most desirable fraction of plant material from the standpoint of its beneficial effects on the soil. Because of its slow rate of decomposition, the total nitrogen demand which it creates is low. In addition, it supplements the native humus of the soil, thereby improving tilling properties, serves as a reservoir for plant nutrients, and holds nutrients against the leaching effects of water.

The composition of wood varies somewhat among species, particularly as regards softwoods and hardwoods, and the importance of lignin content in both wood and bark should be noted. The approximate composition of a typical softwood and hardwood is shown in Table 1.

Baxter (11) points out that the composition of bark is quite different from that of wood in a number of important respects. As shown in Table 2, its lignin, extractive, and ash contents are considerably higher than that of wood, while its carbohydrate content is lower. As discussed subsequently,

Table 1

Approximate Composition of Wood (11)

	Softwood	Hardwood
Acidity - pH	5.1	5.3
Total Organic Matter (%)	98.8	98.6
Mineral Content (%)	0.2	0.4
Water Soluble (%)	4.1	2.5
Carbohydrate (%)	68.5	71.9
Lignin (%)*	28.0	26.5
Nitrogen (%)	0.1	0.1

*Based on extract-free weight

Table 2

Approximate Composition of Bark (11)

	Softwood	Hardwood
Acidity - pH	3.5	3.7
Total Organic Matter (%)	99.0	91.7
Mineral Content (%)	1.0	8.3
Water Soluble (%)	23.0	4.0
Carbohydrates (%)	46.4	55.1
Lignin (%)*	52.6	41.8
Nitrogen (%)	0.2	0.2

*Based on extract-free weight

these differences have a bearing on the relative efficacy of these two materials as soil additives.

For purposes of comparison, analytical data for peat moss are given in Table 3. Peat moss is the most widely used material for mulches, soil conditioners, and other horticultural and agricultural purposes in the United States according to Anderson and Blake (6). Dunn and Wolfe (22) support the belief that since peat moss has many desirable properties and has become somewhat of a standard with which other soil additives are compared, its properties are of particular interest in a discussion of the properties of wood and bark as soil additives.

Table 3

Approximate Composition of Peat Moss (11)

Acidity - pH	3.8
Total Organic Matter	95.7
Mineral Content (%)	--
Water Soluble (%)	5.2
Carbohydrate (%)	41.2
Lignin (%)	18.0
Nitrogen (%)	0.8

Overcoming the Disadvantages and Misconceptions About the Use of Bark and Sawdust as Mulches and Soil Conditioners

There are several disadvantages and misconceptions concerning the use of wood residues, especially fresh material, arising from past experience in their use. These objections can be eliminated through processing and informed usage, and for this reason are discussed in detail. The primary objections to the use of wood residues are: one, they compete with growing plants for available nitrogen; two, they increase soil acidity; three, finer particles tend to pack, and dust and slivers are objectionable; and four, they contain materials toxic to plants.

Nitrogen Competition

Decomposition of organic substances in soil is accomplished through the action of soil micro-organisms. These essential fungi and bacteria require a source of energy plus nitrogen in order to survive and develop. Bollen and Lu (15) found that some residues cause more inhibition than others. Wood and bark particles provide the carbonaceous material needed for energy, but supply little of the necessary nitrogen.

Micro-organisms must draw on the soil as a source of nitrogen, competing with plants for the available supply. Unless sufficient nitrogen is present in the soil, either naturally or from supplemental applications, to supply the needs of both the growing plants and soil organisms, symptoms of nitrogen deficiency will appear. These symptoms are often mistakenly attributed to toxic materials present in the soil amendment.

Although all carbonaceous materials react similarly when mixed with soil, most commonly used amendments naturally contain higher proportions of nitrogen than wood and bark, causing less nitrogen draft from the soil. If the C/N ratio is much wider than 25/1, Bollen and Glennie (14) report that micro-organisms carrying on decomposition compete with plant roots for available nitrogen.

The rate of decomposition of sawdust and bark is much slower than materials such as straw, which decomposes rapidly, causing a larger initial nitrogen deficiency but of shorter duration. Most proteins of plant and animal origin are rapidly decomposed and, if nitrogen is adequate, so also are sugars. Celluloses are decomposed less rapidly, and lignins very slowly. Wood residues are, therefore, most persistent. This is advantageous in providing longer-lasting mulches and more prolonged effects when incorporated in the soil. It may be noted also that decomposibility of resistant carbonaceous materials such as sawdust is not greatly enhanced by additions of available nitrogen. The primary rate of decomposition of plant residues of mixed composition and wide carbon-to-nitrogen ratio responds to added nitrogen to a degree largely dependent upon their water soluble carbonaceous constituents which are responsible for initial nitrogen demand.

Lunt (34) observed that the magnitude of nitrogen deficiency is proportional to the rate of decomposition. The duration of induced nitrogen deficiency varies with the rate of application of the amendment. Applications of 3 to 4 tons of dry material per acre will seldom extend nitrate depletion beyond the first season, provided conditions are suitable for decomposition.

The nitrogen assimilated by decay organisms again becomes available upon their death for use by other organisms or plants. Organisms appear to consume the major portion of this nitrogen until decomposition of the organic matter is completed. Nitrogen then is gradually released to plants as the organisms decompose. Allison and Anderson (1) found that for sawdust this time may vary from four months to several years, depending on temperature, moisture, percentage of nitrogen added, quantity of sawdust applied, and the intimacy with which it is mixed with the soil.

Allison and Murphy (4) (5) found that the wood and bark of softwood and of hardwood species each differ in their rates of decomposition. The hardwood species were more easily decomposed than the softwood species studied. Allison and Klein (3) found similar results on other softwoods. Lunt (34) found that birch chips decomposed more rapidly than either oak or pine and would require the most nitrogen to prevent deficiencies. The overall results of the above findings are summarized by saying that the most effective soil amendments are those with high lignin content, thereby holding nitrogen competition to a minimum and making them more stable in soil mixtures.

Soil Acidity

Most barks and woods are acidic. McCool (37) reports ranges from pH 3.5 (approximate value of many peat mosses) to 7.0. Lunt (34) found that addition of sawdust to soil had no appreciable effect on soil acidity and that its initial effect was to decrease it slightly. Allison and Anderson (1) reported that when sawdust is applied to a lime-requiring crop, any acid in it may be slightly harmful if the soil is already near the lower limit of acidity tolerated by the crop. Lunt and Clark (35) suggest where desirable to maintain pH at levels near neutrality, 10 pounds of agricultural limestone per cubic yard of bark or sawdust is satisfactory. For acid-requiring plants such as azaleas, any resulting acidity is beneficial. According to Salamon (48) it is natural to assume that since ash of plants contains more basic than acid constituents, the ultimate effect should be toward a less acid pH.

Particle Size

The nature and extent of the physical effects of mulches and soil conditioners vary somewhat with the size of the particles added. Coarse particles tend to decrease water-holding capacity if incorporated in the soil, and very fine particles tend to pack and exclude water and air from the soil.

Salomon (48) found that the depressive effects on plants caused by nitrogen deficiencies persisted longer from chips larger than one-fourth inch in diameter than from smaller chips. Likewise, Lunt (34) reported that particles larger than one-half inch reduce plant yields more than smaller sizes due to the presence of undecomposed wood. In general, it has been found by Lunt and Clark (35) that particle sizes from three to ten millimeters are satisfactory for most horticultural and agricultural uses.

Bollen and Glennie (14) found that wood chips, shavings, millrun sawdust, and gang sawdust make satisfactory mulches. However, they reported that resaw sawdust, because of its small particle size, tends to pack tightly and thus retard aeration and moisture penetration. All sawdust performed satisfactorily when incorporated if it was well mixed with the soil.

Lunt and Clark (35) summarize by saying that it appears that nearly all sizes of bark fragments can serve satisfactorily in horticultural applications in short-term growing operations up to about three years, provided nitrogen relationships and acidity are properly controlled.

Toxic Effects

Toxic effects attributed to wood or bark soil amendments and mulches are generally the result of nitrogen depletion and can be prevented or corrected by applying supplemental nitrogen. Lunt and Clark (35) report that some materials do contain sufficient toxic material to retard growth, however. Walnut and cedar shavings adversely effect tomatoes.

Allison and Murphy (4) found no indication that any of the hardwood products used in their study were toxic to organisms that carried out the decay processes. Using garden peas to determine toxicity effects of certain softwood species, Allison, et. al. (2), found that certain west coast woods and barks at low rates of application were very detrimental to growth. Other residues were found to be less detrimental at higher rates. The adverse symptoms observed on the first crop of peas were markedly decreased or entirely absent on a second crop of peas grown on the same medium. These observations are in agreement with those of Gibbs and co-workers (25) (26). Reuszer, et. al. (44) reported that cedar and walnut residues were detrimental to plants. On the other hand, Bollen and Lu (15) found that small amounts of walnut sawdust had no detrimental effect upon plant growth. Armour Research Foundation (9) has found that wood bark treated to neutralize the tannic acids can increase yield more than does peat moss.

Crop Response to Mulches and Soil Conditioners

The beneficial effects of using wood residues as mulches and soil conditioners for ornamental plants have been demonstrated by years of successful use of these materials by horticulturalists and nurserymen in the West, Mid-west and Northeast. Turk (57) reports that considerably less is known by the public about the use of these materials on agricultural crops.

Lunt (34) reports that natural well-rotted pure wood chips or sawdust is a safe material to use under almost any condition.

Sawdust and bark used as mulches have been reported to be superior to other types of mulches for blueberries. Roberts and Mallenthin (46) found that sawdust and bark mulches four to six inches thick were particularly beneficial to blueberries because of their high moisture retention. Similar results were obtained with strawberries. With crops having a higher nitrogen requirement, they recommend the use of one hundred pounds of nitrogen per acre inch of sawdust (twenty tons per acre).

According to Bollen and Glennie (14) farmers in the Bitteroot Valley and Flathead Region of Montana use sawdust almost to the limit of its availability. Some of it is applied directly to fields without having been composted.

Dunn and Emery (21) concluded from field trials that properly composted sawdust is very beneficial to plant growth. Their work dealt with corn, rutabagas, peas, onions, beets, and other crops. Composted sawdust or shavings were superior in promoting plant growth over soil alone with fertilizer.

Lunt and Clark (35) report that normal landscaping and horticultural application of 1/10 to 1/3 by volume (fresh material) may cause nitrogen draft for periods of six months or more. They continue by saying that decomposition limits usefulness of single applications of bark and chips to about five to seven years. One pound actual nitrogen per 100 pounds dry wood or bark, preferably added in three or more applications, is required to offset nitrogen demand.

Because inoculated legumes suffered no reduction in growth following sawdust application and due to erratic results with application of sawdust prior to planting, Lunt (34) recommends that it precede a green manure crop, preferably a legume. Other possibilities are to use sawdust or bark as poultry or cattle bedding before field application, as a mulch preceeding incorporation with the soil or to compost the material before use.

Sawdust mulches one-inch deep in various vegetable plots more than doubled yields and were better than black polyethylene film in experiments conducted by Pratt and Comstock (43) of the New York Agricultural Experiment Station.

In summary, woods and barks, with few exceptions, can be used satisfactorily in agriculture as mulches and for soil humus maintenance, if adequate amounts of nutrients, especially nitrogen and sometimes lime, are supplied. Most woods behave similarly to common carbonaceous crop residues except that they decompose more slowly because they contain less available carbohydrate and more lignin.

PART III

RESEARCH DESIGN

Introduction

Part III consists of detailed descriptions about each of the three separate components which comprise the research portion of the study. They are designated Phase I, II, and III.

The first Phase discusses the general research support data that had to be located and examined prior to the initiation of the second and third phases.

Phase II presents the work plan for conducting a hardwood sawmill field survey and the preparation and administration of a mail survey. Both surveys are concerned with: (1) the gathering of data about the methods used to handle and dispose of sawmill residues, (2) developing insight into the local market potential for wood residues, and (3) determining the stage of development of local agricultural and horticultural markets by the sawmill industry.

The simulation model in Phase III represents a large scale bark and sawdust processing plant developed during the present research to be used as an aid in management decision making. The primary purpose for the development of the model was to examine the profitability of processing wood residue. Secondary reasons were to show that a simulation model could be built and used to test hypotheses concerning the operation of wood residue processing plants and to illustrate the techniques that might be used to build such a simulation. The model was limited to not more than four processing plants operating concurrently, no more than five separate cost centers, no more than three products, no more than 150 suppliers, no more than four markets, and no more than forty-one counties serving as market demand centers. The model could be expanded, however, to model additional types of wood residues and as many markets as desired. The only limitation would be the physical limitations of the computer facilities used.

Phase I: General Research Support

General Study Assumptions

Before significant work could begin on the research program it was necessary to strengthen the study by outlining a number of basic assumptions.

1. The most promising markets for bark and sawdust (wood residues) which are immediately available are agricultural and horticultural markets. Specifically these include: (a) Dairy--cattle bedding; (b) Nursery--stock mulch, soil conditioning, and decorative applications; (c) Orchard--

fruit tree mulch; (d) Consumer packages--mulches, soil conditioners, and decorative material for home gardeners.

2. Most potential buyers of either sawdust or bark products (in bulk) own trucks and are willing to come to the processing plant for their needs and may even pay a premium for the products if they can depend on the following services: (a) a load being available when they get to the plant; (b) the material being loaded for them; (c) short-term credit being available. These same customers have tractors with front loaders to distribute the material once it is dumped near the site of eventual use.

3. Two cubic foot packages of bark, available in one ton units on pallets, will be sold through brokers to food chains, garden center chains, and other chain store organizations that handle lawn and garden products. These chains own large fleets of trucks and can schedule regular pick-up or back-haul the bark products.

4. Priced competitively, new bark and sawdust products will become accepted into the market in direct proportion to the amount of advertising expenditure, product promotion, and industry education programs.

5. The 3 x 3 mile grid system effectively and accurately identifies the location of supplying sawmills, county market demand and the processing plant location in the computer program memory and in reality.

6. Estimated demand for finished products is acceptably accurate on a per-county basis for the study.

<u>Sawmill Size Classes and Production Data</u>

The 1968 <u>Directory of Wood Using Plants in Michigan</u> ( ) was adopted as the basic source of information about the number of hardwood sawmills within the study area and their general size relative to annual lumber production. Mills not listed in the directory were not considered in the study.

All sawmills listed in the directory that are in the 41 southern counties of lower Michigan were included.

Information in the directory was helpful in the preparation of the initial background for the study by describing the general characteristics of each sawmill, listing sawmill addresses, and indicating the general size of each mill's lumber production. Table 4 was prepared as a summary of the size and production of the 150 sawmills included in the study.

In anticipation of questions about the accuracy of the production figures recorded in the directory, a high, low and average production figure is recorded in Table 4 for each sawmill size class. Depending on the condition of the sawmill industry, this range can be used to compute a liberal or conservative estimate of lumber production which will reflect the amount of wood residues available. These data are important to the planning of a processing plant which will require a large supply of wood residues from sawmills as raw material. For detailed information about individual sawmill lumber production, see Appendix B.

Adoption of Conversion Factors

Information concerning wood residues and the quantities of the several fractions of which it is composed was determined through the use of conversion factors. Since it was not an

Table 4

Sawmill Class Size and Production Data* Used in 1968 Directory of Wood Using Plants in Michigan

Mill Size Class[1]	No. of Mills[2]	Lumber Production by Mill[3] Daily	Lumber Production by Mill[3] Annually[4] (000)	Annual Lumber Production By Class[5] (000)	Average Estimated Total Annual Production (000)
A	2	50,000 44,000 37,501	10,000 8,800 7,501	20,000 17,500 15,002	17,500
B	1	37,500 31,000 25,001	7,500 6,200 5,001	7,500 5,200 5,001	6,200
C	7	25,000 20,000 15,001	5,000 4,000 3,001	35,000 28,000 21,007	28,000
D	29	15,000 10,000 5,001	3,000 2,000 1,001	37,000 58,000 29,029	58,000
E	31	5,000 3,750 2,501	1,000 750 501	31,000 23,250 15,531	23,250
F	56	2,500 1,500 501	500 300 101	28,000 16,800 5,656	16,800
LTF	24	500 250 000	100 50 00	2,400 1,200 000	1,200
TOTAL	150				150,950

* All lumber production is in board feet green lumber tally.

1 Size class set forth in Directory of Primary Wood Using Plants in Michigan, 1968. Published by Michigan Department of Conservation - Forestry Division.

2 150 mills selected from Directory are in lower 41 counties of Michigan.

3 Estimated levels of production are high, average, and low, respectively.

4 Assuming 250 working days per year.

5 The combined production of all sawmills within each individual class.

objective of the study to develop new wood residue conversion, a search was made of the literature for results of previous research investigations of the subject. Conversion factors, when multiplied times a thousand board feet of hardwood lumber produced by a sawmill, determine the tons of wood residue of each type that were also produced.

The conversion factors developed by King (32) were adopted as an integral part of the present study because of the very professional approach used by King and the fact that he considered hardwood species reasonably similar to those growing in lower Michigan.

The average amount of hardwood sawdust produced by a circular headsaw is estimated in Table 5 to be 1.04 green tons* per thousand board feet (MBF) of green lumber tally produced. To determine the total quantity of sawdust produced over a period of time it is necessary to multiply the conversion factor (1.04) times the MBF of green lumber produced during the period and the results are in ton units. Example: 6 MBF x 1.04 (sawdust conversion factor) = 6.24 tons. The effect of log diameter variations on the amount of sawdust produced is also shown in the detail of the table.

Hardwood bark production is determined in a similar manner. Table 6 estimates the average quantity of bark

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*Green ton, see Glossary.

Table 5

Estimates of Hardwood Sawdust by Diameter Class for Mills with Circular Headsaws*

Log Diameter Class (inches)		Weight in Tons with Confidence Limits at 95% Probability Level: Per 1000 bd. ft. green lumber tally	Per 1000 bd. ft. Doyle-Scribner Log-Scale	Per 1000 bd. ft. International 1/4 in. Log Scale
7.6-10.5	Green	1.11 ± 0.09	1.85 ± 0.15	1.15 ± 0.09
	Oven-Dry	0.63 ± 0.05	1.05 ± 0.08	0.65 ± 0.05
10.6-13.5	Green	1.18 ± 0.09	1.57 ± 0.12	1.27 ± 0.10
	Oven-Dry	0.67 ± 0.05	0.89 ± 0.07	0.72 ± 0.06
13.6-16.5	Green	0.95 ± 0.07	1.24 ± 0.10	0.91 ± 0.07
	Oven-Dry	0.54 ± 0.04	0.70 ± 0.06	0.52 ± 0.04
16.6-19.5	Green	0.93 ± 0.07	1.04 ± 0.08	1.00 ± 0.08
	Oven-Dry	0.53 ± 0.04	0.59 ± 0.05	0.57 ± 0.05
Average for all four diameter classes --- Green Weight (Tons) Per MBF Green Lumber Tally		1.04 ± 0.08		

*Adapted from King, W. W. 1952. Survey of Sawmill Residue in East Texas, Texas Forest Service. Technical Report No. 3, p. 51.

Table 6

Estimates of Hardwood Bark by Diameter Class for all Mills*

Log Diameter Class (inches)		Weight in Tons with Confidence Limits at 95% Probability Level		
		Per 1000 bd. ft. green lumber tally	Per 1000 bd. ft. Doyle-Scribner Log-Scale	Per 1000 bd. ft. International 1/4 in. Log Scale
7.6-10.5	Green	0.75 ± 0.14	1.30 ± 0.24	0.78 ± 0.15
	Oven-Dry	0.53 ± 0.10	0.91 ± 0.17	0.55 ± 0.10
10.6-13.5	Green	0.64 ± 0.09	0.91 ± 0.12	0.64 ± 0.09
	Oven-Dry	0.45 ± 0.06	0.64 ± 0.09	0.46 ± 0.06
13.6-16.5	Green	0.50 ± 0.08	0.67 ± 0.11	0.47 ± 0.08
	Oven-Dry	0.35 ± 0.06	0.47 ± 0.08	0.33 ± 0.06
16.6-19.5	Green	0.44 ± 0.10	0.53 ± 0.12	0.45 ± 0.10
	Oven-Dry	0.31 ± 0.07	0.37 ± 0.08	0.32 ± 0.07
Average for all four diameter classes --- Green Weight (Tons) Per MBF Green Lumber Tally		0.58 ± 0.10		

*Adapted from King, W. W. 1952. Survey of Sawmill Residue in East Texas. Texas Forest Service. Technical Report No. 3, p. 49.

accumulated per MBF sawn to be 0.58 tons, or roughly 1200 pounds. For purposes of this study, only mills with log debarkers are considered as sources for bark. Mills not owning a debarker accumulate an equal amount of bark but it remains attached to the slabs and edgings.

To make the study complete, the conversion factor for solid residue material is detailed in Table 7. The factor of 1.24 represents the quantity of solid wood residue produced incidental to the manufacture of one thousand board feet of lumber. No bark content is included in the factor.

Table 8 is a summary of the conversion factors just discussed and a comparison is made of the related factors for Southern Pine. In addition, the amount of chippable material (solid wood) is estimated by respective conversion factors.

The conversion factors will be used later in the study to determine the amounts of each type of wood residue produced by each sawmill in the study area. These quantitites in turn will serve as raw material supply inputs for the utilization simulation. For details about the quantities of each type of residue produced by individual sawmills, see Appendix B.

Estimation of Wood Residue Market Demand

The demand for wood residue (bark and sawdust) products was estimated for four separate markets. The markets included

Table 7

Estimates of Solid Residue Material by Diameter Class for Mills with Circular Headsaws*

Log Diameter Class (inches)		Weight in Tons with Confidence Limits at 95% Probability Level: Per 1000 bd. ft. green lumber tally	Per 1000 bd. ft. Doyle-Scribner Log-Scale	Per 1000 bd. ft. International 1/4 in. Log Scale
7.6-10.5	Green	1.64 ± 0.24	2.83 ± 0.41	1.66 ± 0.24
	Oven-Dry	0.93 ± 0.13	1.60 ± 0.23	0.94 ± 0.14
10.6-13.5	Green	1.36 ± 0.13	1.95 ± 0.18	1.40 ± 0.13
	Oven-Dry	0.77 ± 0.07	1.10 ± 0.10	0.79 ± 0.07
13.6-16.5	Green	1.04 ± 0.13	1.41 ± 0.17	0.99 ± 0.12
	Oven-Dry	0.59 ± 0.07	0.80 ± 0.10	0.56 ± 0.07
16.6-19.5	Green	0.92 ± 0.16	1.09 ± 0.19	0.93 ± 0.16
	Oven-Dry	0.52 ± 0.09	0.62 ± 0.11	0.53 ± 0.09
Average for all four diameter classes --- Green Weight (Tons) Per MBF Green Lumber Tally		1.24 ± 0.17		

*Adapted from King, W. W. 1952. Survey of Sawmill Residue in East Texas. Texas Forest Service. Technical Report No. 3, p. 50.

Table 8

Mean Values for the Various Residue Components Based on Per M.B.F. Green Lumber Tally*

	Estimates of Mean Values in Tons			
	PINE		HARDWOOD	
Residue Component	Green	Oven-Dry	Green	Oven-Dry
Bark	0.38	0.26	0.58	0.41
Sawdust	0.85	0.42	1.04	0.60
Solid Material	1.18	0.58	1.24	0.70
Total	2.41	1.26	2.86	1.71
Chippable Material	1.02	0.49	1.08	0.61

*Adapted from King, W. W. 1952. Survey of Sawmill Residue in East Texas. Texas Forest Service. Technical Report No. 3.

were: (1) dairy bedding, (2) orchard mulch, (3) nursery mulch and soil conditioner, and (4) packaged bark for the home landscaping and gardening market.

The total market size for dairy cattle bedding was based on information from the M.S.U. Dairy Department that a dairy cow requires approximately four cubic yards of bedding material each year, whether it be straw, sawdust, corncobs, ground tree bark or something else.

The number of animals in the study area was obtained from M.S.U. Extension Bulletin 582 (62). Figures include the estimated number (in thousands) of dairy cows in each county.

At this point the author made four assumptions:

1. That every dairy cow uses approximately four cubic yards of some type bedding material.

2. That sawdust and/or bark bedding offered for sale by a processing plant could obtain a 10 percent share of the total bedding market in all counties within a reasonable distance.

3. That bark and sawdust would split the 10 percent market share in a 50-50 basis, each getting 5 percent.

4. That demand is best calculated in units of one county to conform to available data.

By multiplying the number of cows times 4 cubic yards (approximately one ton) the approximate tonnage of bedding material required by the market is determined. Ten percent of this total is then taken and divided 50-50 between the requirement for sawdust and ground bark under the heading of dairy.

The four markets within each county are shown in Table 9 and the quantities representing the estimated share obtainable shown in tons.

The demand for orchard mulch was estimated in much the same way as dairy cattle bedding. The number of fruit trees (apple, sour cherry, peach, sweet cherry and pear) in the study area was obtained from M.S.U. Extension Bulletin 582 (p. 58). The trees of each type are listed for each county. After talking with a M.S.U. horticulturist it was then assumed that each tree could be adequately mulched with ground bark or other material using an average of one cubic yard per tree. The second assumption was that, of the total mulch required for trees within each county, bark mulch supplied by a local processing plant could capture a market share of 10 percent. Five cubic yards of ground bark weigh approximately one ton. The tonnages in Table 9 represent 10 percent of the total orchard mulch market.

The demand for nursery mulch and soil conditioners was estimated using the 1969 Directory and Buyer's Guide of the Michigan Association of Nurserymen as a data base. The Directory lists the nurseries in each Michigan county and the number of planted acres operated. The number of acres in

Table 9

Wood Residue Demand Estimated in Tons--A Summary of the Obtainable Market Share in Each County

County	Sawdust		Bark			Package Bark
	Dairy	Nursery	Dairy	Nursery	Orchard	
Allegan	750	2,150	750	2,150	14,080	17
Barry	500	160	500	160		8
Bay	250	1,120	250	1,120		32
Berrien	250	5,500	250	5,500	45,680	50
Branch	500	60	500	60		10
Calhoun	600	1,190	600	1,190		44
Cass	250	530	250	530	1,840	11
Clinton	800	510	800	510		12
Eaton	600	140	600	140		16
Genesee	400	1,420	400	1,420	1,100	124
Gratiot	450	190	450	190		11
Hillsdale	700	150	700	150		10
Huron	1,200	170	1,200	170		10
Ingham	750	1,420	750	1,420		70
Ionia	800	140	800	140	2,160	12
Isabella	700	110	700	110		9
Jackson	600	320	600	320	1,040	40
Kalamazoo	250	2,650	250	2,650	1,340	54
Kent	750	1,830	750	1,830	13,560	119
Lapeer	1,000	830	1,000	830	820	13
Lenawee	600	220	600	220		23
Livingston	650	450	650	450		13
Macomb	450	2,620	450	2,620	1,820	155
Mecosta	400	40	400	40		6
Midland	100	590	100	590		16
Monroe	200	3,120	200	3,120		31
Montcalm	650	770	650	770	740	12
Muskegon	250	1,660	250	1,660	2,840	46
Newaygo	450	60	450	60	2,860	8
Oakland	250	3,140	250	3,140	1,760	228
Oceana	200	160	200	160	26,820	5
Ottawa	700	9,770	700	9,770	4,440	32
Saginaw	600	1,890	600	1,890		60
St. Clair	800	2,910	800	2,910		34
St. Joseph	350	960	350	960		14
Sanilac	1,950	50	1,950	50		10
Shiawassee	650	140	650	140		17
Tuscola	700	170	700	170		13
Van Buren	300	6,880	300	6,880	21,260	17
Washtenaw	700	580	700	580	1,100	57
Wayne	50	3,100	50	3,100		800
TOTAL	23,100	59,870	23,100	59,870	145,260	2,269

each county were tallied. After discussions with nursery operators in the Lansing area, the total mulch and soil conditioner market was estimated to be approximately 100 tons per acre of nursery operated. An assumption was then made based on the fact that bark and sawdust do make good mulching materials, that a processing plant for these materials could realistically capture a 10 percent share of the nursery markets located in nearby counties.

The 10 percent market share amounts to an average of 10 tons per acre of nursery. The demand was estimated to be equally divided between bark and sawdust. The demand would, therefore, amount to a 5-ton per acre average for bark and the same for sawdust. The tonnage (5 percent bark and 5 percent sawdust) representing 10 percent of the total nursery demand per county is shown in Table 9.

Due to the nature and use of packaged bark products sold to the rapidly growing and increasingly affluent lawn and garden market, it was arbitrarily decided by the author that the market was basically limited to households with incomes of $10,000 and over.

The 1968 Michigan Statistical Abstract (17) was used as the source of information about the number of households in each county and their income category.

After talking with the managers of several Lansing area lawn and garden centers, it was apparent that the mulch and soil conditioner market is very large and absorbs great quantities of products. It was suggested during the course of conversation with the managers that a product of the type mentioned above could expect a minimum of sales in the first year amounting to one ton for every 1000 households in the county having an income of $10,000 or more.

Considering the estimated size of the market, the low price of the product, and the limited production of only one processing plant, this method of estimating the market share appears adequate until such a time when the question can be researched in detail.

Phase II: Hardwood Sawmill Residue Survey

Introduction

Hardwood sawmills located within the 41 southern most counties of lower Michigan were selected as the population to be included in this marketing study. In Figure 3 the 41 counties in the study area were divided into four arbitrary quadrants to facilitate analysis. Each of the 150 sawmills within the area is listed in the 1968 *Directory of Wood Using Plants in Michigan* (7). Table 10 shows the number of sawmills within each quadrant; first by county and then by mill size

Figure 3. Location of Wood Residue Study Area Showing 41 Counties Divided into Four Quandrants.

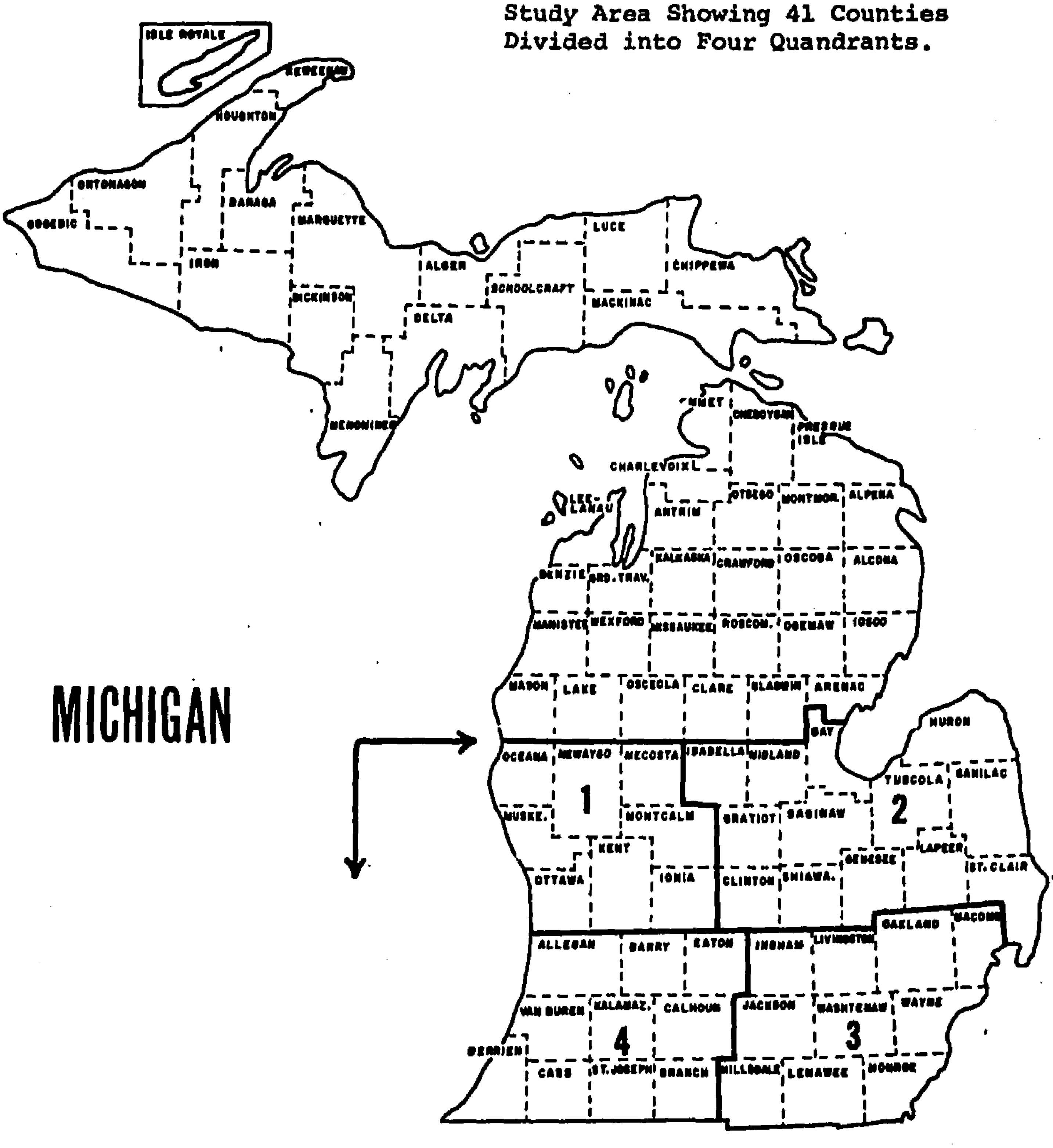


Table 10

Selected Sawmill Study Area Divided Into Arbitrary Quadrants Showing The Stratification of Sawmills in Each by Mill Class (January 1969)

County	Total Sawmills	Class Size A	B	C	D	E	F & LTF
Quadrant No. 1							
Ionia	6	0	0	0	2	1	3
Kent	6	0	0	1	1	1	3
Mecosta*	0	0	0	0	0	0	0
Montcalm	5	0	0	0	2	2	1
Muskegon	5	0	0	0	2	3	0
Newaygo*	8	0	0	2	0	5	1
Oceana*	7	0	0	0	2	2	3
Ottawa	2	0	0	0	0	0	2
Subtotal	39	0	0	3	9	14	13
Quadrant No. 2							
Bay*	1	0	0	0	0	1	0
Clinton	1	0	0	0	1	0	0
Genesee	0	0	0	0	0	0	0
Gratiot	2	0	0	0	0	0	2
Huron	6	1	0	0	0	0	5
Isabella*	3	0	0	0	1	1	1
Lapeer	4	0	0	0	1	1	2
Midland*	3	0	0	0	0	1	2
Saginaw	5	0	0	2	3	0	0
Sanilac	3	1	0	0	2	0	0
Shiawassee	0	0	0	0	0	0	0
Tuscola	9	0	0	0	2	1	6
Subtotal	37	2	0	2	10	5	18

Table 10, cont.

County	Total Sawmills	Class Size A	B	C	D	E	F & LTF
Quadrant No. 3.							
Hillsdale	4	0	0	0	0	0	4
Ingham	4	0	0	0	0	1	3
Jackson	2	0	0	0	0	1	1
Lenawee	3	0	0	0	2	0	1
Livingston	2	0	1	0	1	0	0
Macomb	3	0	0	0	0	1	2
Monroe	2	0	0	0	1	0	1
Oakland	4	0	0	0	0	1	3
St. Clair	6	0	0	0	0	1	5
Washtenaw	3	0	0	0	0	3	0
Wayne	1	0	0	0	1	0	0
Subtotal	34	0	1	0	5	8	20
Quadrant No. 4							
Allegan	5	0	0	0	1	0	4
Barry	9	0	0	0	0	2	7
Berrien	2	0	0	0	0	1	1
Branch	2	0	0	0	2	0	0
Calhoun	4	0	0	0	0	0	4
Cass	5	0	0	1	1	0	3
Eaton	5	0	0	1	1	1	2
Kalamazoo	2	0	0	0	0	0	2
St. Joseph	1	0	0	0	0	0	1
Van Buren	5	0	0	0	0	0	5
Subtotal	40	0	0	2	5	4	29
GRAND TOTAL	150	2	1	7	29	31	80

*Means Region III, as described in the Michigan Conservation Commission <u>Directory of Primary Wood Using Plants in Michigan</u> (1968), has been expanded for purposes of this report to include the next tier of counties adjacent to the northern edge of Region III; thereby including six more counties in the study area and simultaneously reducing the size of Region II by this same amount.

class. Stratification of mills is helpful in determining the general size and location of sawmills in southern Michigan.

The Directory mentioned above indicates the general size of each sawmill by dividing them into seven classes according to estimated annual lumber production. Detailed information about this classification is shown in Table 4.

To confirm the accuracy of lumber production figures presented in the above mentioned directory and to better acquaint the author with the residue problem, a field survey was initiated in the summer of 1968. Later the same year a mail survey was developed that would provide cross-check data for the field survey findings and accumulate new data about the industry which was needed for the eventual industry simulation discussed in Phase III.

Field Survey--Selection of Sample: In selecting a sample of sawmills to include in the field survey, it was arbitrarily decided to include all of the medium and large A, B, C, and D-class sawmills in the study area. Even though small in size, four E-class sawmills, one from each quadrant, and eight F-class mills, two from each quadrant, were also included. No mills with production less than F-class (LTF) were included. The name of each sawmill visited, its size, the city and county in which it is located, are shown in Table 11.

Table 11

Selected Sawmills Included in 1968 Field Survey*

Mill No.	County	Class	Name	City
Quadrant No. 1				
1	Ionia	D	Bauer Lumber Company	Portland
2	Ionia	D	Devereaux Sawmill, Inc.	Pewamo
3	Ionia	F	Hills' Crate Mill	Belding
4	Kent	C	Schneider Lumber Co.,Inc.	Sparta
5	Kent	D	Teesdale Sawmill	Cedar Springs
6	Montcalm	D	Custom Woodworking, Inc.	Howard City
7	Montcalm	D	Waldron's Sawmill	Stanton
8	Muskegon	E	Meyer's Sawmill	Montague
9	Muskegon	D	Roger's Sawmill	Muskegon
10	Muskegon	D	Wenting Bldg. & Mfg. Co.	Muskegon
11	Newaygo	C	O. J. Brigg Lumber Co.	White Cloud
12	Newaygo	C	Dix Lumber Company	Newaygo
13	Oceana	D	Hesperia Crate Works	Hesperia
14	Oceana	D	Shelby Sawmill	Shelby
15	Ottawa	F	Anthony Elenbaas & Sons	Hudsonville
Quadrant No. 2				
16	Bay	E	DuRussell Lumber Co.	Munger
17	Clinton	D	St. Johns Hardwood Lbr.	St. Johns
18	Huron	A	Fairhaven Ind. Wood Prod.	Bay Port
19	Isabella	D	Mobark Lumber Company	Winn
20	Isabella	F	Weber Brothers	Weidman
21	Gratiot	F	A. Inbody Sawmill	Ithaca
22	Lapeer	D	D. T. Fowler Mfg. Co.Inc.	Lapeer
23	Saginaw	C	Devereaux Brothers	Oakley
24	Saginaw	C	M.C. Richmond Lbr. Co.	St. Charles
25	Saginaw	D	S & V Products	St. Charles
26	Saginaw	C	Szepanski Sawmill, Inc.	St. Charles
27	Saginaw	D	Grant Willsie Lumber	Freeland
28	Sanilac	A	Buskirk Lumber Company	Sandusky
29	Sanilac	D	Gordon Ferguson	Snover
30	Sanilac	D	McCarty Brothers, Inc.	Ubly
31	Tuscola	D	Cass River Lumber Co.	Tuscola
32	Tuscola	D	H. Whittaker Hardwood Lbr.	Cass City

Table 11, Cont.

Mill No.	County	Class	Name	City
Quadrant No. 3				
33	Hillsdale	F	Cleveland Lumber Company	Hillsdale
34	Ingham	F	Monroe Brothers Lumber	Webberville
35	Lenawee	D	R. Bradish Veneer & Hdwd.	Adrian
36	Lenawee	D	Hawkins Lumber Company	Rollin
37	Livingston	D	Dimension Hdwd. Lbr. Co.	Milford
38	Livingston	B	Thureson Lumber Company	Howell
39	Monroe	D	Lyle E. Farver & Son	Ida
40	Jackson	E	Love's Sawmill	Springport
41	Wayne	D	Fair Lumber Company	Livonia
Quadrant No. 4				
42	Allegan	D	Door Brothers Lbr. Co.	Wayland
43	Barry	F	Gordon Johncock Mill	Hastings
44	St. Joseph	F	Shear's Sawmill	Centreville
45	Branch	D	Superior Pallet, Inc.	Union City
46	Branch	D	Union City Hardwood Co.	Union City
47	Cass	D	Marquette Lbr. Co, Inc.	Cassopolis
48	Cass	C	Richmond Lumber Mill, Inc.	Dowagiac
49	Eaton	C	L. L. Johnson Lbr. Mfg.Co.	Charlotte
50	Eaton	D	Sunfield Ind.Wood Prod.Inc.	Sunfield
51	Eaton	E	Verhoeven Lumber Company	Lansing

*Mills are listed by quadrant to include: all A, B, C, and D class mills, (1) E class mill and (2) F class mills per quadrant. Quadrants were arbitrarily chosen.

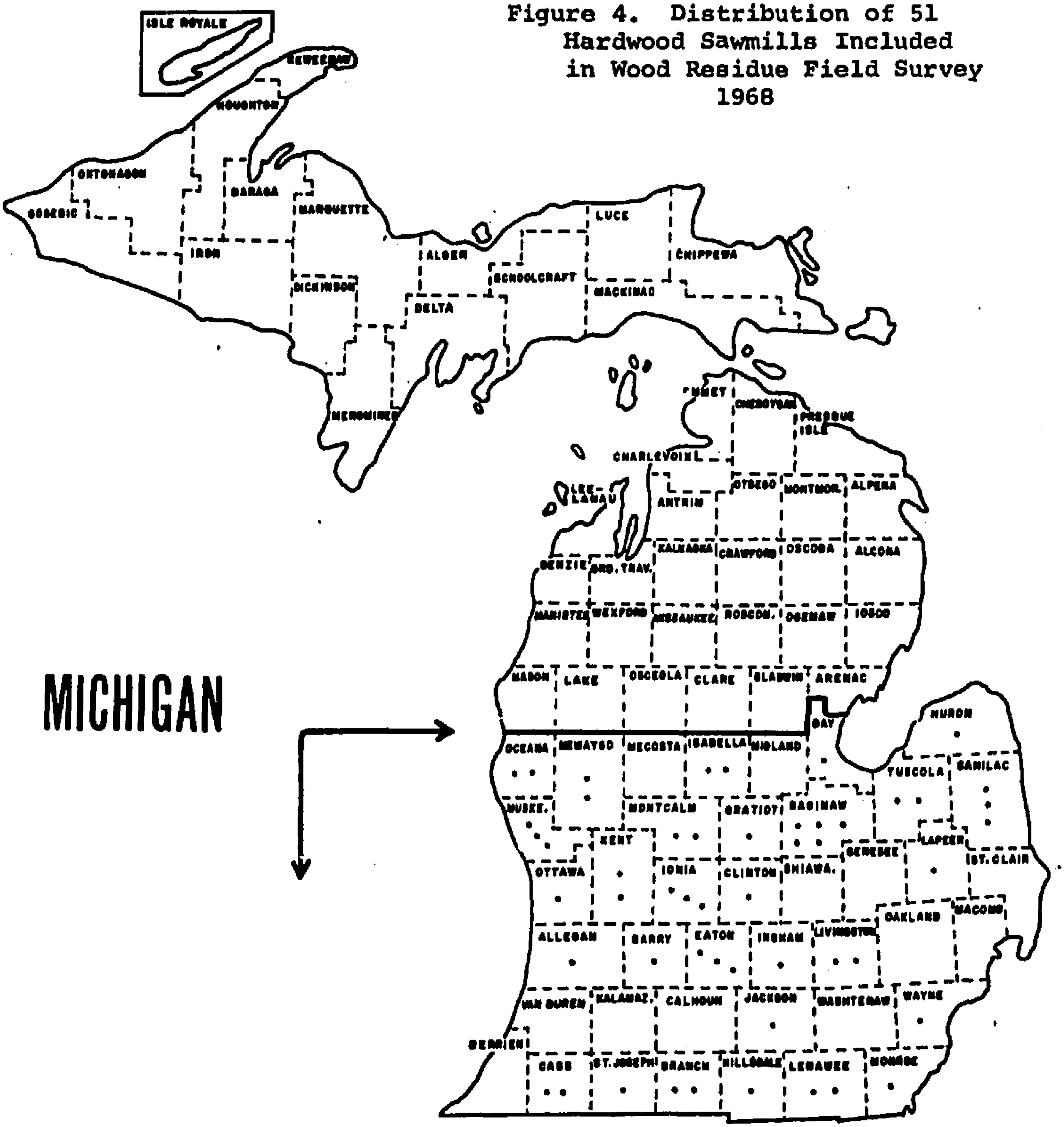
Figure 4 shows the general location of the 51 sawmills included in the field survey. Each dot represents one sawmill. For the general location of all sawmills in the State of Michigan, see Figure 2.

Mail Survey--Selection of the Sample: Reliable information about the Michigan sawmill industry and their wood residues is almost non-existent. For purposes of the study it was, therefore, essential that current data of an original nature be obtained. Hardwood sawmills to be included in the mail survey were selected in the following manner.

First, the study area, as defined in Figure 3, was expanded to include the row of counties located along the northern edge of the basic study area in an effort to check for unusual sawmill operations adjacent to the arbitrarily selected study area. Located within this area are 169 hardwood sawmills. Each sawmill is listed in the 1968 Directory of Wood Using Plants in Michigan (7). It is possible that other mills may be located within this area, but since they are not listed in the Directory there was no opportunity for them to be included in the survey.

Second, it was arbitrarily decided to include 100 percent of the A, B, C, and D-class mills in the study along with 50 percent of the relatively small and numerous E, F, and

Figure 4. Distribution of 51
Hardwood Sawmills Included
in Wood Residue Field Survey
1968



LTF-class mills. The 106 mills included in the mail survey are shown in Table 12.

Table 12

Number of Sawmills Included in Mail Survey

Mill Class	Total No. of Mills	% Included in Sample	No. of Mills in Sample
A	2	100	2
B	2	100	2
C	7	100	7
D	30	100	30
E	38	50	20
F	65	50	33
LTF	25	50	12
	169		106

The Mail Questionnaire: Once the sawmill sample was selected, a short mail questionnaire was developed (Appendix A). The original questionnaire was subjected to six revisions through the combined efforts of both Forest Products and Marketing experts at Michigan State University in an effort to insure the best possible return. The overall effect of the revisions was to reduce the length of the questionnaire and make the questions as clear and concise as possible. Upon completion of the initial revisions a pre-test was conducted among four sawmill operators. Once again revisions were made of a minor nature. The two-page questionnaire, along with a cover letter telling about the study and asking for the individuals' cooperation was then printed. Mailing envelopes were addressed and self-addressed, stamped envelopes were enclosed along with the cover letter and the questionnaires. On February 1, 1969, all questionnaires were mailed. Fourteen days later the first follow-up was mailed; twenty-one days after the initial mailing the second and last follow-up was mailed. The return was 86 percent.

A computer data coding form was drawn up and as the returns came in the responses were recorded. These were later keypunched and analyzed by a simple computer program to determine the frequency of response for each question by mill class. The findings are discussed in Part IV.

Phase III: Wood Residue Processing Simulation

Introduction

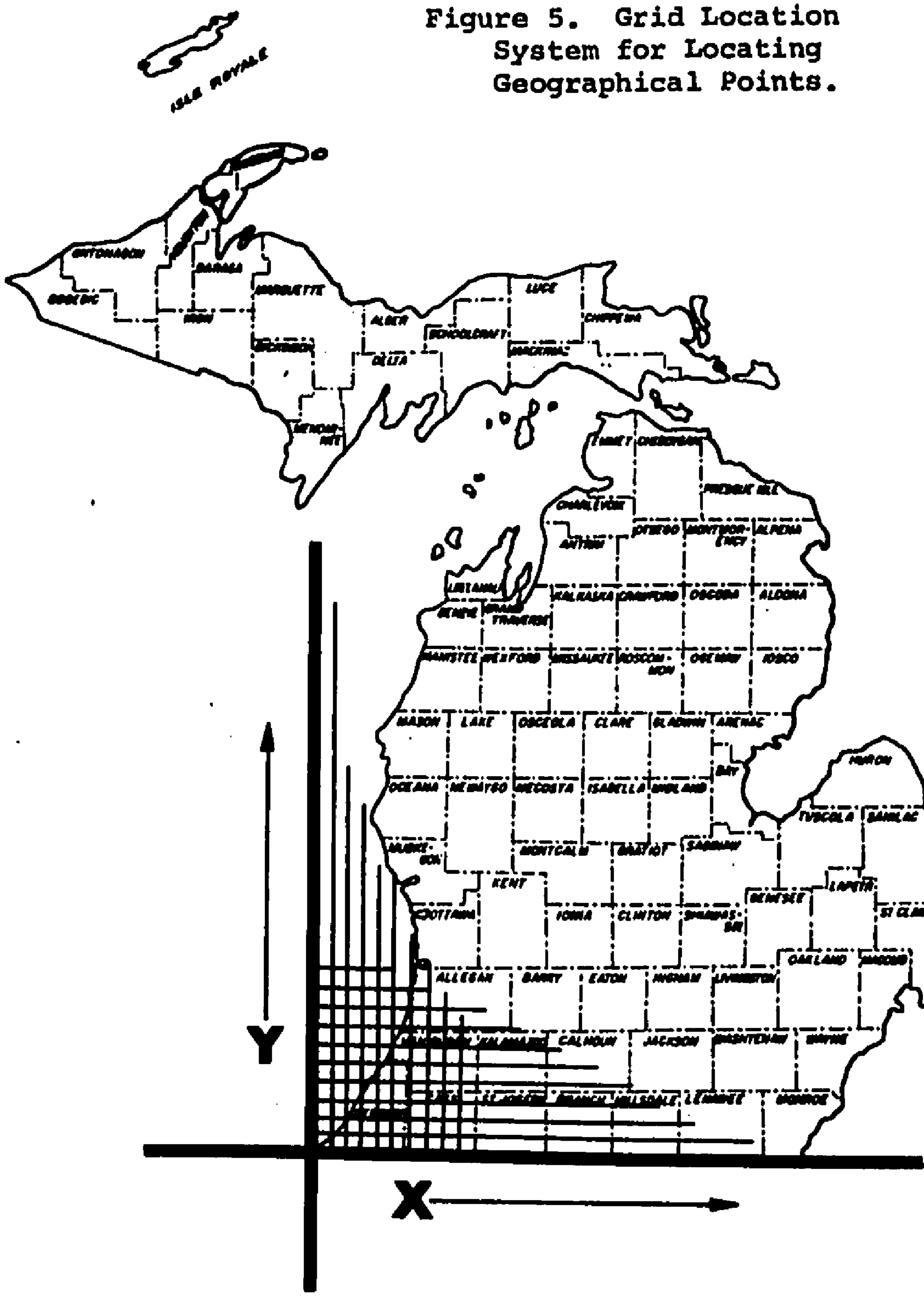
The method used to evaluate the potential success of a large scale bark and sawdust processing plant is heuristic simulation which is often used today by managers in business to aid in making improved management decisions. For purposes of the study the importance of the simulation should not be misunderstood. The development of the simulation is not the primary objective of the study; rather the simulation is used only as a means to an end. The primary objective of the study is to prove or disprove the research hypotheses concerning the feasibility of processing wood residues on a large scale for the agricultural and horticultural markets in southern Michigan. Within Phase III the factors directly related to the development of the grid location system, the inputs and operation of a proposed processing plant and the activities and cost centers influencing the actual simulation are discussed in detail.

The Grid Location System

Before prospective processing plant locations could be selected or supply and demand data used as simulation inputs, it was necessary to develop a means of locating given points on a scale map of Michigan with reasonable accuracy. A map location system was selected which used a transparent grid overlay. The scale of the base map and the grid overlay selected were compatible. A Michigan highway map having a scale of one-inch equals twelve miles was used as the base; making every one-quarter inch equivalent to three miles. It was then possible to use a ¼ x ¼ inch grid overlay making each grid square equivalent to 3 x 3 miles.

The construction of a uniform grid system was necessary to facilitate the storage of location data in electronic computer memory for later use in computing distance, quantity, time and cost data using the Control Data 6500 electronic computer.

Figure 5. Grid Location System for Locating Geographical Points.



To prepare the input data for inclusion in the simulation, coordinates of the following points were located:

(1) All 150 operational hardwood sawmills (SUPPLY);

(2) The geographic center point of 41 southern Michigan counties, Appendix C-4 (DEMAND);

(3) Twelve prospective locations for processing plants.

X-Y axes were drawn on the grid overlay in such a way that most of the grid surface was in the upper right hand quadrant, Figure 5. The center of the axes was located on the southwestern tip of southern lower Michigan and the X-axis lined up parallel with the Michigan-Indiana boundary line.

To number the grid squares, now enclosed on two sides by the X-Y axes, the zero point was located at the intersection of the X-Y axes. Using two position digits, the numbers were placed along the X-axis: 01, 02, 03, 04, 05...etc., placing the numbers under the respective columns of grids. The Y-axis was then numbered in a similar manner placing each number opposite a row of grid squares. All points (grid squares) can now be located by a four digit number; the first two digits being read along the X-axis, the second two along the Y-axis.

In the study, distance from one point to another is always determined in relation to the X-Y axes, never across the shortest distance between the two points. To determine distance in miles from one point to another, first count the grid squares along the X-axis, then along the Y-axis to the target point; add them together and multiply the total by three.

For purposes of uniformity, each mill was assumed to be located in the center of the grid square that overlayed the actual geographic location. In every case only one sawmill was located in any one grid square.

The Computer Simulation Program

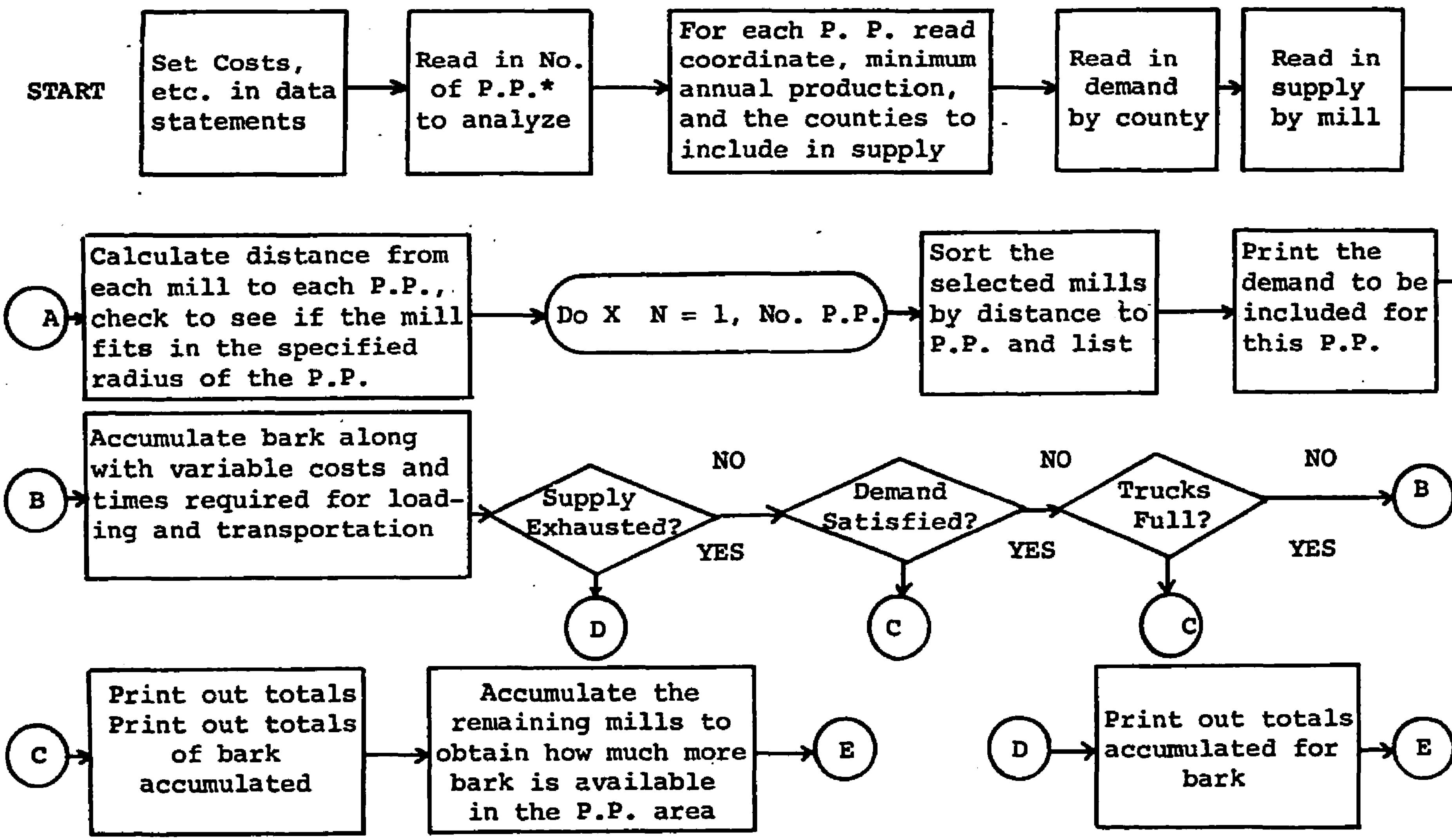
The computer simulation program (Appendix D) uses previous simulation technology to conduct one phase of the current research. The basic ideas involved and the originally written program are unique in their application of simulation to the sawmill industry. Preparation of the program was completed using the professional assistance of the Applications Programming Group of the Michigan State University Computer Laboratory.

Operational Flow Chart

The operational flow chart, Figure 6, shows the basic activities performed by the program in a simplified manner.

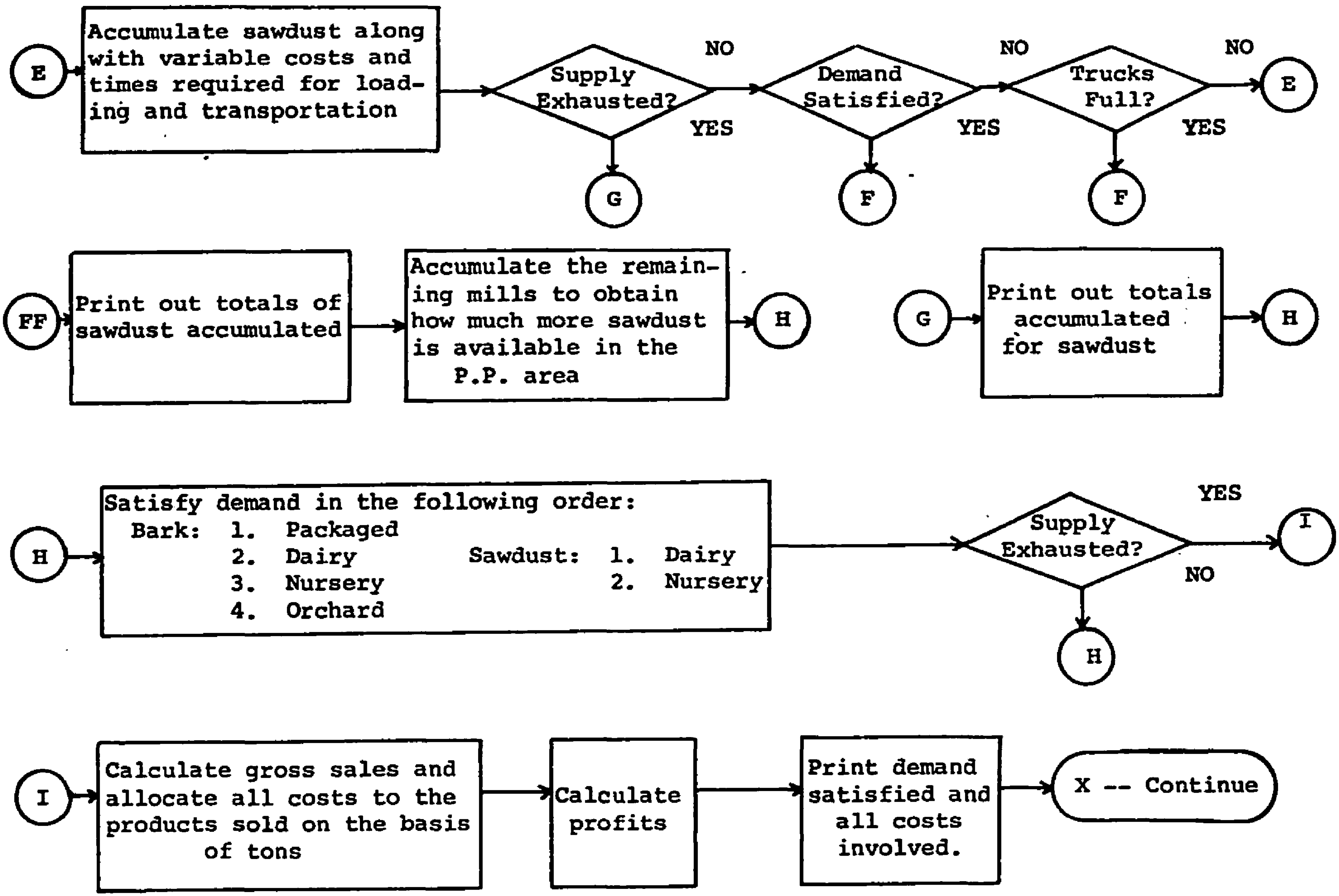
For specific details about the operations performed by the program, see Appendix D. General information describing the format of various inputs and controls are included on the next few pages of the research design.

Figure 6. Basic Flow Chart Showing Major Activities Performed by the Simulation Program



*P.P. = Processing Plant

Figure 6, cont.



Program Deck Order

The order of the deck of cards used in the simulation, Table 13, is included in the research design to better describe the data inputs and system control cards used by the program. It is not considered necessary to describe the individual control cards in detail; but, by having the deck order available, it will be easier to adapt the program to other computer installations provided the computer is compatible with the Control Data 6500.

Format of Supply Inputs

The actual sawmill supply data used in the simulation was determined earlier using the mail survey and the adopted wood residue conversion factors. For use in the simulation the information was put on data cards in the following format:

Card Column	Description
1-3	Sawmill code number
5-8	Sawmill grid coordinate
21-30	Estimated annual lumber production in MBF
31-40	Estimated tons of sawdust
41-50	Estimated tons of bark

Table 13

Deck Order for Control Data 6500
(April 30, 1969)

1. PNC card

2. JOB card

3. FTN(L)

4. LGO

5. 7
8 card
9

6. Program Deck (including all subroutines)

7. 7
8 card
9

8. Parameter Card No. 1

*9. a. Parameter Card No. 2
    b. Corresponding Parameter Card No. 3

10. County Cards with the Demand Data

11. Card with 99 in Column 1-2

12. Data Cards from Supplying Sawmills

13. Card with 999 in Columns 1-3

14. 6
7 card
8
9

Note: A. Cards 8-13 are the data input cards
B. Cards 1-7 and 14 are the system control cards

*Item No. 9 (a. and b.): To get multiple runs these cards can be repeated for up to six processing plants (P.P.). Both cards for P.P. No. 1 should be first, then both cards for P.P. No. 2, etc.

Format of Demand Data

Demand data were estimated earlier and the information concerning each individual county demand center entered on data cards. The geographic center of each county is used as the demand center for each county. All units demanded are in tons.

Card Column	Description
1-2	County code number
3-6	County grid coordinate
7-16	Name of county
21-30	Tons of sawdust demand - Dairy Industry
31-40	Tons of sawdust demand - Nursery Industry
41-50	Tons of bark demand - Dairy Industry
51-60	Tons of bark demand - Nursery Industry
61-70	Tons of bark demand - Orchard Industry
71-80	Tons of bark demand - Package Market

Format of General Simulation Parameters

The general parameters are included to not only detail the computer simulation inputs, but to illustrate that the multiple processing plant simulation is relatively flexible as shown by the notes pointing out positions of variable data entry. Three basic parameter cards are included as follow:

Card No. 1: (one card for each computer run)

Card Column	Description
5	Number of processing plants--as many as six different ones in the same run
10	Insert (1) if it is desired that the supplying sawmills be included in only one processing plant's supply radius during a computer run; thus evaluating multiple processing plant locations. Leave the column blank if the mills can be included in more than one processing plant configuration.

Note: If card column 10 is (1), the sawmills will be included in the first processing plant configuration where it can be used.

<u>Card No. 2</u>: (one card for each processing plant)

Card Column	Description
1-5	Insert the letters "PARAM" to indicate this is a parameter card
6	Processing plant number - must be in a sequence from 1-6. (These will be 1-N, where N is the number in column 5 of parameter card No. 1.)
10-13	Coordinate of the processing plant
14-15	Radius of the proposed supply circle around the processing plant--limits supply to only those sawmills inside the circle.
16-25	Minimum annual lumber production, in thousand board feet (MBF) for the smallest sawmill that the processing plant will include in its supply estimate potential.
26-27	The number of counties (two digits) to be included in the demand portion of the configuration. If all 41 counties in southern Michigan are to be included, insert the number 99.
*28-32	Conversion factor for dairy sawdust demand
*33-37	Conversion factor for nursery sawdust demand
*38-42	Conversion factor for dairy bark demand
*43-47	Conversion factor for nursery bark demand
*48-52	Conversion factor for orchard bark demand
*53-57	Conversion factor for packaged bark demand

*The demand data are recorded assuming ten percent of the market, in which case these columns would have a (1) punched in the rightmost position. If the user wishes to assume a market share of twenty percent, he would insert a (2) or if he wished to assume only five percent, he would insert (.5). Within one computer run the conversion factors for all processing plants must be the same.

Card No. 3*: (one card for each processing plant)

Card Column	Description
1-3	Insert the letters "CTY" to indicate this is a county demand card
6	Processing plant number (1-6) (same as for card No. 2.)
9-10	Demand county code #1
11-12	Demand county code #2
13-14	Demand county code #3
...	etc.
77-78	Demand county code #35

Note: The counties in columns 9-78 do not have to be listed in numerical order, but the simulation does process and satisfy the demand for the first county listed, then proceeds to the next one.

*If columns 26-27 of parameter card No. 2 is equal to 99, indicating all counties are to be included in the demand area, this card must be eliminated.

Description of Simulation Cost Centers

The cost center concept was used in this study. It was used to combine many general costs in the overall simulation into fewer logical units containing all costs common to a specific activity. For purposes of this research study, the five following cost centers are utilized in the analysis:

1. Raw Material Cost
2. Inbound Transportation Cost
   - Fixed
   - Variable
3. Inventory Holding Cost
4. Processing Plant Cost
   - Fixed
   - Variable
5. Outbound Loading Cost

Considering that these costs are all related to the purchasing, concentrating, processing and selling of bark and sawdust, their meaning is self-explanatory. The costs related to these cost centers will be included under the following section, the processing plant, because the simulation uses the processing plant as the hub of all activity.

The cost centers used in this simulation are detailed below with the costs included under each activity. In all cases the figures used may not agree with estimates made by other people. This does not, however, cause great concern because the simulation is flexible enough to accept new cost figures in place of old ones and the results observed in the following computer run.

1. Raw Material Cost:

	Sawdust	\$2.00/ton
	Bark	\$1.25/ton

2. Inbound Transportation Cost: (two trucks)

   Including: A. loading cost
   B. over-the-road
   C. unloading

<u>Fixed Cost Truck</u>

Depreciation	\$3600.00/year
Insurance	600.00/year
License	250.00/year
Total	\$4450.00/year

<u>Variable Cost Truck</u>

Loaded mile charge	\$0.60 each truck
Driver @ \$3.00/hour	\$0.05 per minute for each driver

3. Inventory Holding Cost:

   Annual Raw Material Cost x 2%

4. Processing Plant

   A. Fixed Cost:

Sawdust only	$ 461.00/year
All Bark to (Y)	1,471.00/year
Bulk Bark after (Y)	0.00/year
Package Bark after (Y)	7,631.00/year
To be allocated	22,227.00/year

   B. Variable Cost:

Sawdust only	$ 0.06/ton
All Bark to (Y)	0.18/ton
Bulk Bark after (Y)	0.00/ton
Packaged Bark after (Y)	13.14/ton

5. Outbound Loading Cost:

Sawdust	$ 0.10/ton
Bark (bulk)	0.30/ton
Packaged Bark	0.25/ton

<u>Special Information</u>

Selling Price

Sawdust	$ 4.00/ton
Bark (bulk)	4.00/ton
Bark (packaged)	63.65/ton

Capacity of packaging plant: (one man inside plant)

Output/Day	600 bags or 8.8 tons
Output/Year (250 days)	150,000 bags or 2200 tons

The Processing Plant

The processing plant is designed to buy bark and sawdust from local hardwood sawmills, concentrate and process the material, and sell the finished goods f.o.b. plant.

Supply for the processing plant is to be provided by hardwood sawmills located within a short radius of the processing plant and having a predefined minimum annual lumber production. Raw material is to be purchased on a loaded basis; therefore, it is essential that the sawmill have adequate loading equipment to be considered as a supplier. Raw material will not be purchased from the very small mills because they do not have the necessary material handling equipment or the capital to invest in equipment to load sawdust and bark into large trucks owned and operated by the processing plant.

Sawdust will be purchased in truck load units of forty cubic yards weighing approximately ten tons; bark is somewhat lighter and will be purchased in units of forty cubic yards or approximately eight tons. Two trucks are used to haul raw material to the processing plant.

The trucks loaded with raw material will be driven to the processing plant where the loads are dumped into a forty cubic yard surge hopper. Time to unload is minimal. The driver and truck are then ready to return for another load.

The raw material moves through the processing plant in one of three ways, shown in Figure 7. All finished goods will be stored outside. Sawdust is concentrated at the site and sold only in bulk units. Bark, on the other hand, is processed through a wood hog to reduce the particles to a uniform size, then conveyed to an outdoor storage pile. From here it is either sold in bulk units like sawdust or sent through the packaging plant where it is put into colorful, nicely printed, plastic bags for sale to consumers through grocery chains, nurseries, and garden supply stores.

The processing plant, Figure 8, will employ one manager, one bookkeeper, two truck drivers, one front-loader driver to move raw material into the plant and load customer trucks, one machine operator to operate the bag machine, the sealing machine, load bags onto pallets, and drive the fork-lift to handle finished packaged goods.

All finished products are to be picked up at the processing plant, where plant personnel will load the outbound products on the customer's truck.

Basic assumptions under which the processing plant operation was designed are:

1. A bark and sawdust processing plant can operate all year (250 days) on the raw material supply accumulated by two company owned trucks working a basic forty hour week.

Figure 7. System of Material Movement Through Processing Plant

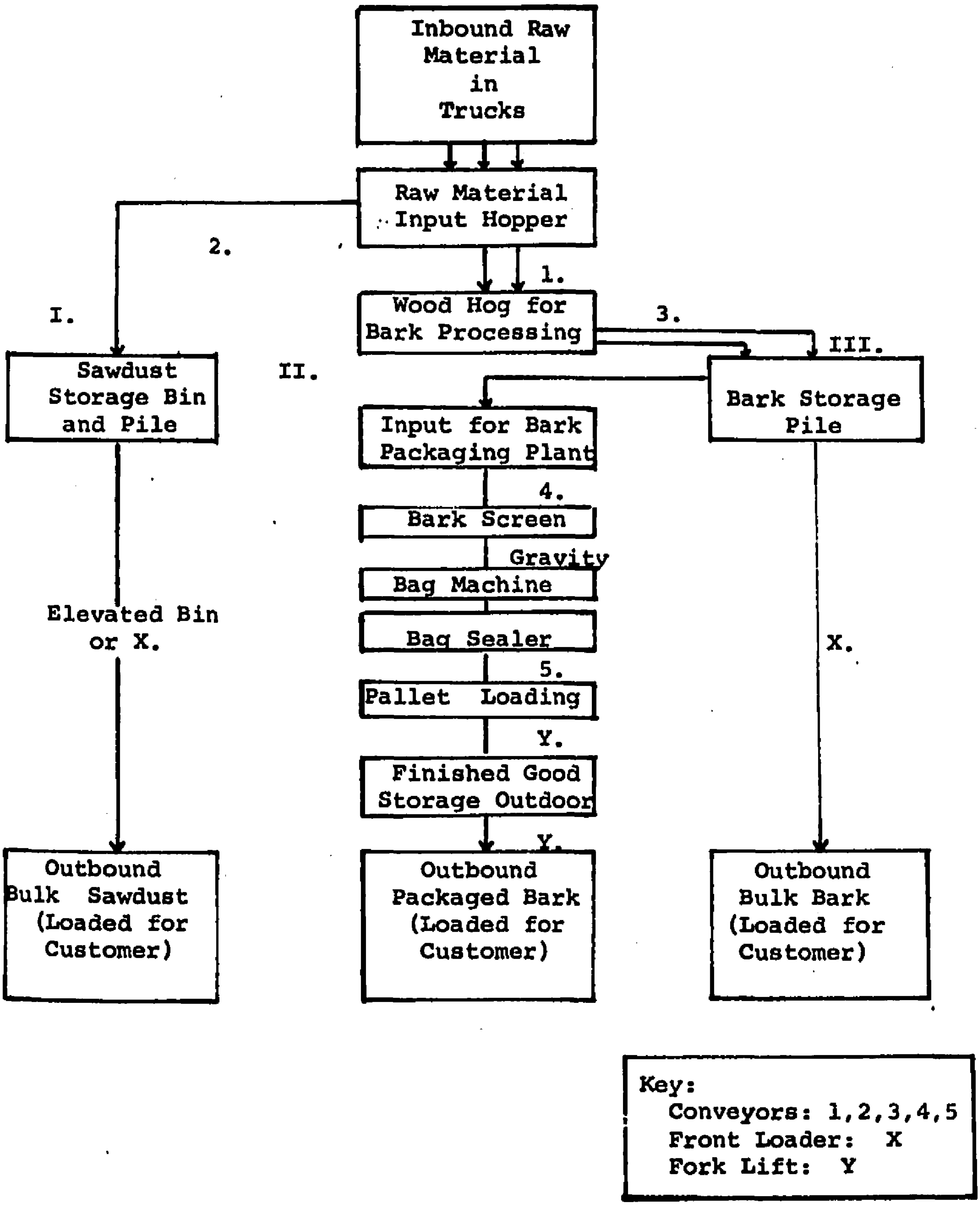
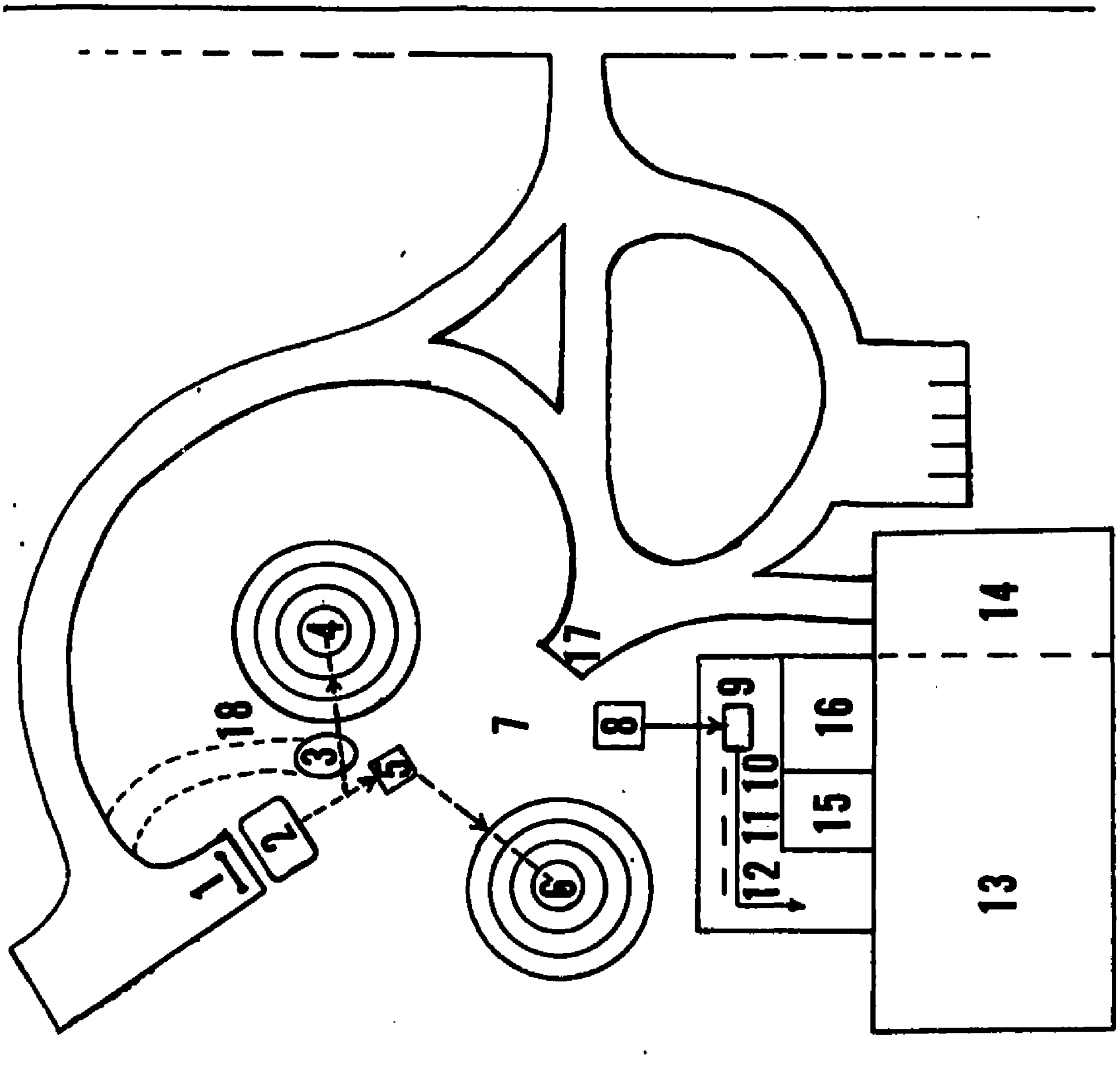


Figure 8. Illustration of Proposed Processing Plant.



KEY

1. Truck Dump
2. Hopper # 1
3. Sawdust Bin
4. Sawdust Pile
5. Wood Hog
6. Bark Pile
7. Front Loader
8. Hopper # 2
9. Screen
10. Bag Machine
11. Bag Sealer
12. Pallet
13. Outside Storage
14. Bag loading Dock
15. Store Room
16. Office
17. Bulk Loading
18. Bin Loading

2. Market demand will dictate the ratio of bark and sawdust that will be accumulated by the processing plant during the year.

3. Packaged bark products return the most profit to the processing plant and, therefore, can justify the most processing expense.

4. The processing plant is able to adjust the product mix and markets served over the course of a year to reduce seasonal variation in demand.

5. All raw materials for the processing plant will be purchased in units of forty cubic yards--no partial loads.

6. Sawmills supplying raw materials to the processing plant will load the company trucks at the mill site. Most mills presently have the necessary handling equipment.

7. The demand for packaged units of bark will be given first priority in the product line; second priority will be given to bulk bark and third priority to bulk sawdust sales.

8. A purchase agreement is signed with each sawmill supplying new material to the processing plant. This will guarantee a source of supply at a given cost.

Specific assumptions that relate to the supply and demand phase of the processing plant simulation are outlined below:

1. All costs are allocated by tons of material processed.
2. Limits built into the computer program are:
   a. maximum of six processing plants
   b. maximum of 83 counties in demand configuration
   c. maximum of 170 sawmills in supply configuration
3. Two dump bed trucks are used to concentrate a supply of raw material. If truck No. 2 is not utilized to seventy percent (70%) capacity, the wages of truck No. 1 driver are figured at overtime, and the cost of truck and driver No. 2 omitted.
4. Classes of costs cannot be added, but some can be left out.
5. The closest sawmill meeting the minimum production limitation is processed through the simulation first.
6. All bark in the supply area is brought into the processing plant first, then sawdust.
7. Pay rate of truck driver is $3.00 per hour.
8. Driver works between: 1870.5 and 1891.7 hours/year.

9. Demand within the simulation is satisfied in the following order:

A. Bark:
   1. Packaged
   2. Dairy
   3. Orchard
   4. Nursery

B. Sawdust:
   1. Dairy
   2. Nursery

10. Raw Material Data Summary:

	Hardwood Bark	Sawdust
Weight: (green)		
Per cubic foot	15#	19#
Per cubic yard	405#	513#
	(5 cubic yards/ ton)	4 cubic yards/ ton)
Cost: (loaded)		
Per cubic yard	$ 0.25	$ 0.50
Per ton	1.25	2.00
Per load	10.00	20.00

11. Truck Capacity: 8 tons 10 tons

12. Rated speed of truck: 40 MPH

The cost figures included under the general cost center categories mentioned earlier require additional background if they are to be evaluated for further use and up-dated. The next few pages briefly outline the costs and calculations used for this particular processing plant simulation that have not already been discussed.

1. Raw Material Cost - Completed

2. Inbound Transportation Costs: (two trucks)

Fixed Costs:

a. Two new trucks @ \$10,000 each = \$20,000 less \$2,000 trade-in value ÷ 5 year depreciation life = \$3,600 cost per year ÷ 250 days = \$14.40 daily cost.

b. Insurance @ \$300 per year per truck = \$600 ÷ 250 days = \$2.40 daily cost.

c. Truck license @ \$125 per year per truck = \$250 ÷ 250 days = \$1.00 daily cost.

Variable Costs:

a. Truck (each) \$0.60 per loaded mile charge to cover gas, oil, tires, and once a year overhaul of \$250.00.

b. Daily truck maintenance (each) \$1.50 per working day to cover driver's maintenance time of thirty minutes.

c. Driver wages (each) @ \$0.05 per minute or \$3.00 per hour; overtime calculated at a rate of \$4.50.

d. Truck loading time @ \$0.05 per minute for driver who is idle; 20 minutes for sawdust and 30 minutes for bark.

e. Truck driving time @ $0.05 per minute for driver.

f. Truck unloading time @ $0.05 per minute for driver who is idle; 10 minutes total for both bark and sawdust.

3. Inventory Holding Cost - Completed

4. Processing Costs: The plant and equipment needs are detailed in Table 14 and 15; first the fixed costs which are allocated according to the product receiving the greatest use each year, and then the variable costs which are allocated in dollars per ton of product produced.

5. Outbound Loading Costs

   a. Bulk Sawdust - using a sawdust bin, it requires two man-minutes per ton at $0.05 per minute; total cost is $0.10 per ton.

   b. Bulk Bark - using a front loader, it requires four man-minutes per ton at $0.05 per minute plus $0.05 per ton for loader gas, oil, tires, and maintenance; total cost is $0.25 per ton.

   c. Packaged Bark - using a fork-lift truck, it requires five man-minutes per ton at $0.05 per minute plus $0.05 per ton for fork-lift gas, oil, tires and maintenance; total cost is $0.30 per ton.

Table 14

Processing Plant Fixed Costs

FIXED COSTS	Total Cost New	Life Years	Trade-in Value Dollars	Cost Allocation Breakdown: Saw-dust Only $/year	All Bark to Y $/year	Package Bark After Y $/year	To be Allo-cated $/year
1. Land: 10 acres @ $200/acre	$ 2,000	25	1,000				40
2. Plant Office (inside plant)	1,200	10	200			25	75
3. 30 x 60 Package Bark Building	2,400	10	240			216	
4. 60 x 100 concrete storage area @ 30¢ per sq. ft.	1,800	10	0			180	
5. Interest on Investment @ 7%	2,436	0	0	186	626	917	707
6. Office Furniture	1,100	10	100			25	75
7. Interest of Office and Furniture @ 7%	160					40	120
8. Manager's Salary	12,000	0	0			3,000	9,000

Table 14, cont.

	FIXED COSTS	Total Cost New	Life Years	Trade-in Value Dollars	Cost Allocation Breakdown: Saw-dust Only $/year	All Bark to Y $/year	Package Bark After Y $/year	To be Allo-cated $/year
9.	Bookkeeper's Salary	5,580	0	0			1,500	4,080
10.	Property Tax	100	0	0			25	75
11.	Insurance	300	0	0			75	225
12.	Telephone	600	0	0			300	300
13.	Utilities	1,052	0	0			452	600
14.	Surge Hopper # 1, 40 cu. yd. capacity	1,200	10	200				100
15.	Conveyor # 1, 20 ft @ $20/foot	400	10	0				40
16.	Conveyor # 2 to sawdust bin and pile, 100 ft @ $20/ft.	2,000	10	0	200			
17.	80 cu. yd. capacity sawdust bin @ $5/cubic yard	400	10	0	40			
18.	Model 60 Mitts & Merrill Wood Hog	6,000	10	600		540		
19.	Wood Hog Installation	200	10	0		20		

Table 14, cont.

	FIXED COSTS	Total Cost New	Life Years	Trade-in Value Dollars	Cost Allocation Breakdown: Saw-dust Only $/year	All Bark to Y $/year	Package Bark After Y $/year	To be Allo-cated $/year
20.	Bldg. for Hog 10 x 10 ft.	500	10	0		50		
21.	Conveyor #3 to bark pile 100 feet @ $20/foot	2,000	10	0		200		
22.	Front Loader with 2 cu. yd. bucket	8,000	10	800				720
23.	Loader Driver @ $3/hr.	6,000	0	0				6,000
24.	Surge Hopper #2, 3 cu. yd. capacity	200	10	20			18	
25.	Conveyor #4, 50 feet @ $20/ft. (yard into plant)	1,000	10	0			100	
26.	6 x 6 ft. vibrating screen	300	10	0			30	
27.	Bag Machine	200	10	0			20	
28.	Electric Heat Type Sealing Machine	1,200	10	120			108	
29.	Conveyor #5 Portable (for finished product)	1,000	10	0			100	

Table 14, cont.

FIXED COSTS	Total Cost New	Life Years	Trade-in Value Dollars	Cost Allocation Breakdown: Saw-dust Only $/year	All Bark to Y $/year	Package Bark After Y $/year	To be Allo-cated $/year
30. 8 Electric Motors	800	5	0	20	20	80	40
31. Total Electrical Wiring	1,200	10	0	15	15	60	30
32. Gas Engine Fork Lift	4,000	10	400			360	
TOTAL FIXED COSTS				$461	$1,491	$7,631	$22,227

Table 15

Processing Plant Variable Costs

VARIABLE COSTS	Cost Allocation Breakdown			
	Saw-dust Only $/ton	All Bark to Y $/ton	Package Bark After Y $/ton	To be Allo-cated $/ton
1. Processing Plant Operator one man producing: 1.5 bags/minute 50 minutes per hour 75 bags output/hour			2.50	
2. Wood Hog Utilities @ $0.10/ton		0.10		
3. Conveyor Motor Utilities @ $0.002/ton/motor	0.04	0.04	0.08	
4. Electric Sealing Machine Utilities @ $0.05/ton			0.05	
5. Wood Hog Maintenance; sharpening and replacements		0.02		
6. Front Loader Gas and Maintenance to move bark into processing plant			0.20	
7. 48 x 48 one-way block pallets			2.25	
8. Multi-color Poly bags, printed @ $0.12 each			8.04	
9. Maintenance on conveyors and surge hoppers	0.02	0.02	0.02	
TOTAL VARIABLE COSTS	$0.06	$0.18	$13.14	

To complete this section of cost data it is necessary to include the price of the finished good sold. The raw material purchase price is also included for sake of comparison with the selling price.

Purchase Price		Product	Selling Price	
(Per Yard)	(Per Ton)		(Per Yard)	(Per Ton)
$0.50	$2.00	Sawdust: Bulk	$1.00	$4.00
$0.25	$1.25	Bark: Bulk	$1.00	$4.00
$0.25	$1.25	Bark: Packaged	$0.95	$63.65

Trial Configurations

Three trial configurations selected from a total of four dozen computer runs are outlined in the research design. Each configuration is different from the other two and serves to illustrate the supply and demand inputs of the computer simulation which were used to compute the findings in Part V.

The supply sawmills for each configuration are shown first in Tables 16, 18, 20. Tables 17, 19, 21, summarize the counties included in the demand portion of the configuration. Lastly, a map showing the approximate location of the processing plant and the surrounding counties constituting the demand area are shown in Figures 8, 9, 10.

Information at the top of the supply table tells:

1. The plant number (1-6) of a multiple computer run.

TABLE 16

Configuration No. 1--Listing of Supplying Mills for Processing Plant

Coordinate 4635...Radius 21 Miles...Minimum Annual Production 501 MBF

Mill No.	Coordinate	Distance	Production (in thous.)	Tons Sawdust	Tons Bark
139	4636	3	1800,000	1872.00	0.00
138	4735	3	4000,000	4160.00	0.00
140	4736	6	11340,000	11793.60	6577.20
137	4732	12	2400,000	2496.00	1392.00
141	4840	21	1050,000	1092.00	0.00
75	4238	21	300,000	312.00	0.00
	Total			21725.60	7969.20

TABLE 17

Configuration No. 1--Listing of Counties in Demand for Processing Plant

Coordinate 4635...No. of Counties 14

County	Coord.	Distance	Tons of Sawdust		Tons of Bark			Pkg.
			Dairy	Nursery	Dairy	Nursery	Orchard	Bark
Isabella	3544	60	700	110	700	110	0	9
Clinton	3928	42	800	510	800	510	0	12
Shiawassee	4728	24	650	140	650	140	0	17
Genesee	5429	42	400	1420	400	1420	1100	124
Oakland	5021	84	250	3140	250	3140	1760	228
Midland	4344	36	100	590	100	590	0	16
Gratiot	3836	27	450	190	450	190	0	11
Saginaw	4836	9	600	1890	600	1890	0	60
Ingham	4320	54	750	1420	750	1420	0	70
Tuscola	5940	54	700	170	700	170	0	13
Macomb	6722	102	450	2620	450	2620	1820	155
Bay	4944	36	250	1120	250	1120	0	32
Livingston	5120	60	650	450	650	450	0	13
Lapeer	6231	60	1000	830	1000	830	820	13
	Totals		7750	14600	7750	14600	5500	773

Total Sawdust	22350.0	Percent of Supply	1.03
Total Bark	28623.0	Percent of Supply	3.59

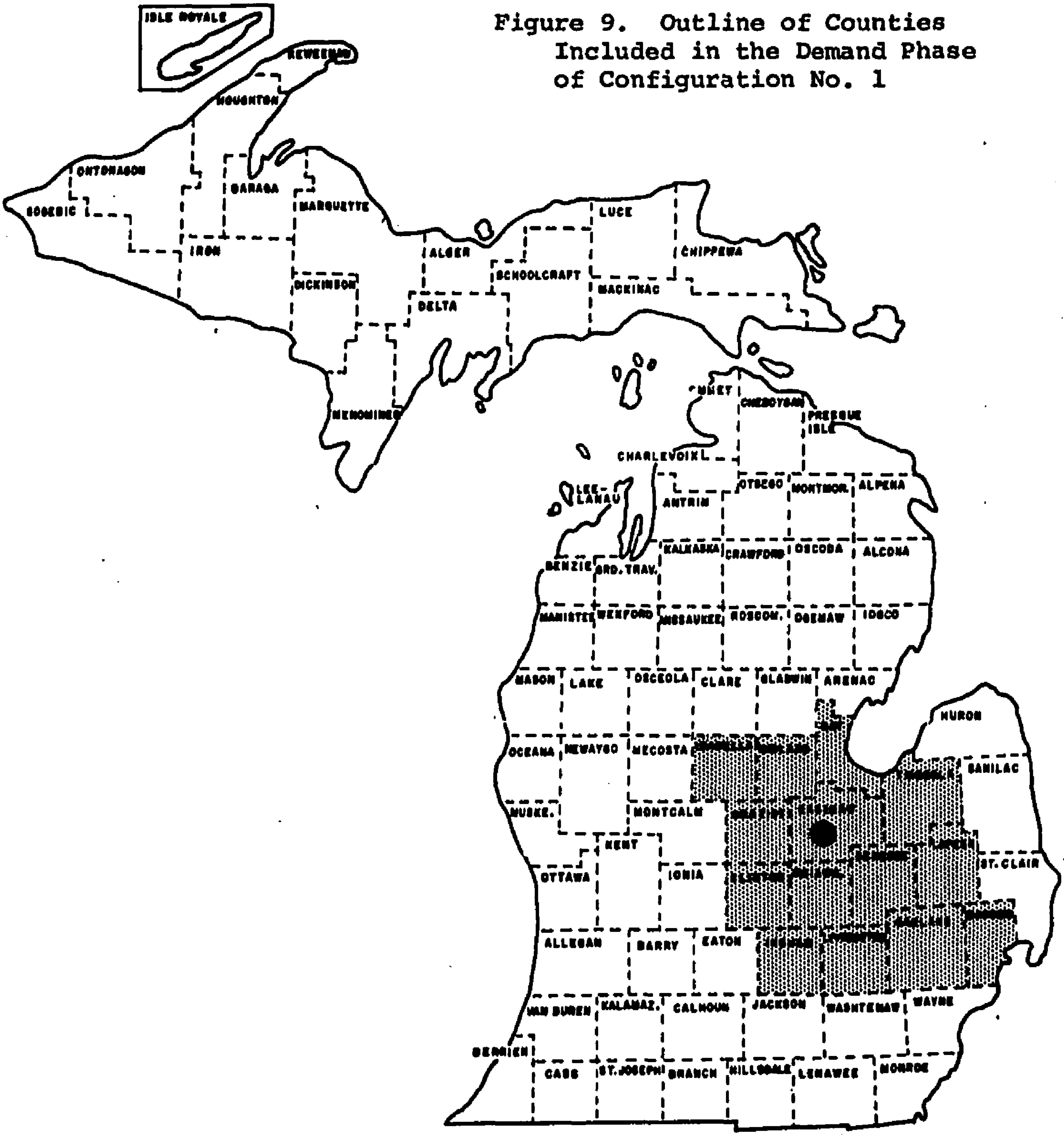


Figure 9. Outline of Counties Included in the Demand Phase of Configuration No. 1

TABLE 18

Configuration No. 2--Listing of Supplying Mills for Processing Plant

Coordinate 3528...Radius 21 Miles...Minimum Annual Production 299 MBF

Mill No.	Coordinate	Distance	Production (in thous.)	Tons Sawdust	Tons Bark
93	3529	3	2640,000	2745.60	1531.20
91	3326	12	1920,000	1996.80	1113.60
69	4028	15	3000,000	3120.00	1740.00
73	3323	21	3000,000	3120.00	1740.00
71	3223	24	50,000	52.00	0.00
95	3024	27	300,000	312.00	0.00
94	2931	27	312,000	324.50	0.00
	Total			11670.90	6124.80

TABLE 19

Configuration No. 2--Listing of Counties in Demand for Processing Plant

Coordinate 3528...No. of Counties 11

County	Coord.	Distance	Tons of Sawdust Dairy	Tons of Sawdust Nursery	Tons of Bark Dairy	Tons of Bark Nursery	Tons of Bark Orchard	Pkg. Bark
Montcalm	3036	39	650	770	650	770	740	12
Ionia	3128	12	800	140	800	140	2160	12
Barry	3720	48	500	160	500	160	0	8
Kent	2330	42	750	1830	750	1830	13560	119
Shiawassee	4728	36	650	140	650	140	0	17
Gratiot	3836	33	450	190	450	190	0	11
Clinton	3928	12	800	510	800	510	0	12
Eaton	3520	24	600	140	600	140	0	16
Ingham	4320	48	750	1420	750	1420	0	70
Oakland	6021	96	250	3140	250	3140	1760	228
Wayne	6212	129	50	3100	50	3100	0	800
Totals			6250	11540	6250	11540	18220	1305

Total Sawdust 22350.0 Percent of Supply 1.03
Total Bark 28623.0 Percent of Supply 3.59

Figure 10. Outline of Counties Included in the Demand Phase of Configuration No. 2.

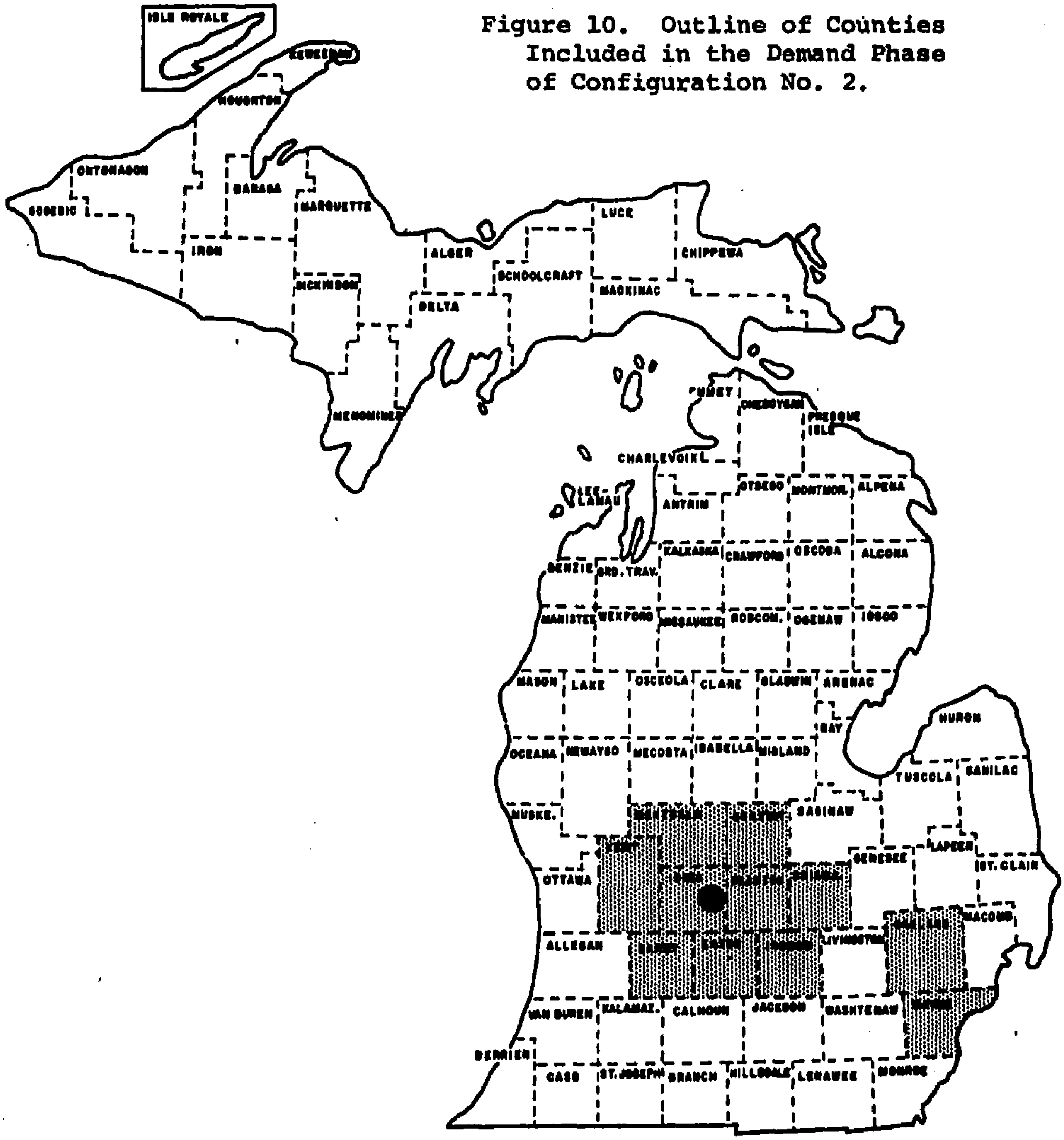


TABLE 20

Configuration No. 3--Listing of Supplying Mills for Processing Plant

Coordinate 3520...Radius 27 Miles...Minimum Annual Production 299 MBF

Mill No.	Coordinate	Distance	Production (in thous.)	Tons Sawdust	Tons Bark
70	3519	3	3875,000	4030.00	2247.50
73	3323	15	3000,000	3120.00	1740.00
74	3922	18	750,000	780.00	0.00
72	3817	18	300,000	312.00	0.00
71	3223	18	50,000	52.00	0.00
88	4119	21	90,000	93.60	0.0
54	2921	21	600,000	624.00	0.00
98	3815	24	800,000	832.00	0.00
91	3326	24	1920,000	1996.80	1113.60
87	4219	24	750,000	780.00	0.00
48	2821	24	750,000	780.00	0.00
47	3116	24	300,000	312.00	0.00
95	3024	27	300,000	312.00	0.00
93	3529	27	2640,000	2745.60	1531.20
89	4016	26	300,000	312.00	0.00
55	2818	27	300,000	312.00	0.00
50	2721	27	300,000	312.00	0.00
49	3016	27	100,000	104.00	0.00
52	2916	30	50,000	52.00	0.00
92	2825	36	750,000	780.00	0.00
61	3013	36	300,000	312.00	0.00
	Total			18954.00	6632.30

TABLE 21

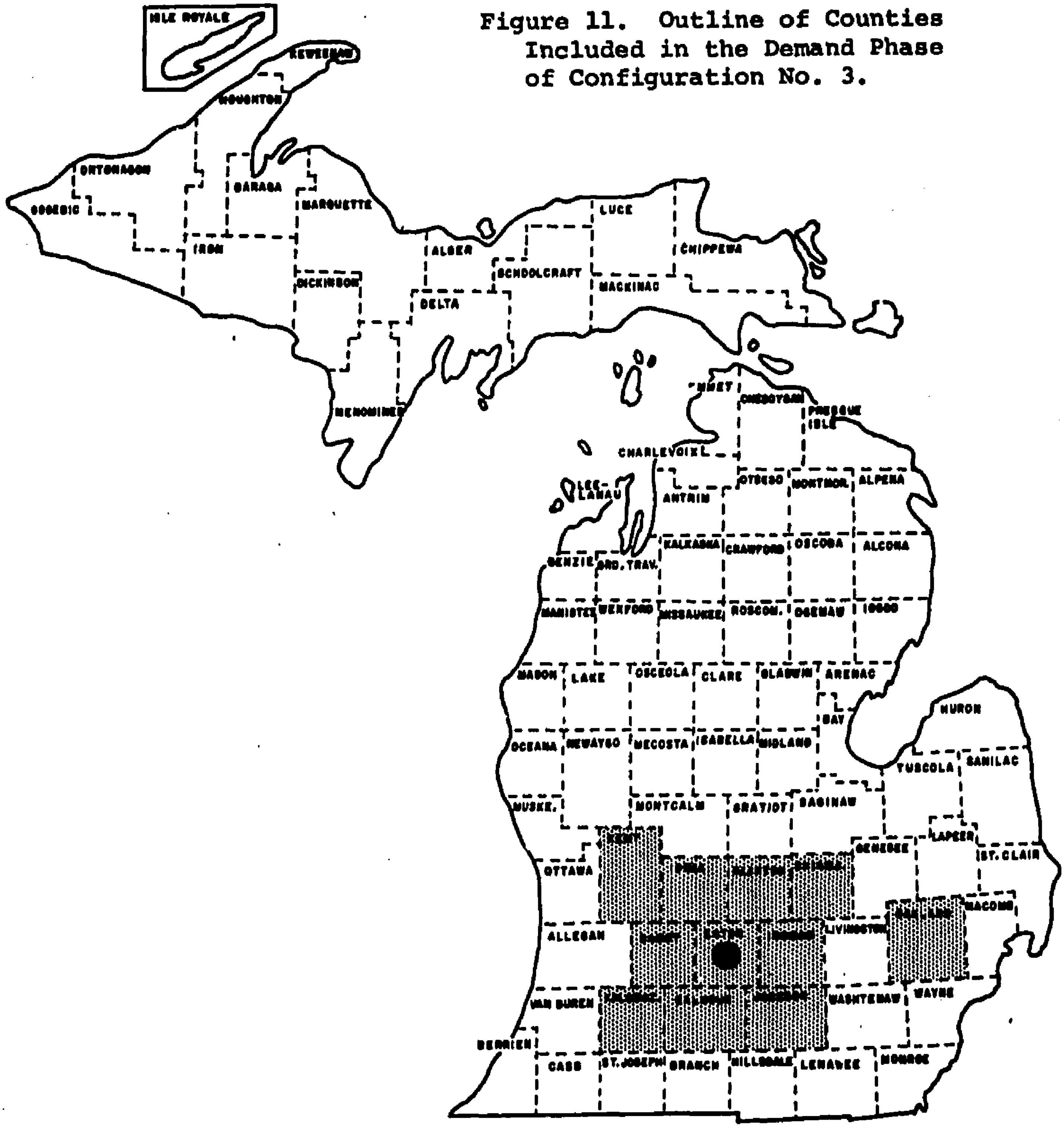
Configuration No. 3--Listing of Counties in Demand for Processing Plant

Coordinate 3520...No. of Counties 11

County	Coord.	Distance	Tons of Sawdust		Tons of Bark			Pkg.
			Dairy	Nursery	Dairy	Nursery	Orchard	Bark
Eaton	3520	0	600	140	600	140	0	16
Clinton	3928	36	800	510	800	510	0	12
Ionia	3128	36	800	140	800	140	2160	12
Barry	2720	24	500	160	500	160	0	8
Kalamazoo	2312	60	250	2650	250	2650	1340	54
Calhoun	3312	30	600	1190	600	1190	0	44
Jackson	4212	45	600	320	600	320	1040	40
Ingham	4320	24	750	1420	750	1420	0	70
Shiawassee	4728	60	650	140	650	140	0	17
Kent	2330	66	750	1830	750	1830	13560	119
Oakland	6021	78	250	3140	250	3140	1760	228
Totals			6550	11640	6550	11640	19860	620

Total Sawdust	18190.0	Percent of Supply	.96
Total Bark	38670	Percent of Supply	5.83

Figure 11. Outline of Counties Included in the Demand Phase of Configuration No. 3.



2. The processing plant coordinate

3. The radius of the supply circle

4. The minimum annual lumber production of mills to be included as suppliers inside the circle.

Now looking at the demand tables, two numbers are shown near the bottom after percent of supply. These two ratios relate the amount of supply to the amount of demand within the configuration. The closer the number is to 1.00 the better supply and demand are in balance.

All other information is reasonably self explanatory.

PART IV

FINDINGS--RELATIVE TO PHASE II

Introduction

The results of the field survey and mail survey are discussed in the following paragraphs. Discussion of both field survey results and mail results are centered on the secondary objectives mentioned earlier and the results obtained from the mail survey presented in summary tables. Tables are presented in the text and in the appendix to facilitate the discussion.

Field Survey Findings

During the field survey it was observed that almost every sawmill site was the scene of vast accumulations of wood residues. Piles of slabs, edgings, end trim, sawdust, and bark were commonplace. In some cases slabs and edgings had been cut into firewood lengths and piled in equally large piles.

Wood Residue Accumulations and Characteristics

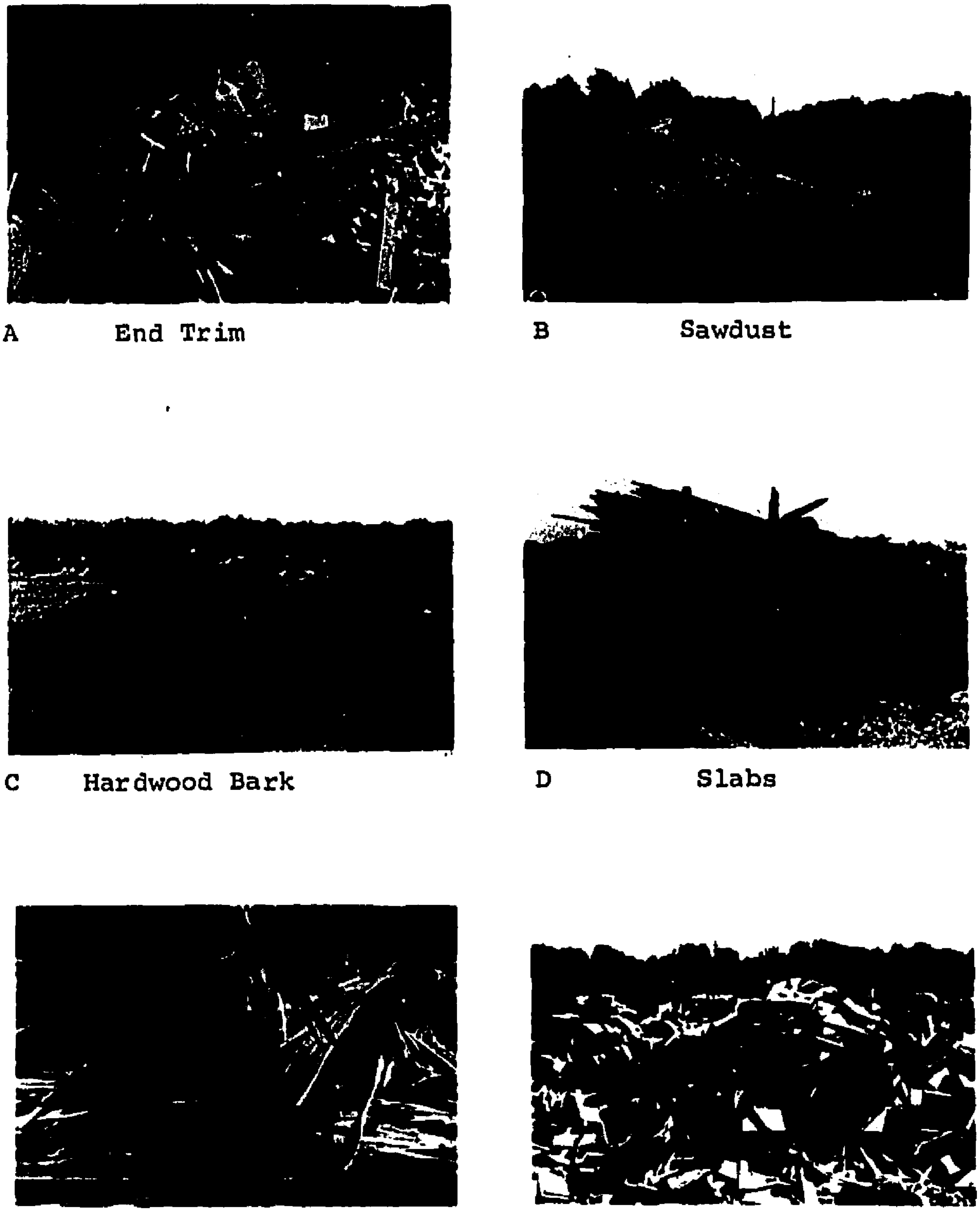
The quantities of wood residue accumulated around the typical hardwood sawmill in southern Michigan were photographed by the author. Figure 12 inadequately illustrates the quantities accumulated adjacent to the sawmill, but the general idea is clearly shown.

To be more specific about what the accumulations of wood residues are like, the characteristics can be seen in the Figure 13 close-up photographs in comparison with engineered wood chips. In photograph (A) hardwood sawdust is shown. The sawdust is relatively free of bark particles because the sawmill uses a log debarker to remove the bark prior to breaking down the log on the head saw.

Photograph (B) shows hardwood bark (American Beech) as it looks when removed from the log by a rosser-head type debarker. The bark is usually green and very wet and, depending on the species, the bark particles vary widely in both size and shape. It is not clearly evident in the photograph, but often as much as 25-50 percent wood fiber is attached to the bark. The percent of wood fiber attached to the bark depends on several factors:

1. the species being debarked
2. the experience of the machine operator
3. the season of the year
4. the uniformity of the log surface
5. the condition of the cutter head

Figure 12. Vast Quantities of Wood Residue Found at Most Sawmill Sites



A End Trim

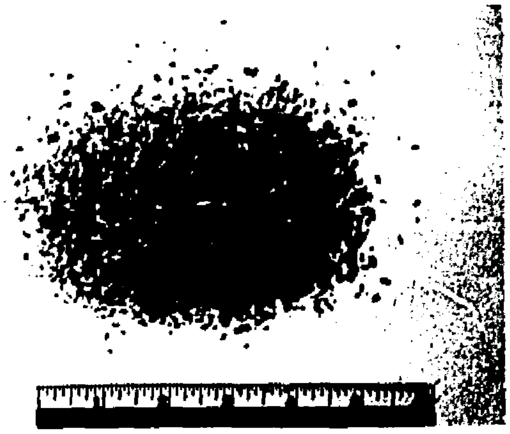
B Sawdust

C Hardwood Bark

D Slabs

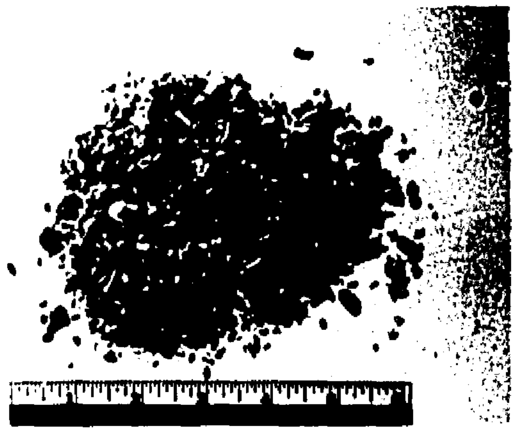
E Edgings

F Slabs cut into Firewood



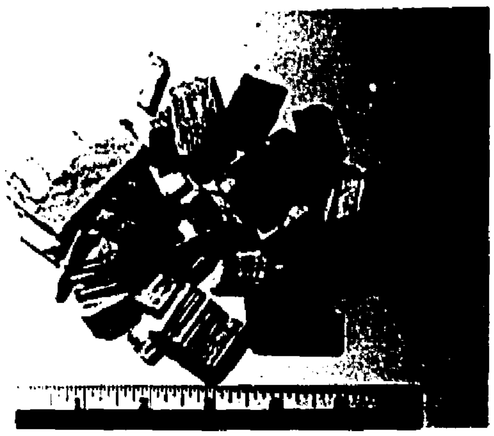
A Sawdust from Mill with Debarker

B Hardwood Bark Removed by Debarker



C Sawdust from Mill without Debarker Contains Bark Particles

D Hogged Bark and Sawdust Mixed



E Engineered Wood Chips

F Dry Planer Shavings

Figure 13. Close-up Photographs Showing Characteristics of Fine Wood Residues Compared to Engineered Wood Chips

Photograph (C) shows the characteristics of sawdust coming from a sawmill without a log debarker. Rather than being a light uniform color, like the sawdust shown in (A), the sawdust contains a considerable amount of dark bark particles.

The hogged bark and sawdust mix seen in photograph (D) represents a combination of bark and sawdust. It can be seen that the bark has more uniform characteristics than in (B). The uniformity is obtained by processing the bark through a mechanical wood hog. Mixing processed bark and sawdust together is often done by sawmills having customers who prefer a product with the basic characteristics of bark, but also want the additional bulk furnished by the sawdust.

Photograph (E) shows the characteristics of uniform engineered wood chips prepared for the pulp and paper industry. The chips are carefully manufactured from coarse wood residue at many sawmills in Michigan. They are shown here for comparison with the fine wood residues.

Dry planer shavings are shown in Photograph (F). Wood shavings have the characteristics of being dry, fluffy, and relatively dust free. Because of these good qualities, there are many profitable markets for shavings.

Current Methods of Residue Disposal

The methods used to dispose of wood residues by different sawmills were observed by the author to be many in number, but essentially the same in that most methods involved an expense to the sawmill rather than a source of income.

The most frequently used methods of fine wood residue disposal are shown in Figure 14. The photographs point out one basic fact: that currently there are many more unprofitable ways being used to dispose of fine wood residues than profitable ones. The greatest percent of wood residues at small sawmills is either burned in the open, given away, or dumped at the back of the mill site. Some of the larger mills operate teepee burners. Of the total mills in southern Michigan, only a very few mills make any effort to sell bark or sawdust.

Current Markets for Wood Residues

Finding out what the current available markets are for hardwood bark and sawdust in southern Michigan was an important part of the field survey. The data in Figure 15 served as the initial indicators for residue markets. Upon interviewing the sawmill operators that are currently engaged in marketing sawdust and bark products, it was found that population density and amount of agricultural activity within a county are in fact reasonably good indicators of the market

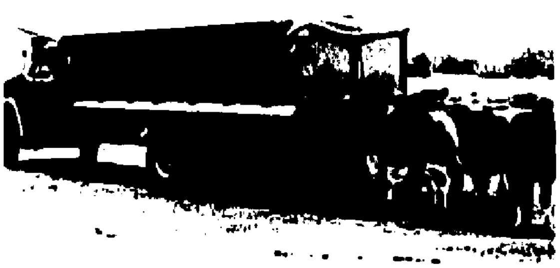
Figure 14. Current Methods of Fine Wood Residue Disposal

A Conveying Residues to Teepee Burner

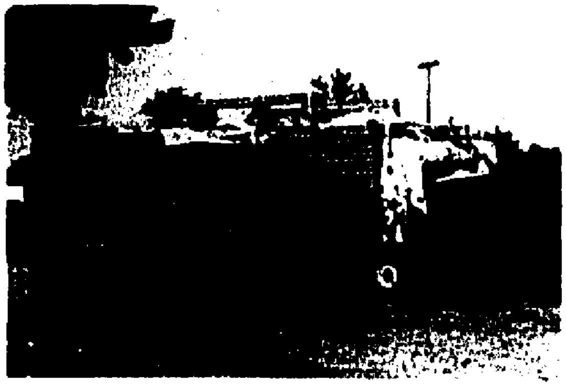
B Open Burning

C Dumping at Back of Mill Site

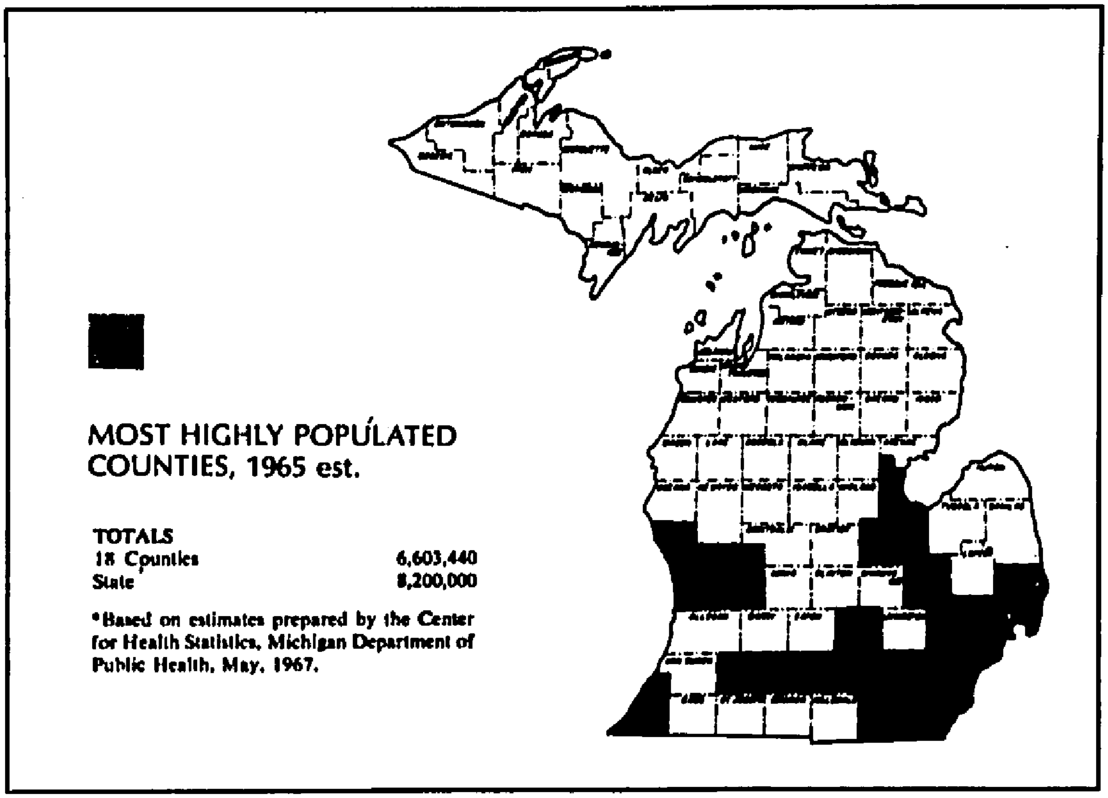
D Conveying to Pile



E Selling Sawdust and Bark for Dairy Bedding, etc.



F Giving Residues Away



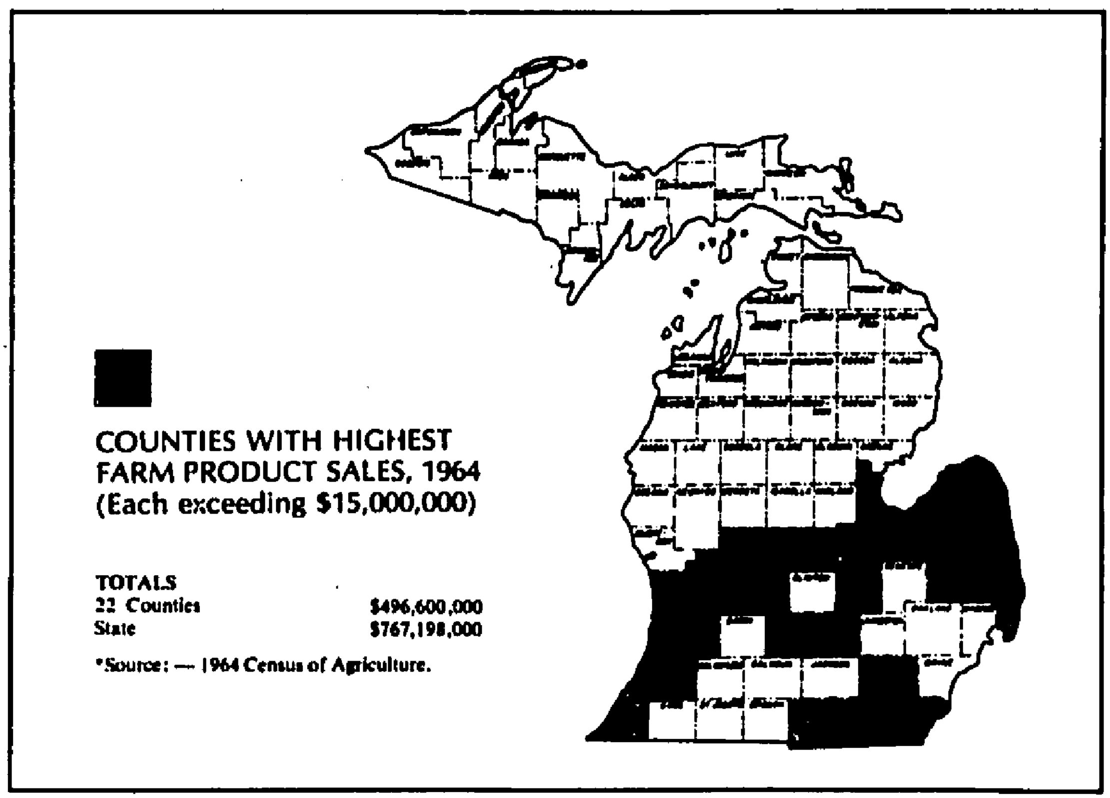


Figure 15. The Two Major Factors Determining the Location of Current Wood Residue Markets--Population and Agriculture

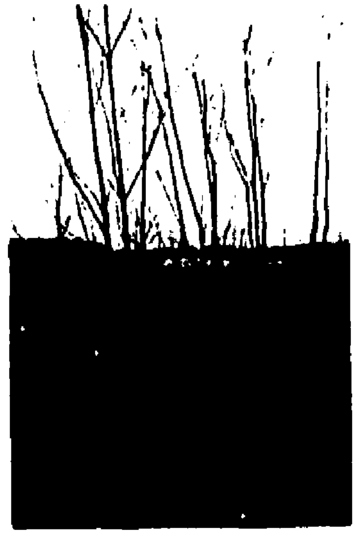
size. The best general indicator for packaged bark markets is population since the product is sold primarily to the home gardener. The amount of agricultural activity within a county was found to be a good general indicator for potential sales of bark and sawdust. Sawmill operators reported that, of the bark and sawdust they sold, the greatest quantity was purchased by dairy farms for cattle bedding. Some bark was reported sold to the orchard industry for fruit tree mulch, and some bark and sawdust had been sold to tree nurseries for mulch.

To check out the reported markets mentioned by the sawmill operators, several visits were made to the purchasers of sawmill bark and sawdust. Figure 16 shows five of the most common uses for wood residues. In all cases the users were well pleased with the actual material even though they were still unsure about the validity of the "old wives' tales" concerning the uses of sawdust and bark. Most were in agreement about the cost being too high and the general difficulty in obtaining the material.

It was observed during the field survey that between 25 and 50 percent of all sawdust produced is being sold, but very little bark. Because of the apparent difficulty in establishing markets for bark, special attention was directed to the problems encountered by sawmills that consider marketing

Figure 16. Current Uses for Wood Residues

A Orchard Mulch



B Nursery Mulch

C Fruit Mulch

D Decorative Ground Cover

E Dairy Bedding

bark products. The findings are summarized as follow:

1. Great quantities of bark are available, usually in scattered locations.

2. The disposal problems surrounding bark are severe and becoming more severe. Burning is not an efficient or profitable disposal technique at this point; air pollution legislation is imminent.

3. Barks are not uniform. Each specie differs and there is a wide range of quality within species.

4. Each bark species has certain advantages and disadvantages. Consideration must be given to color, structure, density, sorptive capacity, resistance to decomposition, and fiber characteristic.

5. Barks in general are considered a waste product or, at best, a low-value product and have little consumer appeal in their natural form.

6. When processed as a decorative mulch or soil conditioner, care must be given to uniformity of color, texture, and size.

7. Foreign matter such as wood fiber, slivers, and splinters have varying degrees of importance upon the finished product.

8. Low cost and effective substitutes for any known bark products are available in local markets at competitive price and volume levels.

9. Demand is limited because bark products are relatively unknown to the consumer.

Wood Residue Market Competition

During the field survey it was found that sawdust and bark used as dairy cattle bedding receives the greatest competition from straw, the traditional bedding material. But it was pointed out that as more hybrid grains are grown the stalks are becoming shorter and shorter making less straw bedding available on the farm. Another current practice is for the dairy farmer to grow less grain crops and spend more time specializing in dairy management. Dairy managers were quick to point out that the competition for suitable bedding material will continue to increase.

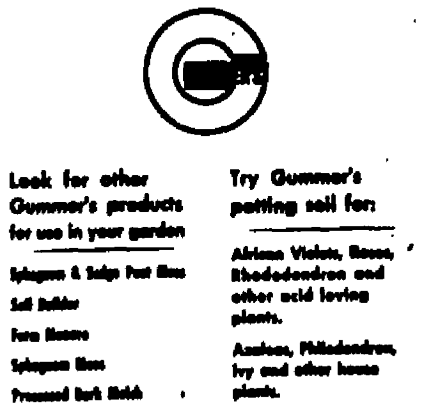
It was found out during talks with nursery operators that the use of sawdust as a nursery mulch has always received stiff competition from peat moss and straw. This has primarily been because of the nitrogen depletion problems that arose if the user was not familiar with the use of sawdust (or bark) as a mulching material. Misinformation and old wives' tales about the toxic content of sawdust were also found to limit the use of wood residues as mulches in nurseries. Many requests were made for up-to-date information on how to use wood residue mulches.

The use of bark as an orchard mulch was found to be limited, not by a competitive material, but by the fact that adequate information is not available on how to use the mulch or resulting benefits. The orchard operators are reluctant to try wood residues as mulches without knowing more about the possible effects.

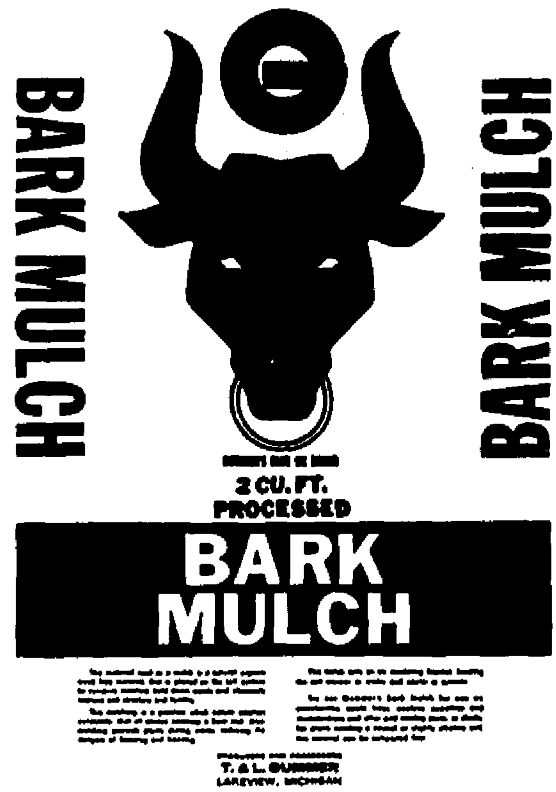
The utilization of packaged bark from various parts of the United States used for soil improvement, soil amendment, growing mediums, and decorative covers was found to be a rapidly growing business. Packaged bark sold through lawn and garden centers was found to be in direct competition with traditional soil amendments such as peat moss, sludge, manures, humus, sand, leaf mold, composted waste products, etc. A summary of the limiting factors for domestic hardwood bark utilization, cited by operators of lawn and garden centers, was that today the customers are demanding a quality bark product free from wood particles, of uniform size and color, and sold at the same price they paid several years ago.

It was reported that the most recent competition in the decorative ground cover market was coming from substitutes such as volcanic rock and ash, colored stones, and wood chips.

Upon visiting Lansing and Grand Rapids area lawn and garden centers it was found that bark is usually sold in bags. Home owners and other small quantity users consume most of the hardwood bark mulch produced. Thus most producers, including one small Michigan producer, market their mulch in colorful plastic bags holding two or three cubic feet, Figure 17. It was reported that retailers and consumers seem satisfied with these bags because they are easily handled, weatherproof, and resistant to damage--especially from internal

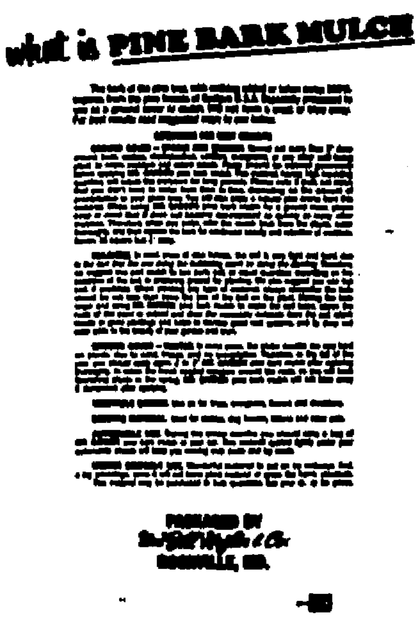


Bag A - Back



Bag A - Front

Bag B - Back



Bag B - Front

Figure 17. Colorful, Informative, Consumer Appealing, Plastic Bags Used Successfully as Bark Mulch Packages

moisture. Retailers reported greatly increased sales of bark products now that attractive, colorful, informative bags are used to merchandise the product as well as function as a container.

Comparative retail prices for mulches, soil conditioners and decorative lawn products observed during the 1968 field survey are presented in Table 22. Competitive bark products from the west coast are presently selling on a tight margin because of high freight rates. The current prices cannot be lowered more than 14 percent and still remain profitable.

In bulk sales, sawmill operators having log debarkers reported selling hardwood bark mulch for $2 to $5 a ton f.o.b. plant. Sales are made to nurseries, orchards, landscapers, dairy farmers, and other large users. To date only a few bark sales in bulk quantities have been reported.

Mail Survey Findings

A total of 106 mail questionnaires were mailed to selected sawmill owners and operators. A total of 92 completed questionnaires were returned. This represents a return of 87 percent which is exceptional.

In some cases the respondents did not answer all of the questions that were asked; therefore, the total number of responses on the following tables will seldom equal 92.

Table 22

Comparative Retail Prices of Mulches, Soil Conditioners, and Decorative Lawn Products, in Lansing, Michigan*

	Item (Summer 1968)	Price at Garden Center or Nursery
1.	2 cu. ft. Hardwood Bark Mulch	1.77
2.	3 cu. ft. Pine Bark Mulch	2.29
3.	4 cu. ft. Pine Bark Mulch, fortified	3.98
4.	3 cu. ft. Vita-Bark Ground Cover	3.98
5.	5 cu. ft. Shredded Hardwood Bark (45#)	3.98
6.	Baled Wheat Straw (35-45#)	1.25
7.	50# Ground Corn Cobs	2.40
8.	1 cu. ft. Sphagnum Peat Moss	0.89
9.	4 cu. ft. Canadian Peat Moss	3.97
10.	50# Buckwheat Hull Mulch	2.95
11.	25# Cocoa Shell Mulch	1.99
12.	50# Dairy Compost	1.59
13.	25# Dairy Compost	0.97
14.	1 cu. yd. engineered wood chips (local del) (local delivery)	10.00
15.	4 cu. ft. Vermiculite (18#)	2.99
16.	50# White Decorative Stone (Marble)	1.99
17.	50# Black Decorative Stone (Obsidion)	2.99
18.	50# Crushed Vitrified Tile	1.65

*Prices listed are extremely variable, depending upon freight charges, sales outlets, local prices of competing goods, and other factors.

None of the questionnaires returned from the six counties outside the basic study area represented any circumstances not common to the basic study area other than the fact that mills further north process softwood species in part or in total.

The findings of the mail survey are included in tables and figures on the following pages along with brief narrative comments. For sake of order, the tables and summary figures are presented in the same order sequence as the questions listed on the questionnaire (Appendix A).

General question (A) asked the sawmill owner or operator to check the appropriate box in front of each piece of equipment used around the sawmill. Table 23 presents the responses. The important point to note is the number of log debarkers and the size mill operating them.

Table 23

Equipment Owned by Hardwood Sawmills

Class	No. of Responses	Debarker	Chipper	Wood Hog	Tractor	Fork lift	Teepee burner
A	2	2	2	1	2	2	1
B	2	2	1	1	0	2	2
C	6	4	4	2	5	6	3
D	24	12	11	1	5	23	3
E	17	4	1	0	10	14	0
F	28	2	2	0	13	24	0
LTF	9	0	0	0	5	6	0
Total	88	26	21	5	40	77	9

Source: Mail Questionnaire - January 1969

General question (B) was self-explanatory in asking for the approximate daily lumber production. The responses to the question were recorded in Table 24 showing the sawmill production by sawmill class and daily production of lumber which is helpful in comparing the actual capacity of mills within the general classes.

Table 24

Estimated Daily Hardwood Lumber Production by Individual Sawmills

Class	No. of Responses	Thousand Board Feet																		
		1	1	2	3	4	5	6	7	8	9	10	11	12	15	18	25	30	45	55
A	2											1								1
B	2									1							1			
C	6								1						3	1			1	
D	24	1					3	1	2	5		6		4	2					
E	17			1	1	3	6			1	1	1		2				1		
F	28	4	4	8	5	1	2	2		1			1							
LTF	9	2	2		2		2			1										
Total	88	7	6	9	8	4	13	3	3	9	1	8	1	6	5	1	1	1	1	1

Source: Mail Questionnaire - January 1969

Average daily lumber production by sawmill class is presented in Table 25. The figures serve as indicators of sawmill size relative to the other mills in the same class and point out where the greatest volume is produced.

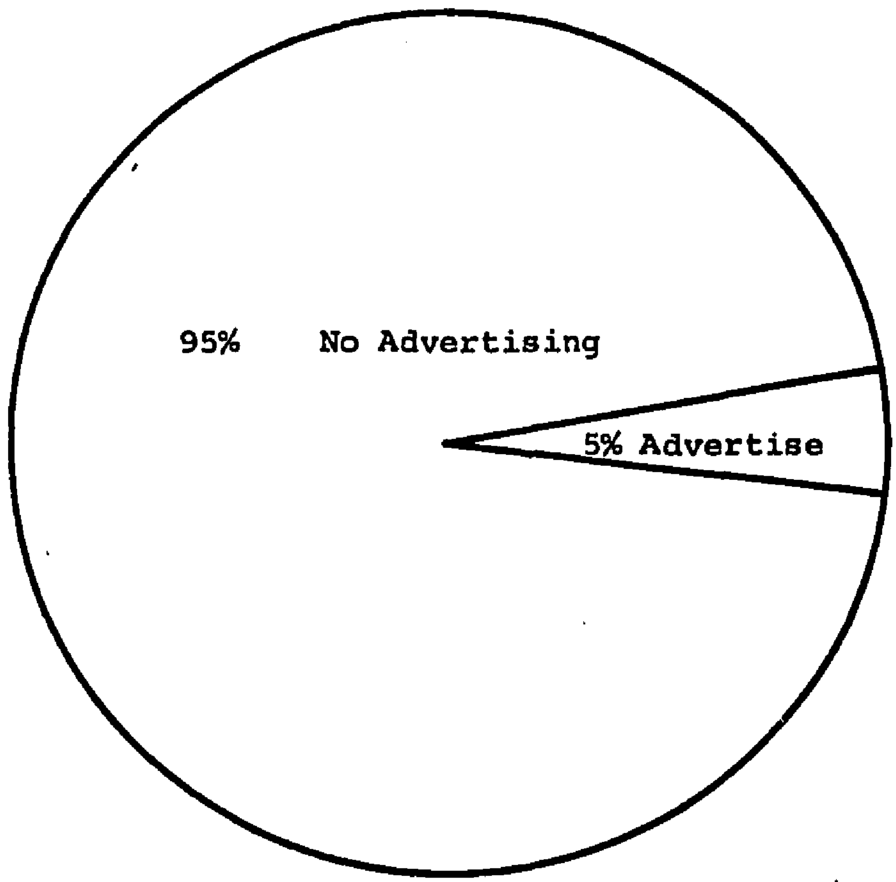
Table 25

Daily Lumber Production by Sawmill Class

Class	Average Daily Production (MBF)	% of Total Production Contributed by Each Sawmill Class
A	32.5	37
B	16.5	18
C	19.7	21
D	8.8	10
E	7.5	8
F	2.9	3
LTF	2.9	3
Total	90.8	100

General question (C) asked the sawmill owner to check the methods of advertising used to promote the sale of wood residues. A summary of responses indicated less than 5 percent of all sawmills in the study area advertise any bark, sawdust, slabs, firewood, bedding or mulch. Figure 18 shows the percentage of sawmills advertising in some manner at this time.

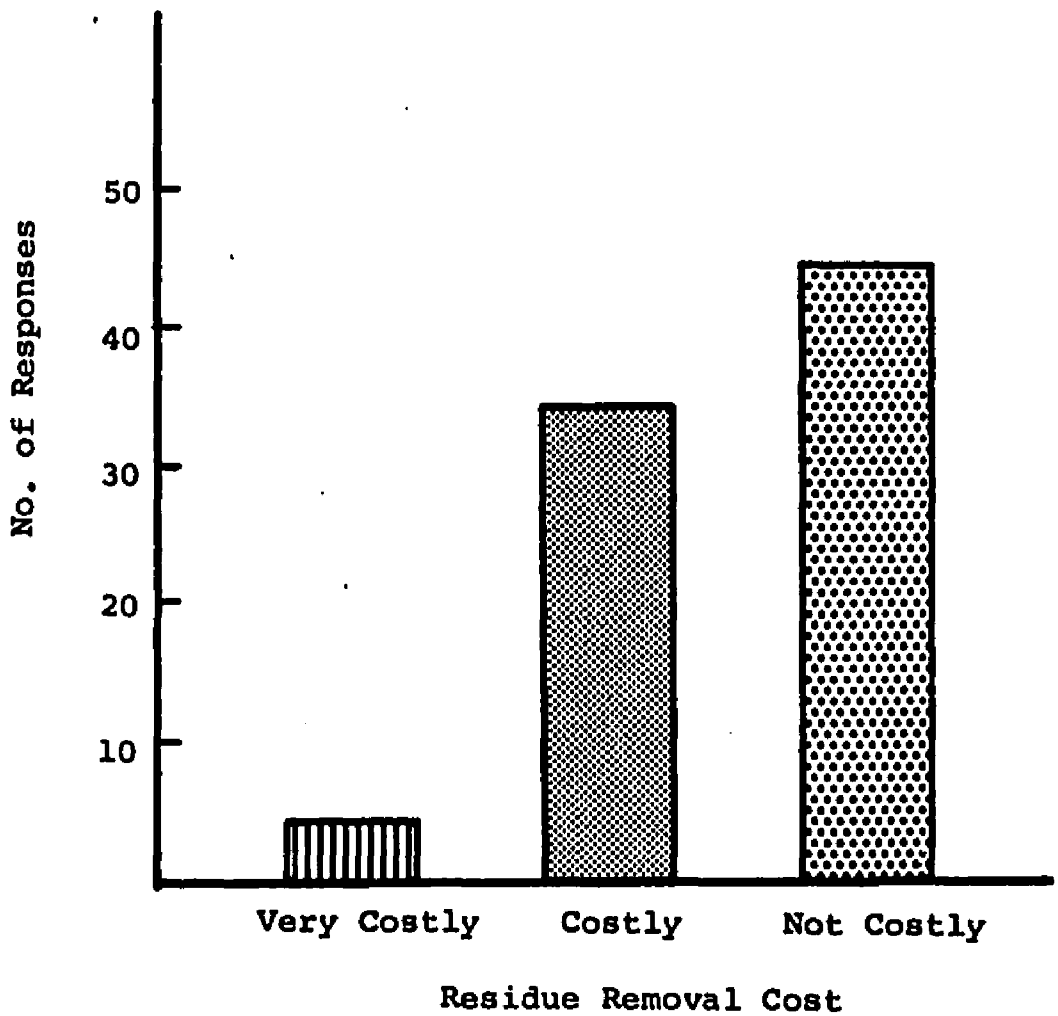
Figure 18. Percentage of Sawmills Advertising Residue Products for Sale.



General question (D) asked sawmill owners to place a check (✓) in front of the approximate quantity of wood residue they produced each year. The responses were determined to be invalid and are not presented in the study.

General question (E) asked sawmill operators to indicate how costly they consider wood residue removal from the sawmill site. The responses are presented in Figure 19.

Figure 19. Sawmill Operators' Estimate of Wood Residue Removal Cost.



In answer to general question (F) sawmill owners each reported several methods of residue disposal. Figures 20 and 21 present a summary of current wood residue disposal methods for sawdust and bark. Because each mill made multiple responses to the question, only general trends can be concluded.

Figure 20. Summary of Reported Methods of Bark Disposal

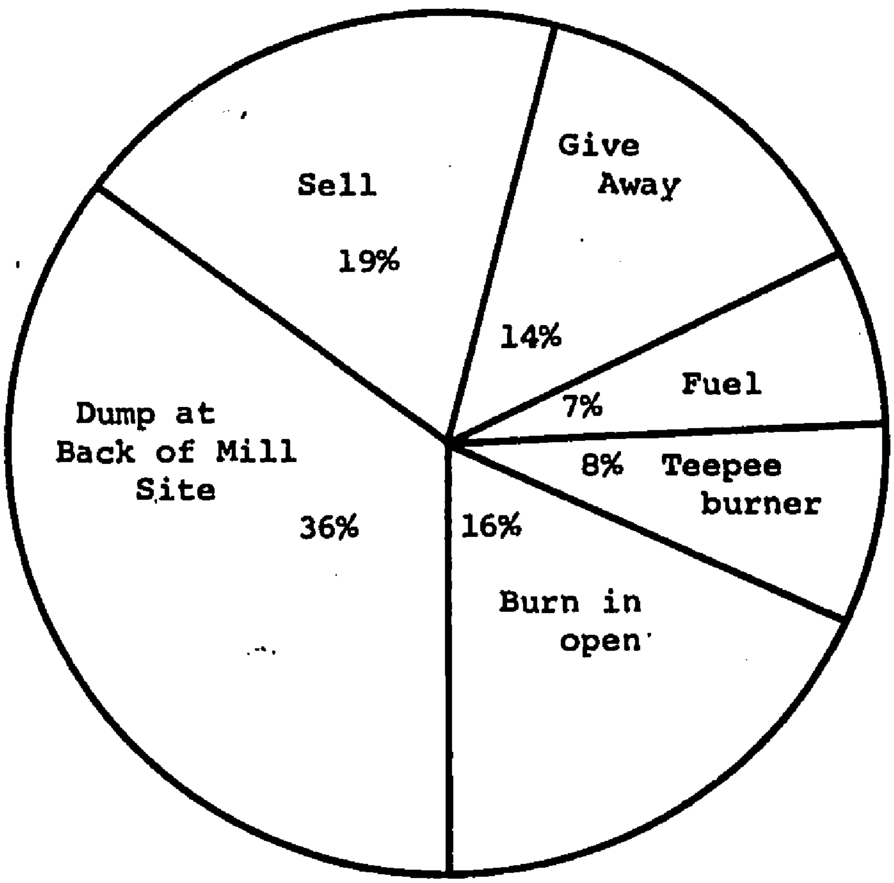
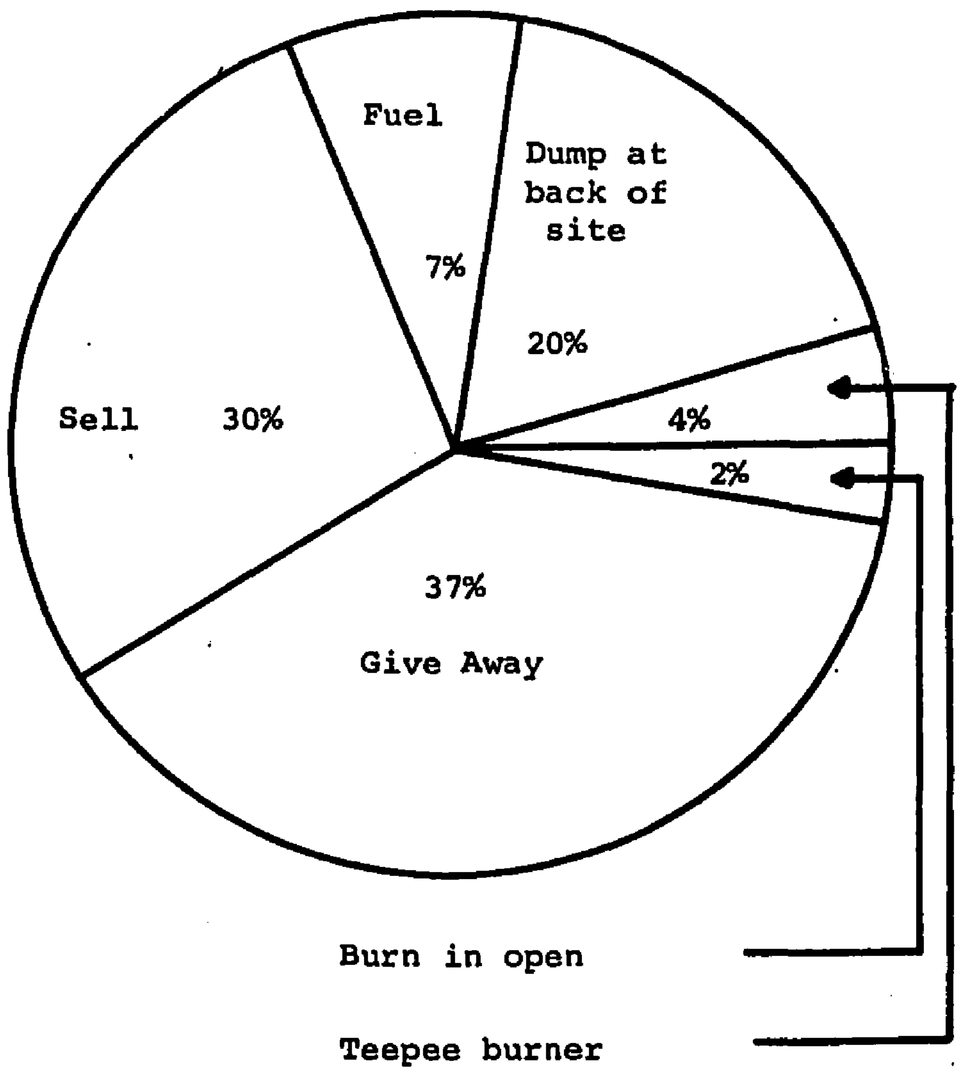


Figure 21. Summary of Reported Methods of Sawdust Disposal



In general question (G) sawmill owners were asked to insert the number of operating days they worked last year. Table 26 presents the responses of 83 mills. By multiplying the number of operating days given in (G) times the daily lumber production figure given in (B) an approximate annual lumber production figure is found for each individual sawmill. The results of these calculations are marked with (*) in Appendix B.

Table 26

Number of Sawmill Operating Days Per Year

Class	No. of Responses	Less than 100	101-150	151-200	201-225	226-250	251-275	276-300	301-325	Over 325	Wt. Avg.
A	2	0	0	0	0	1	1	0	0	0	250
B	2	0	0	1	1	0	0	0	0	0	200
C	6	0	0	2	0	1	2	1	0	0	234
D	22	0	1	2	1	10	1	6	0	1	246
E	15	1	2	3	2	3	1	3	0	0	209
F	28	5	5	8	2	5	0	2	1	0	201
LTF	8	4	2	0	0	2	0	0	0	0	126
Total	83	10	10	16	6	22	5	12	1	1	

Source: Mail Questionnaire - January 1969

General question (H) asked the approximate number of man-hours spent each week in removing wood residues from the mill site. The responses shown in Table 27 were used to estimate the expense involved in residue removal. Of the total responses, 70 percent estimated less than 10 hours were required each week to remove residue.

Table 27

Time Required to Remove Residue from Sawmill Site

Class	No. of Responses	Man-Hours Per Week					
		1-5	6-10	11-15	16-20	21-25	26-30
A	1	1					
B	1					1	
C	4	1	1		1		1
D	16	8	3	1	2		2
E	15	1	6	2	3		3
F	25	16	6		1		2
LTF	7	6	1				
Total	69	33	17	3	7	1	8

Source: Mail Questionnaire - January 1969

Only two of the remaining questions on the questionnaire are important to the study. The others were designed to lead the respondent into the "target questions."

Table 28 presents a summary of estimated sawdust sales during 1968 as a percent of the amount produced by individual sawmills. Only positive responses from mills that did sell some sawdust last year were recorded in the Table.

Table 28

Summary of Sawdust Sold Last Year (1968)

Class	No. of Responses	Percent Sold Annually 1-10	11-20	21-30	31-40	41-50	51-60	61-70	71-90	91-100
A	1					1				
B	1								1	
C	3	1								2
D	13					1	1	3	2	6
E	7	3	1			1	1			1
F	7	1	1			2				3
LTF	3		1							2
Total	35	5	3			5	2	3	3	14

Source: Mail Questionnaire - January 1969

Table 29 summarizes estimated bark sales for calendar year 1968 in terms of percent produced.

The quantity of bark accumulated by sawmills in southern lower Michigan was determined as a direct result of information included in the mail questionnaire. Table 30 summarizes the quantities of bark available by mill class. The data are presented here as a major finding which can be used by the industry in resource evaluation and market planning.

Table 29

Summary of Bark Sold Last Year* (1968)

Class	No. of Responses	Percent Sold Annually 1-10	11-20	21-30	31-40	41-50	91-100
A	2	2					
B	2	2					
C	2	1	1				
D	8	5	1		1		1
E	2	2					
F	0						
LTF	0						
Total	16	12	2		1		1

* By sawmills with log debarkers.
Source: Mail Questionnaire - Jaunary 1969

Table 30

Hardwood Bark Accumulated by Sawmills Operating Log Debarkers in Southern Lower Michigan* (1968)

Mill Class	Estimated Board Feet Lumber Production in 1968	Quantity of Bark at Each Mill (Green Tons)	Total Quantity of Bark by Mill Class (Green Tons)
A	2,500.0	1,450.0	
	12,500.0	7,250.0	8,700.0
B	6,250.0	3,625.0	3,625.0
C	2,880.0	1,670.4	
	3,875.0	2,247.5	
	4,420.0	2,563.6	
	11,340.0	6,577.2	13,058.7
D	2,500.0	1,450.0	
	2,000.0	1,160.0	
	3,525.0	2,044.5	
	3,000.0	1,740.0	
	3,000.0	1,740.0	
	1,920.0	1,113.6	
	2,640.0	1,531.2	
	2,760.0	1,600.8	
	2,000.0	1,160.0	
	2,500.0	1,450.0	
	2,000.0	1,160.0	
	2,400.0	1,392.0	
	2,000.0	1,160.0	
	3,600.0	2,088.0	
	2,400.0	1,392.0	22,181.1
E	3,360.0	1,948.8	1,948.8
F	300.0	174.0	
	300.0	174.0	
	1,380.0	800.4	1,148.4
Total		50,663.0	50,663.0

*Annual green lumber production data for 1968 determined by mail questionnaire, January 1969. MBF then multiplied by conversion factor (0.58) to determine bark quantity produced in green tons.

Table 31 concludes the findings in Part IV. The Table summarizes the residue production for the study. These tables are then multiplied times estimated values for each type of residue to give the cumulative annual gross value of fine and coarse residues. These figures could also be considered the amount of value added to the forest products industry if they were sold.

In summary, Part IV presented the findings of the field and mail survey. Almost in all cases the data presented indicated gross waste of wood residue materials. Most of the current methods used to dispose of wood residues do not yield a return to the sawmill. For the most part little advertising is done to promote the sale of wood residues. Questionnaire responses indicated that the sawmill operator does not consider wood residues to be an unmanageable problem or the cost excessive. Personal interviews with most sawmill operators revealed that few alternatives to current wood residue methods have been considered. The sawmill operators' concern is sawing lumber, whether or not the residues are valuable or what happens to them does not seem to interest them to any measureable degree.

The findings relative to Phase III are discussed in Part V.

Table 31

Sawmill Residue Production Summary for Southern Half of Lower Michigan[a] (1968)

Sawmill Class[b]	No. of Mills	Estimated Total Lumber Sawn Annually[c] (000)	Fine Residue Accumulated Annually: Sawdust (green tons)	Fine Residue Accumulated Annually: Bark (green tons)	Cumulative Annual Gross Value of Fine Residue[d] (dollars)	Coarse Residue Accumulated Annually: W/O Bark (green tons)	Coarse Residue Accumulated Annually: W/Bark (green tons)	Cumulative Annual Gross Value of Coarse Residue[e] (dollars)
A	2	15,000.00	15,600.00	8,700.00	42,075.00	18,600.00	0.00	93,000.00
B	1	6,250.00	6,500.00	3,625.00	17,531.25	7,750.00	0.00	38,750.00
C	7	32,265.00	33,555.60	13,058.70	83,434.57	27,918.60	17,745.00	175,083.00
D	29	63,995.00	66,554.80	22,182.80	160,837.22	47,423.80	46,865.00	330,849.00
E	31	32,095.00	33,378.80	1,948.80	69,193.60	4,166.40	52,297.70	125,427.40
F	56	22,037.00	22,918.50	1,148.40	47,272.50	2,455.20	36,503.70	85,283.40
LTF	24	2,125.50	2,210.50	0.00	4,421.00	0.00	3,868.50	7,737.00
Total	150	173,767.50	180,718.20	50,663.00	424,765.15	108,314.00	157,279.90	856,129.80

[a] 41 counties in southern half of lower peninsula of Michigan

[b] Defined in Directory of Primary Wood Using Plants in Michigan, 1968, Michigan Department of Conservation-Forestry Division

[c] Board feet of green lumber sawn; reported on January, 1969, mail questionnaire

[d] Estimated at a value of $2 per green ton for sawdust and $1.25 per ton for bark loaded on customer's truck at the sawmill

[e] Estimated at a value of $5 per green ton for debarked slabs and edgings and $2 per ton for coarse residue with bark attached.

PART V

FINDINGS--RELATIVE TO PHASE III

Introduction

The results of the experiments using heuristic simulation are discussed in the following paragraphs. The discussion is centered on the hypotheses presented earlier and presents the results from three of the most typical processing configurations. Tables are presented in the text and in the appendix to facilitate the discussion.

Findings Relative to Hypothesis I

The first hypothesis, agricultural and horticultural use of sawdust and bark in bulk units dictates a raw material positioned processing unit, was investigated using the specially designed heuristic simulation program to calculate all of the costs. The same configuration was processed through the computer six times using a different supply radius. Various supply radii used were 9, 15, 21, 27, 33, and 39 miles. The distance between the processing plant and the sawmills included within the supply radius was found to be critical for high-bulk and low-value products like sawdust and bark.

Table 32 illustrates that it is not profitable to transport these materials to a processing plant except over very short distances. The inbound transportation cost difference between 15 miles and 39 miles is more than double and the increase in tons of raw material increased from 27,389 to only 30,567. The per unit cost of bulk sawdust and bark increases very rapidly as distance between raw material location and processing plant are increased. The most critical cost is inbound transportation. To hold this most important factor to a minimum, it was found necessary to locate as near as possible to the raw material supply.

Findings Relative to Hypothesis II

The second hypothesis, as scale of operations increase, unit costs will decrease up to an optimum size, utilizes the data from three separate configurations. Even though the configurations, Tables 33, 34, and 35, are not located in the same geographic part of the state, the data included from all three will be similar in the general trends because the least cost per unit radius in each configuration was selected. Detailed supply data developed by the computer for each configuration is shown in Appendix E and the individual costs are summarized in Table 36.

Table 32

The Effect of Radius Change on Costs in a Processing Plant Configuration Simulation

Supply Radius (Miles)	9	15	21	27	33	39
Raw Material Cost	43,860	48,780	48,780	48,780	50,950	51,680
Total Inbound Transportation	17,178	20,761	20,761	20,761	27,543	42,195
Total Fixed Cost	45,844	45,844	45,844	45,844	45,844	45,844
Total Variable Cost	12,625	13,286	13,286	13,286	13,773	14,379
Inventory Holding Cost	877	975	975	975	1,019	1,033
Total Cost	123,849	133,619	133,619	133,619	143,536	160,162
Profit	35,762	37,938	37,938	37,938	34,981	24,505
Total Tons Processed	24,403	27,389	27,389	27,389	29,129	30,567
Average Unit Cost	5.08	4.88	4.88	4.88	4.93	5.24

Table 33

Summary of Trial Configuration No. 1
(Coordinate 4635--Radius 21 miles)

County	Packaged Bark Lawn and Garden Tons	Packaged Bark Lawn and Garden Sales	Bulk Bark* Dairy Tons	Bulk Bark* Dairy Sales	Sawdust Dairy Tons	Sawdust Dairy Sales	Sawdust Nursery Tons	Sawdust Nursery Sales	Gross Sales
Isabella	9	572.85	700	2800.00	700	2800.00	110	440.00	6612.85
Clinton	12	763.80	800	3200.00	800	3200.00	510	2040.00	9203.80
Shiawassee	17	1082.05	650	2600.00	650	2600.00	140	560.00	6842.05
Genesee	124	7892.60	400	1600.00	400	1600.00	1420	5680.00	16772.60
Oakland	228	14512.20	250	1000.00	250	1000.00	3140	12560.00	29072.20
Midland	16	1018.40	100	400.00	100	400.00	590	2360.00	4178.40
Gratiot	11	700.15	450	1800.00	450	1800.00	190	760.00	5060.15
Saginaw	60	3819.00	600	2400.00	600	2400.00	1890	7650.00	16179.00
Ingham	70	4455.50	750	3000.00	750	3000.00	1420	5680.00	16135.50
Tuscola	13	827.45	700	2800.00	700	2800.00	170	680.00	7107.45
Macomb	155	9865.75	450	1800.00	450	1800.00	2620	10480.00	23945.75
Bay	32	2036.80	250	1000.00	250	1000.00	1120	4480.00	8516.80
Livingston	13	827.45	650	2600.00	650	2600.00	344	1374.40	7401.85
Lapeer	13	827.45	446	1784.80	1000	4000.00	0	0.00	6612.25
Total Demand Satisfied	773	49201.45	7196	28784.80	7750	31000.00	13664	54654.40	163640.65

*No bulk bark was available to satisfy demand of nurseries or orchards, dairy consumed total.

Table 33, cont.

Costs	Packaged Bark	Bulk Bark	Sawdust Dairy	Sawdust Nursery	Gross Sales
Raw Material	866.10	8993.90	15490.16	27309.84	52760.00
Driver	295.36	2749.64	1930.48	3403.52	8379.00
Variable Truck	408.56	3803.44	3074.87	5421.13	12708.00
Fixed Truck	117.07	1089.86	1173.73	2069.34	4450.00
Total Inbound Trans.	820.99	7642.94	6179.08	10893.99	25537.00
Inventory Holding	19.32	179.88	309.80	546.20	1055.20
Allocated Fixed Cost	426.90	3974.19	4280.03	7545.89	16227.00
Sawdust Fixed Cost	0.00	0.00	166.84	294.16	461.00
All Bark Fixed Cost	142.68	1328.32	0.00	0.00	1471.00
Pack. Bark Fixed Cost	7631.00	0.00	0.00	0.00	7631.00
Bulk Bark Fixed Cost	0.00	0.00	0.00	0.00	0.00
Total Fixed Costs	8200.58	5302.50	4446.87	7840.04	25790.00
Sawdust Variable Cost	0.00	0.00	465.00	819.82	1284.82
All Bark Variable Cost	139.14	1295.32	0.00	0.00	1434.46
Pack. Bark Var. Cost	10157.22	0.00	0.00	0.00	10157.22
Bulk Bark Var. Cost	0.00	0.00	0.00	0.00	0.00
Total Variable Cost	10296.36	1295.32	465.00	819.82	12876.49
Loading Costs	231.90	1799.05	775.00	1366.36	4172.31
Total Costs	20535.26	25213.58	27665.91	48776.25	122191.00
Profit (Loss)	28666.19	3571.22	3334.09	5878.15	41449.65

Table 34

Summary of Trial Configuration No. 2
(Coordinate 3528--Radius 21 miles)

County	Packaged Bark Lawn and		Bulk Bark* Dairy		Sawdust Dairy		Sawdust Nursery		Gross
	Tons	Sales	Tons	Sales	Tons	Sales	Tons	Sales	Sales
Montcalm	12	763.80	650	2600.00	650	2600.00	770	3080.00	9043.80
Ionia	12	763.80	800	3200.00	800	3200.00	140	560.00	7723.80
Barry	8	509.20	500	2000.00	500	2000.00	160	640.00	5149.20
Kent	119	7574.35	750	3000.00	750	3000.00	1830	7320.00	20894.35
Shiawassee	17	1082.05	650	2600.00	650	2600.00	140	560.00	6842.05
Gratiot	11	700.15	450	1800.00	450	1800.00	190	760.00	5060.15
Clinton	12	763.80	800	3200.00	800	3200.00	510	2040.00	9203.80
Eaton	16	1018.40	220	879.20	600	2400.00	140	560.00	4857.60
Ingham	70	4455.50	0	0.00	750	3000.00	1420	5680.00	13135.50
Oakland	228	14512.20	0	0.00	250	1000.00	69	275.60	15787.80
Wayne	800	50920.00	0	0.00	50	200.00	0	0.00	51120.00
Total Demand Satisfied	1305	83063.25	4820	19279.20	6250	25000.00	5369	21475.60	148818.05

*No bulk bark was available to satisfy demand of nurseries or orchards, dairy consumed total.

Table 34, cont.

Costs	Packaged Bark	Bulk Bark	Sawdust Dairy	Sawdust Nursery	Gross Sales
Raw Material	1627.84	6012.16	12479.67	10720.33	30840.00
Driver	646.86	2389.09	2238.51	1922.94	7197.40
Variable Truck	1285.18	4746.62	5210.15	4475.65	15717.60
Fixed Truck	327.29	1208.77	1567.46	1346.48	4450.00
Total Outbound Trans.	2259.33	8344.47	9016.12	7745.07	27365.00
Inventory Holding	32.56	120.24	249.59	214.41	616.80
Allocated Fixed Cost	1193.45	4407.81	5715.76	4909.98	16227.00
Sawdust Fixed Cost	0.00	0.00	247.98	213.02	461.00
All Bark Fixed Cost	313.42	1157.58	0.00	0.00	1471.00
Packaged Bark Fixed Cost	7631.00	0.00	0.00	0.00	7631.00
Bulk Bark Fixed Cost	0.00	0.00	0.00	0.00	0.00
Total Fixed Costs	9137.87	5565.39	5963.74	5123.00	25790.00
Sawdust Variable Cost	0.00	0.00	375.00	322.13	697.13
All Bark Variable Cost	234.90	867.56	0.00	0.00	1102.46
Pack. Bark Var. Cost	17147.70	0.00	0.00	0.00	17147.70
Bulk Bark Variable Cost	0.00	0.00	0.00	0.00	0.00
Total Variable Costs	17382.60	867.56	375.00	322.13	18947.30
Loading Costs	391.50	1204.95	625.00	536.89	2758.34
Total Costs	30831.71	22114.78	28709.13	24661.83	106317.44
Profit (Loss)	52231.54	-2835.58	-3709.13	-3186.23	42500.61

Table 35

Summary of Trial Configuration No. 3
(Coordinate 3520--Radius 27 miles)

County	Packaged Bark Lawn and Garden		Bulk Bark * Dairy		Sawdust Dairy		Sawdust Nursery		Gross Sales
	Tons	Sales	Tons	Sales	Tons	Sales	Tons	Sales	
Eaton	16	1018.40	600	2400.00	600	2400.00	140	560.00	6376.40
Clinton	12	763.80	800	3200.00	800	3200.00	510	2040.00	9203.80
Ionia	12	763.80	800	3200.00	800	3200.00	140	560.00	7723.80
Barry	8	509.20	500	2000.00	500	2000.00	160	640.00	5149.20
Kalamazoo	54	3437.10	250	1000.00	250	1000.00	2650	10600.00	16037.10
Calhoun	44	2800.60	600	2400.00	600	2400.00	1190	4760.00	12360.60
Jackson	40	2546.00	600	2400.00	600	2400.00	320	1280.00	8626.00
Ingham	70	4455.50	750	3000.00	750	3000.00	1420	5680.00	16135.50
Shiawassee	17	1082.05	650	2600.00	650	2600.00	140	560.00	6842.05
Kent	119	7574.35	462	1849.20	750	3000.00	1830	7320.00	19743.55
Oakland	228	14512.20	0	0.00	250	1000.00	3140	12560.00	28072.20
Total Demand Satisfied	620	39463.00	6012	24049.20	6550	26200.00	11640	46560.00	136272.20

*No bulk bark was available to satisfy demand of nurseries or orchards, dairy consumed total.

Table 35, cont.

Costs	Packaged Bark	Bulk Bark	Sawdust Dairy	Sawdust Nursery	Gross Sales
Raw Material	773.10	7496.90	13071.19	23228.81	44570.00
Driver	331.13	3211.07	2783.68	4946.87	11272.75
Variable Truck	706.05	6846.75	7213.35	12818.85	27585.00
Fixed Truck	111.15	1077.85	1174.25	2086.75	4450.00
Total Inbound Trans.	1148.33	11135.67	11171.28	19852.47	43307.75
Inventory Holding	15.46	149.94	261.42	464.58	891.40
Allocated Fixed Cost	405.31	3930.40	4281.91	7609.38	16227.00
Sawdust Fixed Cost	0.00	0.00	166.00	295.00	461.00
All Bark Fixed Cost	137.51	1333.49	0.00	0.00	1471.00
Packaged Bark Fixed Cost	7631.00	0.00	0.00	0.00	7631.00
Bulk Bark Fixed Cost	0.00	0.00	0.00	0.00	0.00
Total Fixed Costs	8173.82	5263.89	4447.91	7904.38	25790.00
S Sawdust Variable Cost	0.00	0.00	393.00	698.40	1091.40
All Bark Var. Cost	111.60	1082.21	0.00	0.00	1193.81
Packaged Bark Var. Cost	8146.80	0.00	0.00	0.00	8146.80
Bulk Bark Variable Cost	0.00	0.00	0.00	0.00	0.00
Total Variable Costs	8258.40	1082.21	393.00	698.40	10432.01
Loading Costs	186.00	1503.07	655.00	1164.00	3508.07
Total Costs	18555.11	26631.69	29999.81	53312.63	128499.24
Profit (Loss)	20907.89	-2582.49	-3799.81	-6752.63	7772.96

Table 36

Summary of Cost Data from Three Test Configurations*

Product and Configuration no.	(A) No. Tons	(B) Total Cost	(C) Inbound Transportation Costs	(D) Unit Cost	(E) Trans. Unit Cost	(F) Unit Cost Excluding Trans.
Packaged Bark						
No. 1	773	20535.26	820.99	26.56	1.06	25.50
No. 2	1305	30831.71	2259.33	23.33	1.73	21.89
No. 3	620	18555.11	1148.33	29.92	1.86	28.06
Bulk Bark						
No. 1	7196	25213.58	7642.94	3.50	1.06	2.44
No. 2	4820	22114.78	8344.47	4.59	1.73	2.86
No. 3	6012	26631.69	11135.67	4.42	1.86	2.56
Sawdust						
No. 1	21414	76442.16	17072.98	3.57	.79	2.78
No. 2	11619	53390.96	16761.19	4.59	1.44	3.15
No. 3	18190	83312.44	31023.75	4.58	1.70	2.88

*Note. A fourth configuration operating on a 20 percent larger scale than number three proved to be less efficient for all products except packaged bark and per unit cost reversed and began to increase, see trend in column (D) above relative to tons processed in column (A).

In column (D) of Table 36 the unit cost is shown and, when compared with the number of raw material tons in column (A), it is found that unit cost for larger scale operations does decrease up to an optimum size and past that point begins to increase. The same results are found when the costs in columns (E) and (F) are likewise compared to the quantities processed in column (A).

Although the increasing cost per unit figures which result when the optimum size scale of operations has been passed are not included in the Table, this was indeed found to be true during the trial computer runs. Over 48 different configurations were tested and six intensively. The computer program and data card listing used in this research are included in Appendix D.

Findings Relative to Hypothesis III

The third hypothesis, the type of raw material used as product input (i.e., sawdust or bark) will influence the location of the processing unit, was also analyzed using the processing plant simulation. As different processing plant locations were evaluated it was found that the raw material used as product input had a considerable effect on the location of the processing plant.

The primary reason found as an explanation for this occurrence was a rather simple one. Only about two dozen sawmills in lower Michigan have debarkers; therefore, since bark is the most profitable raw material input, the processing unit should locate relatively close to this supply. During actual experiments tried with the simulation, it was found that the type of raw material used as product input did influence the location of the processing plant and the total profitability of the configuration. By locating near the supply of bark, it was possible to maximize the margin on bark products. Likewise, to maximize the less profitable margin on sawdust, the processing plant had to be located extremely close to large sources of sawdust supply.

The conclusions and implications of the results presented above are discussed in Part VI. In addition, suggestions for further research, based on the present project, are presented.

PART VI

CONCLUSIONS AND IMPLICATIONS

After careful coverage of the field survey results, mail survey results, and hypotheses, there is sufficient background upon which to report the author's conclusions concerning the central thesis behind the entire study.

The thesis was:

> There presently exist agricultural and horticultural markets for fine sawmill residues, and that transformation of the sawmill residue disposal problem into a source of income through the establishment of a firm to collect, process, and market the material is economically feasible.

After careful examination of the findings, it was concluded that the research data supports the establishment of a wood residue processing plant as outlined in the study.

Because of a wide profit margin between bark as a raw material and units of packaged bark, it was shown that packaged bark products can almost always be produced at a reasonable profit in the majority of configurations. In many cases when the processing plant is located near good supplies of bark, the profit on bark products is sufficient to carry large losses on sawdust products. Sawdust products have a very narrow profit margin and contribute to the profitability of only those few configurations having a large concentration of sawmills within a 15 mile radius of the processing plant. The above should be pointed out as one of two reservations about the success of the processing plant. To overcome this limitation, a processing plant could be designed just to process bark initially into upgraded products such as cat litter, floor sweeping compound, etc., a little at a time to increase the size of product lines.

The second reservation is that minimum realistic costs were used in simulation. Before entering such a business, it would be necessary for a person to update the program and cost figures to evaluate selected locations for current profitability. Also, to be considered by a person interested in operating a processing plant would be: one, local and out-of-state competition; two, the changes that have taken place in the sawmill industry since the study was completed; and three, changes in the types of sawmill products and methods of producing them.

Because the processing plant is designed to process both sawdust and bark, bulk sales of each can be sold only in local markets until such a time that demand becomes sufficient to raise the price to a level where it is possible to transport the material greater distances. As opportunities arise for sawdust to be upgraded as a final product, and increased vertical integration takes place in the sawmill industry, increases in both markets and profit will be possible in many more configurations.

Results of the field survey interviews confirm the fact that agricultural and horticultural markets for sawdust and bark products are rapidly growing. Whether or not the market potential is exploited depends on the future attitude of production oriented sawmill operators toward marketing.

The field survey was considered as beneficial, since the information that was set forth in the secondary objectives was obtained in detail. Each of the 50 sawmills visited was in operation during the summer of 1968 and in all cases either the owner or regular operator was on hand and willing to talk and express opinions about wood residue utilization.

Even though vast quantities of wood residues are accumulated around typical Michigan sawmills, it was concluded from talking with the sawmill owners and operators that the typical sawmill does not at this time consider wood residue disposal a serious problem. In general, they do not consider the cost of burning or dumping as significant enough to spend any effort developing bark and sawdust markets. A few mills have developed markets and report being very pleased. It could be concluded that with the advent of stiffer air pollution legislation, more sawmills will begin aggressive bark and sawdust marketing programs.

It was concluded from on-site observation of the wood residue quantities available that there is definitely enough raw material available in the form of bark and sawdust to provide significant growth to the present sawmill industry and new wood related industries which would use these materials as a basis for new products. The major limiting factor at this time is technology. Until products of greater retail value can be made from these materials, utilization will continue to be limited to agricultural and horticultural markets.

Photographs taken of wood residue will provide a capsule summary of information about its basic characteristics for the agricultural and horticultural markets. It is considered reasonable to assume that the more information that is available to the prospective markets, the sooner they will begin using the products.

During the personal visits to sawmill operations, it was possible to learn whether or not any bark or sawdust was being sold in local markets. Several sawmill operators mentioned markets which were currently buying bark and/or sawdust. Upon visiting some of these markets--orchards, nurseries, dairy farms and lawn and garden centers--it was concluded that there are very definite applications for which bark and sawdust are considered "naturals." The two biggest limiting factors are price and available sources of supply, but both can be overcome as more utilization information is made available to sawmill operators and potential consumers.

The competition for packaged bark products in lawn and garden centers was briefly listed in Table 22. It can be concluded from a comparison of prices that local hardwood bark mulch in a package is very competitive. A large part of the success is considered to be a direct result of producers using attractive, colorful, informative, plastic bags as containers that merchandise as well as serve a functional purpose. It was concluded that the additional cost of these more expensive bags, over plain paper or plastic bags, is not significant since the affluent lawn and garden market seems to be quality conscious and attracted to these expensive packages.

Concluded from visits to orchards, nurseries, and dairy farms, was that bark is most acceptable to these markets when it has been processed through a wood hog and reduced to a uniform size. This is an expensive process, but numerous sawmills are finding the additional effort well worth the expense in premium sales.

The mail survey was effective in obtaining data not previously available for sawmills in southern Michigan. The major contribution is made in the form of annual hardwood lumber production data. Detailed information on wood residue handling and disposal methods, even though of lesser importance, add greatly to current information about the sawmill industry.

Responses on the mail questionnaire were interpreted to conclude the same as the field survey with respect to the residue problem. From the data in Figure 19 and Table 27 sawmill owners and operators as a whole do not at this time consider wood residue disposal a costly or time consuming task as was believed.

The amount of advertising being done by sawmills, Figure 18, in an effort to stimulate the sale of wood residues, is very small. It can be concluded that the amount being done may be too little and not in the proper media.

The mail survey detailed the disposal methods used for sawdust and bark in Figures 20 and 21, respectively. It is concluded from these data and actual sales data in Tables 28 and 29, that very little bark is presently sold. Sawdust on the other hand was reported to be given away or sold by over half of the respondents. The general conclusion from this information is that sawdust currently enjoys more markets than does bark and reflects the stronger demand by commanding almost twice the price of bark.

Lastly, it was concluded that the computer simulation designed specifically for the sawmill industry did serve as an effective management decision tool in determining the probable success of the proposed processing plant. The heuristic simulation, even though not a new technique in the wood industry, is nevertheless original in design, structure and application and was effective in bringing new knowledge to the wood industry.

Due to the flexible nature of the program, it will be possible for a computer programmer to update current cost figures and use the simulation for future market evaluations.

Conclusions relative to the first hypothesis, agricultural and horticultural use of sawdust and bark in bulk units dictates a raw material positioned processing unit, were positive. Wood residues are high-bulk, low-value products, which do not greatly increase in value when processed for agricultural and horticultural use. For this reason they cannot be transported very far. The cost of inbound transportation and per unit cost for raw material brought to the processing plant from supply points located at increasing distances increase rapidly. The data in Table 32 shows the limiting influence of distance. The importance of locating near the source of raw material is provided in this one data summary and constitutes the necessary proof accepting the hypothesis.

Conclusions relative to the second hypothesis, as scale of operations increase, unit costs will decrease up to an optimum size, were also positive.

Table 36 is a summary of three configurations, each a different scale of operation and each representing the least cost per unit radius for that particular configuration.

Experiments were completed using radii from 3 miles to 39 miles for each of the three configurations. In each case where a larger radius was tried for each of the three configurations included in the study, the scale of operations increased and per unit cost increased. This is due to the radius selected for each of the configurations included being of an optimum nature. It was concluded that unit cost did in each case decrease up to an optimum size scale of operation and then began to increase. On the basis of the above experiments the hypothesis is accepted.

Conclusions relative to the third hypothesis, the type of raw material used as product input (i.e., sawdust and bark) will influence the location of the processing unit, were also positive.

Raw material inputs are often in small quantities and at scattered sawmill locations. Experiments with the simulation program showed that if bark is the desired primary input it was necessary to locate near the bark supply, not only to reduce per unit cost but because bark is not available at every sawmill. Since inbound transportation costs for wood residues often become prohibitive at radii over 21 miles, conclusions were that raw material input will most definitely influence the location of the processing unit. On the basis of the above simulation experiments, this hypothesis is accepted.

Implications

The general implication of the above conclusions is that if wood residues are to be sold as an alternative means of disposal, much more basic marketing research and data collection is necessary. Not only the sawmills need to be studied, but the markets and the methods of reaching them need to be evaluated. It is essential that a program of utilizing wood residues rather than disposing of them in the traditional manner would add as much as $2,000,000 to the industry income in southern lower Michigan. This would include money earned on new products and dollars saved in disposal costs.

For the most part this study concentrated on the wood residue situation at the sawmill site, although during the field survey contact was made with the dairy industry, orchard industry, nursery industry, and lawn and garden industry. The four industries currently represent the major markets for wood residues and yet persons in the wood industry know very little about the markets and their needs. Going one step further, it can be said that even less is known about how to reach these various markets. In short, the wood industry has remained production oriented during a period when most industries have become market oriented. To meet the competition effectively, even in the bark and sawdust markets, new thinking and new research are necessary in the wood industry to form the needed background.

The simulation that became such an important part of the study is a research tool capable of mass data analysis. This technique is only one of many sophisticated tools that has been brought into the wood industry in recent years to help form a data base upon which to draw the producers of wood residue together with the current needs of the markets. It is almost certain that as demand for these markets increase, the sawmill industry with a long history of production orientation, will at last become aware of the markets around them and effectively change their residue disposal problem into a profitable market opportunity.

The major implication running through this study is that the industry is rapidly changing, in part as a result of progress and technology, but also as a result of outside influences such as air pollution legislation. The pressure from this one program alone will do much to promote the utilization of wood residues by forcing sawmill owners to seek new alternatives to disposal.

The elimination of the expense of residue disposal would contribute significantly to additional income in the sawmill industry each year. Not only would the expense of disposing of the material with no return be reversed, but formal marketing would begin and the materials would be paying their own way; not only to existing businesses but in some cases becoming the primary raw material product of new industries such as the one in the study.

Suggestions for Further Research

As a result of the present research several areas for further study can be identified. The first such area in need of development is a standard unit measure for fine wood residues. The current study used the ton measure, but responses on the mail survey indicated many rather arbitrary units of measure were being used during the sale of residues. This is necessary not only to facilitate the sale of present sawmill residues, but will provide a measure for the time when large scale marketing is done.

A second area for further research is concerned with determining the cost of residue disposal at the sawmill site. Answers on the mail questionnaire reported only small costs being involved. Observations made during the field survey suggest that considerable expense is involved in both men and machine-time to dispose of daily mill residues. The availability of accurate cost figures might provide the impetus toward greater wood residue utilization when presented in conjunction with increasing market opportunities.

A third area in which a great deal of important research could be conducted deals with obtaining detailed market data on the size of agricultural and horticultural markets including the determination of long-range requirements. For purposes of the present survey the size of each market was estimated using available agricultural statistics. A secondary purpose of the study would be to conduct "missionary" work in the potential markets in order to create interest, to inform people about the uses for wood residues and where they might be obtained.

Another area for research is the identification of wood residue markets not included in this study which may offer equally valuable opportunity. Only a small percent of total wood residue quantities produced are utilized and these have not been the high dollar markets offering sizeable return.

One example would be the particle board industry which may have a need for raw material with characteristics similar to available sawmill residues.

A final area for particularly useful research deals with the development of a heuristic simulation of the Grand Rapids, Michigan, furniture industry residue. With the current interest in particle boards made from sawmill and furniture plant residue, it would be extremely valuable to the furniture industry to have detailed data on quantities and costs of residues produced within the city.

By having access to a highly specialized computer simulation such as this, it would be possible for the Furniture Manufacturer's Association to take positive action in planning the future utilization of their wood residues.

GLOSSARY

GLOSSARY

To facilitate a better understanding of the study, the following definitions are included.

AGRICULTURE: the science or art of cultivating the soil, harvesting crops, and raising crops.

BARK: outer layer of a tree, comprising the inner bark, or thin, inner living part, and the outer bark, or corky layer, composed of dry, dead tissue.

BOARD FOOT: a unit of measurement represented by a board 1 foot long, 1 foot wide and 1 inch thick, abbreviated bd. ft.

CHIPPABLE MATERIAL: that portion of the solid residue component 1" x 1" x 24" or larger which can be converted into pulp chips.

COARSE WOOD RESIDUE: around a sawmill operation; considered to be the slabs, edgings, and end trimmings that are produced incidental to the manufacture of lumber. Is a valuable source of solid wood often not utilized.

CONFIGURATION: the general arrangement of elements to be included in a given system. In this application, meaning the geographic arrangement of supply sawmills and demand counties surrounding the residue processing plant.

COST CENTERS: a group of the most important and closely related activities divided into basic functional units of the business for purposes of accurate control and cost accounting.

FINE WOOD RESIDUE: around a sawmill operation, considered to be the sawdust, bark, and wood shavings that accumulate incidental to the manufacture of lumber.

FIXED COSTS: are those elements of expense which do not vary with changes in volume of output but are related to time and plant capacity.

GREEN LUMBER TALLY: a record of lumber giving the number of boards or pieces by size, grade and species actually sawed from logs in the sawmill. The moisture content of the lumber varies from 30 to 300 percent when it is "green" or unseasoned.

GREEN TON: a unit of measure for sawdust and bark which takes into consideration their high moisture content at the time of processing at the sawmill, equal to 2000 pounds.

HARDWOODS: .generally one of the botanical groups of trees that have broad leaves in contrast to the conifers or softwoods. The term has no reference to the actual hardness of the wood.

HEURISTIC SIMULATION: is designed to seek an acceptable solution to a given problem. The total heuristic process attempts to keep reducing the problem to a manageable size, allowing managerial intervention at critical points in the search process in order to guarantee acceptable results.

HEURISTICS: is the study of the methods of discovery and invention, and a heuristic is a maxim or proverb or way of approaching a problem which more often than not will yield useful results. A heuristic is not a formula, however, and may or may not work.

HORTICULTURE: the cultivation of an orchard, garden or nursery on a small or large scale.

INBOUND TRANSPORTATION COST: the cost of truck and driver to move the raw materials from sawmill to processing plant.

INVENTORY HOLDING COST: the cost to hold raw materials at the processing plant for processing and finished goods inventory for sale.

LOG DEBARKER: a machine used to mechanically remove the bark from logs prior to further processing.

MOISTURE CONTENT OF WOOD: the weight of the moisture in wood, expressed as a percentage of its ovendry weight, abbreviated as m.c.

MULCH: any substance, as straw, bark, sawdust, leaves, spread upon the ground to protect the roots of plants from heat, cold, or drought.

OUTBOUND LOADING COST: the cost of loading finished goods on the customer's truck, includes men and machine time.

PROCESSING PLANT COST: fixed and variable costs realized during the annual operation of the plant; to include men, plant, equipment, utilities and taxes.

RAW MATERIAL COST: the cost of bark and sawdust purchased at rhw sawmill site and loaded on the truck.

SIMULATION: is a process by which a model of a particular situation is developed and tested using facts from real world conditions.

SOIL CONDITIONER: any substance used to improve the structure of the soil and increase its porosity and crumbliness.

SPECIFIC GRAVITY OF WOOD: the decimal ratio of the ovendry weight of a piece of wood to the weight of the water displaced by the wood at a given moisture content, abbreviated as sp.gr.

VARIABLE COST: are those expenses that vary with changes in volume of output; they are usually considered as costs of volume which will increase in total at the same rate as volume increases.

WOOD RESIDUE: all forms of wood resulting from sawmill manufacturing operations that are not currently marketed at a profit because of current economic conditions, insufficient technological development, or inadequate marketing efforts.

WOOD RESIDUE CONVERSION FACTORS: factors that have been determined through research to represent the quantity (in tons) of wood residue produced during the process of sawing one thousand board feet of lumber. Separate factors are available for individual types of residue produced.

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LITERATURE CITED

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A P P E N D I C E S

APPENDIX A

Mail Survey Cover Letter and Questionnaire

December 16, 1968

Dear Sawmill Operator:

I am a graduate student at Michigan State University, and I am presently doing a study on the nature and uses of wood residue products in Michigan. If I am successful in my research, I hope to help you and other sawmill operators convert your wood residue from a nuisance to a by-product in the lumber industry.

In order to complete my research, I need some important information that only you as a sawmill operator can supply. I wonder if you would take a few minutes and fill out the attached questionnaire. I know all these figures will not be at your fingertips, so I would appreciate your best estimates if you can't find the exact figures.

Thank you in advance for your help, and you may be sure that all of your answers to the attached questionnaire will be held strictly confidential.

Sincerely,

Harley T. Thomas

Harley Thomas
Research Associate

Eldon A. Behr

Eldon A. Behr
Professor

MICHIGAN SAWMILL DATA FORM

January 1969

GENERAL QUESTIONS:

A. Check (✓) the following equipment if used by your sawmill:

☐ Debarker ☐ Tractor with front loader bucket
☐ Chipper (pulp chips) ☐ Fork-lift truck or tractor
☐ Wood Hog ☐ Teepee burner

B. Approximately how many thousand board feet of lumber do you saw each work day? ____________MBF

C. Place checks in the columns under each wood product indicating what methods you use to advertise. (NOTE: Use as many checks (✓) as necessary)

	BARK	SAW-DUST	SLABS	FIRE-WOOD	"HOGGED" BEDDING & MULCH
Sign at the mill	☐	☐	☐	☐	☐
Newspapers	☐	☐	☐	☐	☐
Trade journal	☐	☐	☐	☐	☐
DO NOT ADVERTISE	☐	☐	☐	☐	☐

D. How much wood residue did you produce last year? (Check one)

☐ Large quantity (over 1000 green tons)
☐ Medium quantity (500 - 1000 green tons)
☐ Small quantity (under 500 green tons)

E. Generally speaking, how costly do you consider wood residue to remove from your sawmill? (check one)

☐ Very costly ☐ Costly ☐ Not Costly

F. Place checks in the column under each of the four wood products indicating all methods of residue disposal you used last year. (NOTE: Use as many checks as necessary)

	BARK	SAWDUST	SLABS	TRIM & EDGINGS
Selling (pulp chips, firewood, etc.)	☐	☐	☐	☐
Give Away	☐	☐	☐	☐
Fuel	☐	☐	☐	☐
Burn in Open	☐	☐	☐	☐
Burn in teepee burner	☐	☐	☐	☐
Dump at back of mill site	☐	☐	☐	☐

G. How many days did your mill operate last year? ____________ days

H. Estimate how many man-hours it takes each week to remove the wood residue from your mill. ________________ man-hours

SAWDUST:

A. What percent (%) of your sawdust did you sell last year? ____________%

B. How do you sell sawdust? (Check one) ☐ Truck load, ____________ size truck
☐ Cubic yard ☐ pounds or tons

C. How much do you charge per unit?
1. Loaded by customer _________ per unit
2. Loaded by mill __ _________ per unit
3. Delivered ________________ per unit

BARK: (Answer only if you have a debarker)

A. What percent (%) of your bark did you sell last year? ____________%

B. How many cubic yards of bark did you "peel" last week? __________ cu. yd.

C. Approximately how many cubic yards of bark do you usually "peel" in one week?
________________ cubic yards

D. Do you process bark through a "wood hog"? ☐ Yes ☐ No

E. How much would you charge me for 10 cubic yards of bark if I parked my truck under the bark conveyor at your mill? ____________ dollars

SLABS: (Answer only if you DO NOT produce chips)

A. Do you sell slabs? ☐ Yes ☐ No

B. In your mill do you direct your slabs past a "cut-off" saw where they are cut into FIREWOOD? ☐ Yes ☐ No

C. How much per cord do you charge for FIREWOOD picked up at the sawmill by the customer? ____________ price per cord - short cord 2x4x8'
If you deliver? ____________ price per cord - average

WOOD CHIPS: (Answer only if you are a chip producer)

A. Do you buy debarked slabs? ☐ Yes ☐ No

B. Where do you sell chips? ☐ Detroit ☐ Otsego ☐ Muskegon

C. How many road miles is it (one way) from your mill to: Detroit ____________
Muskegon ____________ Otsego ____________

D. How many chip vans do you OWN? ____________ RENT OR LEASE? ____________
CONTRACT? ____________

E. How many TONS of chips did you haul last week? ____________ green tons

F. How many TONS of chips do you haul in an average week? __________ green tons

G. If you had the opportunity to go into pulp chip production, and were not already in the business, would you make the investment? ☐ Yes ☐ No

Thank you.

G. How many days did your mill operate last year? ____________ days

H. Estimate how many man-hours it takes each week to remove the wood residue from your mill. ______________ man-hours

SAWDUST:

A. What percent (%) of your sawdust did you sell last year? ____________%

B. How do you sell sawdust? (Check one) ☐ Truck load, __________ size truck ☐ Cubic yard ☐ pounds or tons

C. How much do you charge per unit?
1. Loaded by customer ________ per unit
2. Loaded by mill __________ per unit
3. Delivered ______________ per unit

BARK: (Answer only if you have a debarker)

A. What percent (%) of your bark did you sell last year? ____________%

B. How many cubic yards of bark did you "peel" last week? _________ cu. yd.

C. Approximately how many cubic yards of bark do you usually "peel" in one week? ______________ cubic yards

D. Do you process bark through a "wood hog"? ☐ Yes ☐ No

E. How much would you charge me for 10 cubic yards of bark if I parked my truck under the bark conveyor at your mill? ___________ dollars

SLABS: (Answer only if you DO NOT produce chips)

A. Do you sell slabs? ☐ Yes ☐ No

B. In your mill do you direct your slabs past a "cut-off" saw where they are cut into FIREWOOD? ☐ Yes ☐ No

C. How much per cord do you charge for FIREWOOD picked up at the sawmill by the customer? ___________ price per cord - short cord 2x4x8'
If you deliver? ___________ price per cord - average

WOOD CHIPS: (Answer only if you are a chip producer)

A. Do you buy debarked slabs? ☐ Yes ☐ No

B. Where do you sell chips? ☐ Detroit ☐ Otsego ☐ Muskegon

C. How many road miles is it (one way) from your mill to: Detroit __________ Muskegon ___________ Otsego ___________

D. How many chip vans do you OWN? __________ RENT OR LEASE? ___________ CONTRACT? ___________

E. How many TONS of chips did you haul last week? ___________ green tons

F. How many TONS of chips do you haul in an average week? _________ green tons

G. If you had the opportunity to go into pulp chip production, and were not already in the business, would you make the investment? ☐ Yes ☐ No

Thank you.

APPENDIX B

ESTIMATED QUANTITY OF HARDWOOD RESIDUE PRODUCED BY SAWMILLS IN SOUTHERN HALF OF LOWER MICHIGAN 1968

County	No.	Directory Class	Actual lumber production (in. thous.)	Quantity in Tons: Sawdust	Bark	Solid Wood W/O Bark	Solid Wood With Bark	Mill Code No.	Sawmill Grid Coordinate
Allegan	1	LTF	67.5*	70.2	0.0	0.0	122.9	42	1818
	2	D	2500.0*	2600.0	1450.0	3100.0	0.0	43	2121
	3	F	300.0	312.0	0.0	0.0	546.0	44	2023
	4	F	50.0*	52.0	0.0	0.0	91.0	45	1521
	5	F	480.0*	499.2	0.0	0.0	873.6	46	1442
		Total	3397.5	3533.4	1450.0	3100.0	1633.5		
Barry	6	F	300.0	312.0	0.0	0.0	546.0	47	3116
	7	E	750.0	780.0	0.0	0.0	1365.0	48	2821
	8	F	100.0*	104.0	0.0	0.0	182.0	49	3016
	9	F	300.0	312.0	0.0	0.0	546.0	50	2721
	10	E	750.0	780.0	0.0	0.0	1365.0	51	2621
	11	LTF	50.0	52.0	0.0	0.0	91.0	52	2916
	12	F	300.0	312.0	0.0	0.0	546.0	53	2517
	13	F	600.0*	624.0	0.0	0.0	1092.0	54	2921
	14	F	300.0	312.0	0.0	0.0	546.0	55	2818
		Total	3450.0	3588.0	0.0	0.0	6279.0		

County	No.	Directory Class	Actual lumber production (in. thous.)	Quantity in Tons: Sawdust	Bark	Solid Wood W/O Bark	Solid Wood With Bark	Mill Code No.	Sawmill Grid Coordinate
Bay	15	E	250.0*	260.0	0.0	0.0	455.0	2	5339
		Total	250.0	260.0	0.0	0.0	455.0		
Berrien	16	E	750.0	780.0	0.0	0.0	1365.0	56	1102
	17	F	300.0	312.0	0.0	0.0	546.0	57	0705
		Total	1050.0	1092.0	0.0	0.0	1911.0		
Branch	18	D	2000.0	2080.0	0.0	0.0	3640.0	58	3107
	19	D	2000.0	2080.0	1160.0	2480.0	0 0.0	59	3007
		Total	4000.0	4160.0	1160.0	2480.0	3640.0		
Calhoun	20	F	300.0	312.0	0.0	0.0	546.0	60	3509
	21	F	300.0	312.0	0.0	0.0	546.0	61	3013
	22	LTF	50.0	52.0	0.0	0.0	91.0	62	2813
	23	LTF	300.0*	312.0	0.0	0.0	546.0	63	2909
		Total	950.0	988.0	0.0	0.0	1729.0		
Cass	24	F	700.0*	728.0	0.0	0.0	1274.0	64	1606
	25	F	300.0	312.0	0.0	0.0	546.0	65	1905
	26	F	150.0*	156.0	0.0	0.0	273.0	66	1706
	27	D	3525.0*	3666.0	2044.5	4371.0	0.0	67	1504
	28	C	2880.0*	2995.2	1670.4	3571.2	0.0	68	1306
		Total	7555.0	7857.2	3714.9	7942.2	2093.0		

County	No.	Directory Class	Actual lumber production (in. thous.)	Quantity in Tons: Sawdust	Bark	Solid Wood W/O Bark	Solid Wood With Bark	Mill Code No.	Sawmill Grid Coordinate
Clinton	29	D	3000.0*	3120.0	1740.0	3720.0	0.0	69	4028.
		Total	3000.0	3120.0	1740.0	3720.0	0.0		
Eaton	30	C	3875.0*	4030.0	2247.5	4805.0	0.0	70	3519
	31	LTF	50.0	52.0	0.0	0.0	91.0	71	3223
	32	F	300.0	312.0	0.0	0.0	546.0	72	3817
	33	D	3000.0	3120.0	1740.0	3720.0	0.0	73	3323
	34	E	750.0	780.0	0.0	0.0	1365.0	74	3922
		Total	7975.0	8294.0	3987.5	8525.0	2002.0		
Gratiot	35	F	300.0	312.0	0.0	0.0	546.0	75	4238
	36	F	180.0*	187.2	0.0	0.0	327.6	76	3835
		Total	480.0	499.2	0.0	0.0	873.6		
Hillsdale	37	F	300.0	312.0	174.0	372.0	0.0	77	3903
	38	F	285.0*	296.4	0.0	0.0	518.7	78	3702
	39	F	300.0	312.0	0.0	0.0	546.0	79	3804
	40	F	90.0	93.6	0.0	0.0	163.8	80	3602
			975.0	1014.0	174.0	372.0	1228.5		
Huron	41	F	300.0	312.0	0.0	0.0	546.0	81	6745
	42	A	2500.0*	2600.0	1450.0	3100.0	0.0	82	6047
	43	LTF	50.0	52.0	0.0	0.0	91.0	83	7050
	44	LTF	50.0	52.0	0.0	0.0	91.0	84	6950
	45	F	495.0*	514.8	0.0	0.0	900.9	85	7049
	46	LTF	50.0	52.0	0.0	0.0	91.0	86	6650
		Total	3445.0	3582.8	1450.0	3100.0	1719.9		

County	No.	Directory Class	Actual lumber production (in. thous.)	Quantity in Tons: Sawdust	Quantity in Tons: Bark	Quantity in Tons: Solid Wood W/O Bark	Quantity in Tons: Solid Wood With Bark	Mill Code No.	Sawmill Grid Coordinate
Ingham	47	E	750.0	780.0	0.0	0.0	1365.0	87	4219
	48	F	90.0*	93.6	0.0	0.0	163.8	88	4119
	49	F	300.0	312.0	0.0	0.0	546.0	89	4016
	50	F	300.0	312.0	174.0	372.0	0.0	90	4421
		Total	1440.0	1497.6	174.0	372.0	2074.8		
Ionia	51	D	1920.0*	1996.8	1113.6	2380.8	0.0	91	3326
	52	E	750.0	780.0	0.0	0.0	1365.0	92	2825
	53	D	2640.0*	2745.6	1531.2	3273.6	0.0	93	3529
	54	F	312.0*	324.5	0.0	0.0	567.8	94	2931
	55	F	300.0	312.0	0.0	0.0	546.0	95	3024
	56	LTF	50.0	52.0	0.0	0.0	91.0	96	2831
		Total	5972.0	6210.9	2644.8	5654.4	2569.8		
Isabella	57	E	3360.0*	3494.4	1948.8	4166.4	0.0	8	3444
	58	D	2760.0*	2870.4	1600.8	3422.4	0.0	9	3440
	59	F	1380.0*	1435.2	800.4	1711.2	0.0	10	3544
		Total	7500.0	7800.0	4350.0	9300.0	0.0		
Jackson	60	F	100.0*	104.0	0.0	0.0	182.0	97	4110
	61	E	800.0*	832.0	0.0	0.0	1456.0	98	3815
		Total	900.0	936.0	0.0	0.0	1638.0		
Kalamazoo	62	F	300.0	312.0	0.0	0.0	546.0	99	2215
	63	F	750.0*	780.0	0.0	0.0	1365.0	100	2309
		Total	1050.0	1092.0	0.0	0.0	1911.0		

County	No.	Directory Class	Actual lumber production (in. thous.)	Quantity in Tons				Mill Code No.	Sawmill Grid Coordinate
				Sawdust	Bark	Solid Wood W/O Bark	Solid Wood With Bark		
Kent	64	LTF	30.0*	31.2	0.0	0.0	54.6	101	2524
	65	LTF	345.0*	358.8	0.0	0.0	627.9	102	2231
	66	F	300.0	312.0	0.0	0.0	546.0	103	2334
	67	E	1265.0*	1315.6	0.0	0.0	2302.3	104	2226
	68	C	4420.0*	4596.8	2563.6	5480.8	0.0	105	2132
	69	D	2400.0*	2496.0	0.0	0.0	4368.0	106	2234
		Total	8760.0	9110.4	2563.6	5480.8	7898.8		
Lapeer	70	D	2000.0	2080.0	0.0	0.0	3640.0	107	6030
	71	F	300.0	312.0	0.0	0.0	546.0	108	6634
	72	F	300.0	312.0	0.0	0.0	546.0	109	6534
	73	E	750.0	780.0	0.0	0.0	1365.0	110	6434
		Total	3350.0	3484.0	0.0	0.0	6097.0		
Lenawee	74	D	1000.0*	1040.0	0.0	0.0	1820.0	111	4903
	75	D	1500.0*	1560.0	0.0	0.0	2730.0	112	4404
	76	F	2695.0*	2802.8	0.0	0.0	4904.9	113	5206
		Total	5195.0	5402.8	0.0	0.0	9454.9		
Livingston	77	D	2000.0	2080.0	1160.0	2480.0	0.0	114	5420
	78	B	6250.0*	6500.0	3625.0	7750.0	0.0	115	5120
		Total	8250.0	8580.0	4785.0	10230.0	0.0		
Macomb	79	E	1600.0*	1664.0	0.0	0.0	2912.0	116	6819
	80	LTF	50.0	52.0	0.0	0.0	91.0	117	7023
		Total	1650.0	1716.0	0.0	0.0	3003.0		

County	No.	Directory Class	Actual lumber production (in. thous.)	Quantity in Tons				Mill Code No.	Sawmill Grid Coordinate
				Sawdust	Bark	Solid Wood W/O Bark	Solid Wood With Bark		
Midland	81	E	3000.0*	3120.0	0.0	0.0	5460.0	20	4343
	82	LTF	50.0	52.0	0.0	0.0	91.0	21	3946
	83	F	300.0*	312.0	0.0	0.0	546.0	22	4047
		Total	3350.0	3484.0	0.0	0.0	6097.0		
Monroe	84	D	2600.0	2704.0	0.0	0.0	4732.0	118	5704
	85	LTF	150.0*	156.0	0.0	0.0	273.0	119	6007
		Total	2750.0	2860.0	0.0	0.0	5005.0		
Montcalm	86	D	2500.0*	2600.0	1450.0	3100.0	0.0	120	2537
	87	E	750.0	780.0	0.0	0.0	1365.0	121	2436
	88	F	600.0*	624.0	0.0	0.0	1092.0	122	3135
	89	E	750.0	780.0	0.0	0.0	1365.0	123	3237
	90	D	2000.0*	2080.0	1160.0	2480.0	0.0	124	3235
		Total	6600.0	6864.0	2610.0	5580.0	3822.0		
Muskegon	91	E	720.0*	748.8	0.0	0.0	1310.4	125	1333
	92	E	750.0	780.0	0.0	0.0	1365.0	126	1039
	93	D	2400.0*	2496.0	1392.0	2976.0	0.0	127	1132
	94	D	2000.0*	2080.0	1160.0	2480.0	0.0	128	1232
	95	E	750.0	780.0	0.0	0.0	1365.0	129	1733
		Total	6620.0	6884.8	2552.0	5456.0	4040.4		

County	No.	Directory Class	Actual lumber production (in. thous.)	Quantity in Tons				Mill Code No.	Sawmill Grid Coordinate
				Sawdust	Bark	Solid Wood W/O Bark	Solid Wood With Bark		
Newaygo	96	E	1000.0*	1040.0	0.0	0.0	1820.0	23	1842
	97	C	4350.0*	4524.0	0.0	0.0	7917.0	24	1942
	98	C	1400.0*	1456.0	0.0	0.0	2548.0	25	2039
	99	E	1000.0*	1040.0	0.0	0.0	1820.0	26	1542
	100	E	750.0	780.0	0.0	0.0	1365.0	27	1846
	101	LTF	50.0	52.0	0.0	0.0	91.0	28	1640
	102	E	1000.0*	1040.0	0.0	0.0	1820.0	29	2042
	103	E	2000.0	2080.0	0.0	0.0	3640.0	30	1740
		Total	11550.0	12012.0	0.0	0.0	21021.0		
Oakland	104	F	300.0	312.0	0.0	0.0	546.0	130	5619
	105	E	2000.0	2080.0	0.0	0.0	3640.0	131	6026
	106	LTF	135.0*	140.4	0.0	0.0	245.7	132	5816
	107	LTF	50.0	52.0	0.0	0.0	91.0	133	5716
	108	F	300.0	312.0	0.0	0.0	546.0	134	5826
		Total	2785.0	2896.0	0.0	0.0	5068.7		
Oceana	109	E	400.0*	416.0	0.0	0.0	728.0	31	0945
	110	D	2000.0	2080.0	0.0	0.0	3640.0	32	1442
	111	F	300.0	312.0	0.0	0.0	546.0	33	1242
	112	D	3600.0*	3744.0	2088.0	4464.0	0.0	34	0943
	113	LTF	50.0	52.0	0.0	0.0	91.0	35	1045
	114	LTF	50.0	52.0	0.0	0.0	91.0	36	1043
	115	E	750.0	780.0	0.0	0.0	1365.0	37	1541
		Total	7150.0	7436.0	2088.0	4464.0	6461.0		

County.	No.	Directory Class	Actual lumber production (in. thous.)	Quantity in Tons: Sawdust	Bark	Solid Wood W/O Bark	Solid Wood With Bark	Mill Code No.	Sawdust Grid Coordinate
Ottawa	116	F	300.0	312.0	0.0	0.0	546.0	135	1826
	117	F	300.0	312.0	0.0	0.0	546.0	136	1829
		Total	600.0	624.0	0.0	0.0	1092.0		
Saginaw	118	D	2400.0*	2496.0	1392.0	2976.0	0.0	137	4732
	119	C	4000.0	4160.0	0.0	0.0	7280.0	138	4735
	120	D	1800.0*	1872.0	0.0	0.0	3276.0	139	4636
	121	C	11340.0*	11793.6	6577.2	14061.6	0.0	140	4736
	122	D	1050.0*	1092.0	0.0	0.0	1911.0	141	4840
		Total	20590.0	21413.6	7969.2	17037.6	12467.0		
St. Clair	123	F	300.0	312.0	0.0	0.0	546.0	142	7430
	124	LTF	50.0	52.0	0.0	0.0	91.0	143	7036
	125	LTF	248.0*	257.9	0.0	0.0	451.4	144	7228
	126	E	750.0	780.0	0.0	0.0	1365.0	145	7029
	127	LTF	50.0	52.0	0.0	0.0	91.0	146	7525
	128	F	300.0	312.0	0.0	0.0	546.0	147	7130
		Total	1698.0	1765.9	0.0	0.0	3090.4		
St. Joseph	129	F	300.0	312.0	0.0	0.0	546.0	148	2304
		Total	300.0	312.0	0.0	0.0	546.0		
Sanilac	130	A	12500.0*	13000.0	7250.0	15500.0	0.0	149	6938
	131	D	3000.0*	3120.0	0.0	0.0	5460.0	150	6639
	132	D	1150.0*	1196.0	0.0	0.0	2093.0	151	6742
		Total	16650.0	17316.0	7250.0	15500.0	7553.0		

County	No.	Directory Class	Actual lumber production (in. thous.)	Quantity in Tons				Mill Code No.	Sawmill Grid Coordinate
				Sawdust	Bark	Solid Wood W/O Bark	Solid Wood With Bark		
Tuscola	133	F	300.0	312.0	0.0	0.0	546.0	152	5735
	134	F	300.0	312.0	0.0	0.0	546.0	153	6040
	135	D	2000.0	2080.0	0.0	0.0	3640.0	154	5536
	136	F	300.0	312.0	0.0	0.0	546.0	155	5637
	137	E	750.0	780.0	0.0	0.0	1365.0	156	6342
	138	F	300.0*	312.0	0.0	0.0	546.0	157	5939
	139	F	1440.0*	1497.6	0.0	0.0	2620.8	158	6236
	140	LTF	50.0	52.0	0.0	0.0	91.0	159	5738
	141	D	1250.0*	1300.0	0.0	0.0	2275.0	160	6443
		Total	6690.0	6957.6	0.0	0.0	12175.8		
Van Buren	142	F	300.0*	312.0	0.0	0.0	546.0	161	1316
	143	F	300.0	312.0	0.0	0.0	546.0	162	1508
	144	LTF	50.0	52.0	0.0	0.0	91.0	163	1711
	145	F	440.0*	457.6	0.0	0.0	800.8	164	1714
	146	F	300.0	312.0	0.0	0.0	546.0	165	1611
		Total	1390.0	1445.6	0.0	0.0	2529.8		
Washtenaw	147	E	450.0*	468.0	0.0	0.0	819.0	166	5313
	148	E	750.0	780.0	0.0	0.0	1365.0	167	4909
	149	E	1250.0*	1300.0	0.0	0.0	2275.0	168	5508
		Total	2450.0	2548.0	0.0	0.0	4459.0		
Wayne	150	D	2000.0	2080.0	0.0	0.0	3640.0	169	5915
		Total	2000.0	2080.0	0.0	0.0	3640.0		
	GRAND TOTAL		173767.5	180718.2	50663.0	108314.0	157279.8		

APPENDIX C-1

Excerpt From 1968 Michigan Standard Specifications for Landscaping Materials

State of Michigan
Department of State Highways

7.21.02 Mulching Materials:

a. Manure.--Manure shall consist of well rotted cow manure or well rotted horse manure aged for at least 3 months in a building or large pile. It shall be free from shavings, sawdust and cornstalks. Straw or similar bedding may be present to the extent of not more than 15 percent by volume, provided that it is well rotted.

In lieu of the above a uniform mixture of 50 percent well rotted, pulvarized sheep manure and 50 percent salvaged soil may be used.

Only well rotted cow manure shall be used in planting areas intended for roses or evergreens.

b. Well Rotted Deciduous Leaves.

c. Wood Chips.--Wood chips shall be the product of a mechanical brush chipper. Not more than 5 percent of the chips shall be over 4 inches in size. At least 50 percent of the chips shall be one inch or less in size. Suitability of chips material and size will be determined by visual inspection.

d. Shredded Bark.--This material shall consist of tree bark which has been stripped and shredded from saw logs by means of a de-barking machine. The material shall be sufficiently fine and free from extraneous material so that it will readily pass through a conventional mulch blower.

e. Coarsely Ground Corncobs.

Special Note: Sawdust and peat moss were deleted from the specifications as a mulch on July 30, 1968.

APPENDIX C-2

LUMBER AND RESIDUE FRACTIONS DEVELOPED FROM SAWMILLING (1)

Fractions	Cubic Foot Volume Per MBF (2)	Cubic Foot Volume in Percent	Weight per MBF in Pounds (2)	Weight in Percent
Bark:				
Green bark (3)	28.66	13.9	1,260	10.3
Green logs w/o bark (4)	178.10	86.1	10,970	89.7
Green logs including bark	206.76	100.0	12,230	100.0
Sawdust:				
Green sawdust	33.12	18.6	2,040	18.6
Solid Residue:				
Green slabs	20.12	11.3	1,240	11.3
Green edgings	20.88	11.7	1,290	11.7
Green trim ends	6.84	3.8	420	3.8
Total Green Wood Residue (5)	80.96	45.4	4,990	45.4
Lumber:				
Rough Green Lumber (6)	97.14	54.6	5,980	54.6
Rough Dry Lumber	88.62	49.8	3,710	33.9
Water in Lumber	8.52	4.8	2,270	20.7
Dry Wood Residue:				
Dry shavings	28.22	15.9	1,330	12.1
Dry trim ends	1.86	1.0	70	0.7
Total Dry Wood Residue	30.08	16.9	1,400	12.8
TOTALS:				
Total Green & Dry Wood Residue (8)	111.04	62.3	6,390	58.2
Total Dressed & Dried Lumber (9)	58.54	32.9	2,310	21.1

SOURCE: Applefield, Milton, 1954. Economic Considerations for a Successful Utilization of Wood Residue. Forest Products Journal 4(4):11A-17A.

Appendix C-2, cont.

In order to better evaluate the data in the previous example an explanation of the basis for the calculations of the author and the interpretations are listed in items (1) through (9) below, corresponding with the parenthesized numbers in the table.

(1) The various fractions are the result of processing 1,000 board feet, mill tally, of average southern yellow pine logs into 1,000 nominal board feet of finished and dried 4/4 lumber.

(2) The volumes and weights represent solid wood values.

(3) Single bark thickness averages .41 inches per log. The bark fraction has not been considered wood residue.

(4) The average pine saw-log on which these data are based is 9.4" in diameter at the small end, inside bark, and 14.6' including 3" trimming allowance. This log scales 50 board feet mill tally, and has an average, inside bark, taper of 2.4". This average green log, without bark, represents the entire wood volume (100%) from which all residue fractions and percents were calculated. (Log diameter is the principal variable affecting available volume of sawmill wood residue.)

(5) The weight, per cubic foot, used for all green wood fractions, is 61.6 pounds, obtained as an average of numerous weighings. This coincides very closely with the weight given in U. S. Forest Products Laboratory Technical Note No. 218 which gives cubic foot and board foot weights for various species and moisture contents of round and sawn wood.

(6) Green lumber is actually sawn 3/32" full in thickness and 1/2" full in width, but is nominally considered 1" lumber. Thus, true volume of 1,000 nominal board feet of rough green lumber is 1,181 board feet and it requires a conversion factor of 10 board feet to make one cubic foot.

Appendix C-2, cont.

(7) The water in lumber cannot be considered waste or residue, though it is not used in the final lumber end-product. It has been isolated in order to determine more accurately the remaining fractions, and it must be pointed out that the drying and consequent shrinkage of wood does not represent a straight line volume-weight ratio. This fraction represents the water in green lumber, with a 110 percent moisture content which has been kiln dried to about 12 percent moisture content, based on oven-dry weight.

(8) Excludes the fraction representing water loss from lumber drying.

(9) Finished lumber, though scant 7/32" in thickness and 3/8" in width, is considered nominal 1" lumber. Thus, there are only 748 actual board feet per nominal MBF of this lumber which requires a conversion factor of 15 1/2 board feet per cubic foot. Average weights of southern yellow pine lumber per MBF (nominal dimensions) are available from the Southern Pine Association, New Orleans, Louisiana.

Applefield's data has been presented on the basis of both weight and volume. In examining the residue fractions, however, most people will prefer to use weight as the standard of measurement because it is simpler to apply in practice, and is also more accurate because there are few variables involved.

Based on these weights, the manufacture of one thousand board feet of finished, nominal 4/4 lumber produces 2,040 pounds of green sawdust and 2,950 pounds of solid green wood residue (slabs, edgings and trims). Dry residue, consisting primarily of shavings, weighs 1,400 pounds. In addition, there is also a bark fraction weighing 1,260 pounds.

APPENDIX C-3

Selected Markets for Wood Residues Visited During Field Survey

Included in the field survey were dairy farms, nurseries, and lawn and garden centers.

DAIRY FARMS:

(1) Smith's Dairy - Potterville

(2) Green's Dairy - Leslie

(3) Meadow's Dairy - Swartz Creek

NURSERIES:

(1) Maple Hill - Charlotte

(2) Smith - Lansing

(3) Cottage Garden - Lansing

LAWN AND GARDEN CENTERS:

(1) Fruit Basket - Grand Rapids

(2) Frank's Nursery - Lansing

(3) Meijer's Thrifty Acres - Lansing

APPENDIX C-4

County Code and Grid Location of Geographic Center

Code No.	Grid	Name
03	1820	Allegan
08	2720	Barry
09	4944	Bay
11	0804	Berrien
12	3204	Branch
13	3312	Calhoun
14	1604	Cass
19	3928	Clinton
23	3520	Eaton
25	5429	Genesee
29	3836	Gratiot
30	3904	Hillsdale
32	6648	Huron
33	4320	Ingham
34	3128	Ionia
37	3544	Isabella
38	4212	Jackson
39	2312	Kalamazoo
41	2330	Kent
44	6231	Lapeer
46	4804	Lenawee
47	5120	Livingston
50	6722	Macomb
54	2744	Mecosta
56	4344	Midland
58	5804	Monroe
59	3036	Montcalm
61	1235	Muskegon
62	1942	Newago
63	6021	Oakland
64	1244	Oceana
70	1528	Ottawa
73	4836	Saginaw
74	7229	St. Clair
75	2304	St. Joseph
76	7039	Sanilac
78	4728	Shiawassee
79	5940	Tuscola
80	1512	Van Buren
81	5312	Washtenaw
82	6212	Wayne

APPENDIX C-5

Functions of Mulches and Soil Conditioners

A mulch is used to:

1. Reduce evaporation of the soil moisture.
2. Lower soil temperatures in the summer and protect plants from extremely low temperatures in winter.
3. Improve the appearance of landscaped areas.
4. Control water run-off and, to a degree, prevent erosion.
5. Aid in controlling weeds. A good mulch may take the place of frequent cultivation in the control of many kinds of weeds.
6. Protect fruits and flowers from soil spattered by rain, as in the case of strawberries, tomatoes, etc.
7. Aid seed germination. Because mulching materials reduce evaporation, assist in maintaining uniform temperatures and aid in preventing erosion, they may be used frequently.

A soil conditioner is used to:

1. Improve the porosity of the soil (making it more friable), which in turn improves the admission of water and oxygen into the soil.
2. Improve the water-holding capacity (unless the particles are too large).
3. Help prevent crusting.
4. Assist and improve the biological processes that occur within the soil.
5. Lower the bulk density of soil, which is important for nurserymen who grow plants in containers.

Source: Basham, B. M. and W. S. Thompson 1967. An Economic Study of the Production and Use of Sawdust and Bark as Mulches and Soil Amendments for Horticultural and Agricultural Purposes. Mississippi Forest Products Utilization Laboratory, Information Series No. 6.

APPENDIX D

Computer Simulation Program

```
PROGRAM     SA=SIM     FORTRAN EXTENDED V 1.0              05/16/89          .22.29.09.

          M=IPR2(J,IPROC)
          PRINT1(J)=TOTPP(L)
          PRINT2(J)=TOT1(L)
          PRINT3(J)=TOT2(L)
          PRINT4(J)=TOTPP(M)
          PRINT5(J)=TOT1(M)
      650 PRINT6(J)=TOT2(M)
      660 FORMAT(1H0,A8,10X,F8,0,12X,F9,0,17X,F10,2,14X,F10.2,15X,F10.2,12X)
      680 FORMAT(1H0,A8,9X,I7  ,12X,4(F8,1,16X),3X)
          IT=8H TOTAL
          WRITE(1,660) IT,(PRINT1(M),M=2,6)
          WRITE(2,680) IT,(PRINT4(M),M=2,6)
          IT=8H TRUCK 1
          WRITE(1,660) IT,(PRINT2(M),M=2,6)
          WRITE(2,680)IT,(PRINT5(M),M=2,6)
          IT=8H TRUCK 2
          WRITE(1,660) IT,(PRINT3(M),M=2,6)
          WRITE(2,680) IT,(PRINT6(M),M=2,6)
          GO TO (690,695)IPROC
      690 IF(IYBARK,EQ,0)  GO TO 700
          GO TO (345,347)IYBARK
      695 IF(IYSAW,EQ,0)  GO TO 700
          GO TO (385,387)IYSAW
      500 CONTINUE
C
C                PRINT EXCESS
C
          GO TO (505,510)IPROC
      505 IF(IYBARK,EQ,0)4000,515
      510 IF(IYSAW,EQ,0)4000,515
      515 DO 520 M=18,29
      520 EXCESS(M)=EXCESS(M)/60,
          DO 525 M=1,6
          L=IPR1(M,IPROC)
          J=IPR2(M,IPROC)
          PRINT1(M)=EXCESS(L)
      525 PRINT2(M)=EXCESS(J)
          IT=8H TOTAL
          WRITE(1,660) IT,(PRINT1(M),M=2,6)
          WRITE(2,680) IT,(PRINT2(M),M=2,6)
          GO TO 700
C
C                PROCESS AT END OF EACH PROCESSING PLANT
C
     4000 IF(TOT1(29),EQ,0.)  GO TO 4070
          IF(TOT2(29),EQ,0.) GO TO 4010
          IF(TOT2(29),LE, 75000) GO TO4050
     4002 DO 4005M=1,29
     4005 TOTPP(M)=TOTPP(M)+TOT1(M)+TOT2(M)
          GO TO 4040
     4010 PRINT 615,ITITLE
     4020 DO 4025M=1,29
     4025 TOTPP(M)=TOTPP(M)+TOT1(M)
```

```
      SUBROUTINE SORT(I)
      COMMON/SORT/ISNOS(150)
      COMMON/SUPPLY/SUP,NMILLPP,MILLPP
      DIMENSION SUP(7,170),NMILLPP(6),MILLPP(2,150,6),ARR(200)
      TYPE INTEGER ARR
      TYPE INTEGER STORE
      NM=NMILLPP(I)
      DO 5 J=1,NM
      ARR(J)=MILLPP(2,J,I)
    5 ISNOS(J)=0
      M=1
   10 STORE=ARR(1)
      DO 15 K=1,NM
      IF(ARR(K).LE.STORE)25,15
   15 CONTINUE
      ISNOS(M)=L
      ARR(L)=999999
      IF(M.EQ.NM)35,20
   20 M=M+1   $   GO TO 10
   25 L=K
      STORE=ARR(K)
      GO TO 15
   35 RETURN
      END
```

```
PROGRAM     SAWSIM     FORTRAN EXTENDED V 1.0                05/16/69          .22.29.09.

            DO 915 M=1,13
        915 TOTS(M )=TOTS(M )+SAT(M ,N)
        917 CONTINUE
      C
      C                ADD UP COSTS   -   SAWDUST
      C
        920 K=5
            DO 925 J=9,11,2
            IF(SAW.EQ.0.)  GO TO 921
            X=TOTS(J)/SAW
            GO TO 922
        921 X=0.
        922 COST(1,K)=CSAW*X
            COST(2,K)=CDRIVS*X
            COST(3,K)=VTCOSTS*X
            COST(4,K)=FTCS * X
            COST(5,K)=COST(2,K)+COST(3,K) +COST(4,K)
            COST(6,K)=COST(1,K)*.02
            COST(7,K)=FCSAWAL*X
            COST(8,K)=PCOST(1,2)*X
            COST(13,K)=PCOST(2,2)*TOTS(J)
            COST(18,K)=PCOST(3,2)*TOTS(J)
            K=K+1
        925 CONTINUE
      C
      C                COSTS ALL BARK TO Y
      C
            K=1
            DO 940 J=1,7,2
            IF(BARK.EQ.0.)  GO TO 926
            X=TOTS(J)/BARK
            GO TO 927
        926 X=0.
        927 COST(1,K)=CBARK*X
            COST(2,K)=CDRIVB*X
            COST(3,K)=VTCOSTB*X
            COST(4,K)=FTCB*X
            COST(5,K)=COST(2,K)+COST(3,K)+ COST(4,K)
            COST(6,K)=COST(1,K)*.02
            COST(7,K)=FCBKAL*X
            COST(9,K)=PCOST(1,3)*X
            COST(14,K)=PCOST(2,3)*TOTS(J)
            K=K+1
        940 CONTINUE
      C
      C                COST FOR PACKAGED BARK
      C
            IF(BARK.EQ.0.)943,942
        942 COST(10,1)=PCOST(1,4)
            COST(15,1)=PCOST(2,4)*TOTS(1)
            COST(18,1)=PCOST(3,4)*TOTS(1)
            GO TO 944
        943 COST(10,1)=COST(15,1)=COST(18,1)=0.
```

```
SUBROUTINE  PRDEM       FORTRAN EXTENDED V 1.0                05/16/69            .22.29.09.
            SUBROUTINE PRDEM(I)
            COMMON/A/DEM(95,6),NCTY
            COMMON/DEMAND/CTY(10,83)
            COMMON/B/TOTSUP(2)
            DIMENSION TOT(8)
            DIMENSION ICTY(10,83)
            EQUIVALENCE(CTY,ICTY)
            TYPE INTEGER DEM
            DO 1 J=1,8
          1 TOT(J)=0.
            IOVF=43
            JJ=DEM(5,I)
            IF(JJ.EQ.99)JJ=NCTY
            DO 200 K = 1,JJ
            L= DEM(K+5,I)
            IF(IOVF.GE.43)GO TO 100
         40 PRINT 45,L,ICTY(3,L),ICTY(1,L),ICTY(2,L),ICTY(10,L),
           1(CTY(NN,L),NN=4,9)
         45 FORMAT (1H ,I2,X,A10,3X,I2,X,I2,8X,I3,2X,6F15.1)
            IOVF=IOVF+1
            DO 50 J=1,6
            N=J+3
         50 TOT(J)=TOT(J)+CTY(N,L)
        200 CONTINUE
            TOT(7)=TOT(1) + TOT(2)
            DO 210 J=3,6
        210 TOT(8)=TOT(8)+TOT(J)
            PCTSAW=TOT(7)/TOTSUP(1)
            PCTBRK=TOT(8)/TOTSUP(2)
            PRINT 220,(TOT(M),M=1,7),PCTSAW,TOT(8),PCTBRK
        220 FORMAT(1H0,10X,*TOTALS*10X,6F15.1/1H0,10X,*TOTAL SAWDUST*F15.1,15X
           1*PERCENT OF SUPPLY *F10.2/1H ,10X*TOTAL BARK*3X,F15.1,15X,*PERCENT
           3 OF SUPPLY *F10.2)
            RETURN
      C
      C                      HEADING ROUTINE
      C
        100 PRINT 105, I,  DEM(1,I),DEM(2,I),JJ
        105 FORMAT (1H1,30X*LISTING OF COUNTIES IN DEMAND FOR PROCESSING PLANT
           1* I4/1H0,30X,*COORDINATE *2I3* NO. OF COUNTIES *I4)
            PRINT 108
            PRINT 110
        110 FORMAT     (1H ,5X *COUNTY*5X,*COORD*,5X*DISTANCE*10X,*DAIRY*8X
           1*NURSERY*10X*DAIRY*8X*NURSERY*8X*ORCHARD*7X*PACKAGED*//)
        108 FORMAT(1H0/1H ,49X*TONS OF SAWDUST* 22X*TONS OF BARK*)
            IOVF=0
            GO TO 40
            END
```

```
      TBARK=0.
      GO TO 875
C
C                   SATISFY DEMAND FOR HULK BARK
C
  840 L=3
      DO 855 K=6,8
      DO 850 N=1,JJ
      MM=N+5
      M=DEM(MM,I)
      IF(TBARK.LT.CTY(K,N))  GO TO 870
      SAT(L,M)=CTY(K,N)
      SAT(L+1,M)=CTY(K,N)*SP(2)
      TBARK=TBARK-CTY(K,N)
  850 CONTINUE
      L=L+2
  855 CONTINUE
      PRINT 860,TBARK
  860 FORMAT(1H0*BARK NOT ALL SOLD *F10.1,* LEFT OVER*)
      GO TO 875
  870 SAT(L,M)=TBARK
      SAT(L+1,M)=TBARK*SP(2)
      TBARK=0.
C
C                   SATISFY DEMAND SAWDUST
C
  875 TSAW=SAW
      L=9
      DO 885 K=4,5
      DO 880 N=1,JJ
      MM=N+5
      M=DEM(MM,I)
      IF(TSAW.LT.CTY(K,N))  GO TO 895
      SAT(L,M)=CTY(K,N)
      SAT(L+1,M)=CTY(K,N)*SP(1)
      TSAW=TSAW-CTY(K,N)
  880 CONTINUE
      L=L+2
  885 CONTINUE
      PRINT 890,TSAW
  890 FORMAT(1H0,*SAWDUST NOT ALL SOLD *F10.1* TONS LEFT OVER*)
      GO TO 900
  895 SAT(L,M)=TSAW
      SAT(L+1,M)=TSAW*SP(1)
      TSAW=0.
C
C                   ACCUMULATE TOTALS
C
  900 DO 905 J=1,13
  905 TOTS(J)=0.
      DO 917 N=1,JJ
      DO 910 K=2,12,2
  910 SAT(13,N)=SAT(13,N)+SAT(K,N)
```

```
      GO TO(430,435)IPROC
  430 IF(IVBARK.EQ.1.OR.IVBARK.EQ.3)600,500
  435 IF(IVSAW.EQ.1.OR.IVSAW.EQ.3)600,500
  450 WRITE(1,455) I,DEM(1,I),DEM(2,I),ITITLE
  455 FORMAT (1H1,30X,*LISTING OF SUPPLY COSTS FOR PROCESSING PLANT *
     1I5 * COORDINATE * 2I3,37X/1H0,51X*SUPPLYING MILLS OF *A10,55X)
      WRITE(1,460)
  460 FORMAT(1H0*  MILL  *12X*TONS*10X*COST RAW MATERIAL*11X*VAR TRUCK C
     1OST*10X,*COST OF DRIVER*13X*TOTAL COST*12X)
      WRITE(1,461)
  461 FORMAT(1H * NO COORD DIS*)
      WRITE(2,462)I,DEM(1,I),DEM(2,I)    ,ITITLE
  462 FORMAT(1H1,30X,*LISTING OF SUPPLY TIMES FOR PROCESSING PLANT *I5*
     1COORDINATE *2I3,37X/1H0,51X,*SUPPLYING MILLS OF *A10,55X)
      WRITE (2,465)
  465 FORMAT (1H0,*  MILL  *8X*NO. LOADS*9X,*TIME TO LOAD*12X*TIME TO TR
     1ANS*,10X,*TIME TO UNLOAD*12X,*TOTAL TIME*8X,*TRUCK*,5X)
      WRITE (2,470)
  470 FORMAT (1H0* NO COORD DIS*)
      IOVF=0
      IF(IVSAW.EQ.4)  GO TO 3020
      GO TO 485
  600 IF(TOT2(29).EQ.0.) GO TO 610
      IF(TOT2(29).LE. 75000) GO TO 630
  602 DO 605 M=1,29
  605 TOTPP(M)=TOTPP(M)+TOT1(M)+TOT2(M)
      GO TO 640
  610 PRINT 615,ITITLE
  615 FORMAT(1H0,*TRUCK 2 NOT USED FOR *A10)
  620 DO 625 M=1,29
  625 TOTPP(M)=TOTPP(M)+TOT1(M)
      GO TO 640
  630 IF(IPROC.EQ.1)  GO TO 602
      PRINT 635
  635 FORMAT (H0,*TRUCK2 NOT TO 70 PERCENT CAPACITY *)
      GO TO 602
  640 PRINT 645, (NTRUCK1(N),N=1,NTR1)
  645 FORMAT (1H0,*LISTING OF MILLS ON TRUCK 1 */5(1H ,10I10/))
      IF(NTR2.LE.0) GO TO 655
      PRINT 650, (NTRUCK2(N),N=1,NTR2)
  650 FORMAT (1H ,*LISTING OF MILLS ON TRUCK 2 */5(1H ,10I10/))
C                      WRITE TOTALS ON LU
C
C                             CHANGE MINUTES TO HOURS
C
  655 DO 656 M=1,29
  656 TOTALPP(M)=TOTALPP(M)+TOTPP(M)
      DO 657 M=10,29 $ TOT1(M)=TOT1(M)/60. $ TOT2(M)=TOT2(M)/60.
  657 TOTPP(M)=TOTPP(M)/60.
C
C
      DO 658 J=1,6
      L=IPR1(J,IPROC)
```

```
      SUBROUTINE PRSUP (I)
      COMMON/SUPPLY/SUP,NMILLPP,MILLPP
      COMMON/SORT/ISNOS(150)
      DIMENSION SUP(7,170),ISUP(7,170),NMILLPP(6),MILLPP(2,150,6)
      COMMON/A/DEM(55,6),NCTY
      COMMON/D/TOTSUP(2)
      EQUIVALENCE(SUP,ISUP)
      TYPE INTEGER DEM
       TOTSUP(1)=TOTSUP(2)=0.
      NM= NMILLPP(I) $ IOVF=43
      DO 500 JJ=1,NM
      K=ISNOS(JJ)
      J=MILLPP(1,K,I)
      IF(IOVF .GE. 43) GO TO 100
   45 PRINT 50, J,ISUP(1,J),ISUP(2,J),MILLPP(2,K,I),(SUP(M,J),M=3,5)
   50 FORMAT (1H ,I7,5X,I2,X,I2,5X,I8,5X,F14.3,5X,F12.2,5X,F9.2)
      IOVF=IOVF+1
      DO 55 N=1,2
      M=N+3
   55 TOTSUP(N)=TOTSUP(N)+SUP(M,J)
  500 CONTINUE
      PRINT 505, TOTSUP
  505 FORMAT(1H0,10X,*TOTAL* 39X,F12.2,5X,F9.2)
      RETURN
C
C                          HEADING ROUTINE
C
  100 PRINT 105, I,(DEM(KK,I),KK=1,4)
  105 FORMAT (1H1,30X,*LISTING OF SUPPLYING MILLS FOR PROCESSING PLANT *
     1I4/*0*28X,*COORDINATE *2I3* RADIUS *I4* MIN ANNUAL PROD *I10)
      PRINT 110
  110 FORMAT (1H0/1H ,*MILL NO*5X*COORD*5X*DISTANCE*5X,*PROD(IN THOUS)*
     15X,*TONS SAWDUST*5X*TONS BARK*//)
      IOVF = 0
      GO TO 45
      END
```

```
          N=DEM(M,I)
          PRINT 1020,ICTY(3,N),(SAT(K,MM),K=1,13)
     1020 FORMAT(1H ,A10,5X,6(F7,0,F11.2),F12,2)
     1025 CONTINUE
          PRINT 1030,TOTS
     1030 FORMAT(1H0,3X,*TOTAL*,7X,6(F7,0,F11,2),F12,2/1H0,11H***COSTS***,/)
          DO 1040 J=1,18
          PRINT 1035,(NAMES(K,J),K=1,2),(COST(J,L),L=1,7)
     1035  FORMAT(1H ,2A10,1X,F12,2,5(6X,F12,2),F12,2)
     1040 CONTINUE
          PRINT 1045,PROCCST
     1045 FORMAT(1H0,*TOTAL COSTS*4X,6(6X,F12,2),F12,2)
          PRINT 1050,PROFIT
     1050 FORMAT(1H0,*PROFIT (LOSS)*2X,6(6X,F12.2),F12,2)
          PRINT 1060,I
     1060 FORMAT(1H1,*END OF PROCESSING PLANT *I5)
    C
    C                      END OF DO LOOP
    C
     2000 CONTINUE
          PRINT 2005
     2005 FORMAT(1H1*END OF RUN*)
          END
```

```
PROGRAM       SAWSIM      FORTRAN EXTENDED V 1.0                 05/16/69             .22.29.09.

          741 FORMAT(1H1,20X,*PROCESS SAWDUST*)
              IPROC=2
              ITITLE=10HSAWDUST
              NTR1=NTR2=0
              REWIND 1  $  REWIND 2
              DO 743 M=18,29
              TOT1(M)=TOT1(M)*60
              TOT2(M)=TOT2(M)*60
              TOTPP(M)=TOTPP(M)*60
          743 CONTINUE
              IOVF=46
              DO 746 M=1,28
          746 TOT1(M)=TOT2(M)=TOTPP(M)=0.
              KM=7    $   IYSAW=0    $    GO TO 208
          744 PRINT 745
          745 FORMAT (1H1*END OF SUPPY STAGE -- BEGIN PROCESSING*)
        C
        C                     BEGIN PROCESSING
        C                       CLEAR ARRAYS
          800 DO 805 J=1,29
          805 TEMP(J)=TOTALPP(J)
              DO 810 J=1,546
          810 SAT(J)=0.
              DO 815 J=1,126
          815 COST(J)=0.
              DO 820 J=1,7
          820 PROCCST(J)=0.
        C                  ALLOCATE FIXED COSTS ON TONS
        C                  OF SAWDUST AND BARK
              X=SAW+BARK
              PSAW=SAW/X
              PBARK=BARK/X
              FCSAWAL=PCOST(1,1)*PSAW
              FCBKAL=PCOST(1,1)*PBARK
              FTCS=TRFIXC * PSAW
              FTCB=TRFIXC*PBARK
        C
        C                        SATISFY DEMAND PACKAGE BARK
        C
              TBARK=BARK
              JJ=DEM(5,I)
              IF(JJ.EQ.99)JJ=NCTY
              DO 825 M=1,JJ
              MM=M+5
              N=DEM(MM,I)
              IF(TBARK.LT.CTY(9,N))  GO TO 830
              SAT(1,M)=CTY(9,N)
              SAT(2,M)=CTY(9,N)*SP(3)
              TBARK=TBARK-CTY(9,N)
          825 CONTINUE
              GO TO 840
          830 SAT(1,M)=TBARK
              SAT(2,M)=TBARK*SP(3)
```

```
      GO TO 4040
 4030 IF(IPROC.EQ.1)  GO TO 4002
      PRINT 635
      GO TO 4002
 4040 PRINT 645, (NTRUCK1(N),N=1,NTR1)
      IF(NTR2.LE.0) GO TO 4055
      PRINT 650, (NTRUCK2(N),N=1,NTR2)
 4055 DO 4054 M=1,29
 4054 TOTALPP(M)=TOTALPP(M)+TOTPP(M)
      DO 4057M=10,29 $ TOT1(M)=TOT1(M)/60. $ TOT2(M)=TOT2(M)/60.
 4057 TOTPP(M)=TOTPP(M)/60.
      DO 4058J=1,6
      L=IPR1(J,IPROC)
      M=IPR2(J,IPROC)
      PRINT1(J)=TOTPP(L)
      PRINT2(J)=TOT1(L)
      PRINT3(J)=TOT2(L)
      PRINT4(J)=TOTPP(M)
      PRINT5(J)=TOT1(M)
 4058 PRINT6(J)=TOT2(M)
      IT=8H TOTAL
      WRITE(1,660) IT,(PRINT1(M),M=2,6)
      WRITE(2,680) IT,(PRINT4(M),M=2,6)
      IT=8H TRUCK 1
      WRITE(1,660) IT,(PRINT2(M),M=2,6)
      WRITE(2,680)IT,(PRINT5(M),M=2,6)
      IT=8H TRUCK 2
      WRITE(1,660) IT,(PRINT3(M),M=2,6)
      WRITE(2,680) IT,(PRINT6(M),M=2,6)
      GO TO 700
C
C                    NO SAWDUST OF WARK
C
 4070 PRINT 4075, ITITLE
 4075 FORMAT(1H0,*NO * A10,* TO BE PROCESSED*)
      GO TO 740
C                    PRINT LU 1 AND LU 2
C
  700 ENDFILE 1
      ENDFILE 2
      REWIND 1
      REWIND 2
      LU=1
  705 READ(LU,710)IN
  710 FORMAT(13A10,A6)
      IF(EOF(LU))725,715
  715 PRINT 710, IN
      GO TO 705
  725 IF(LU.EQ.2)740,730
  730 LU=2
      GO TO 705
  740 IF(IPROC.EQ.2)  GO TO 744
      PRINT 741
```

```
PROGRAM     SAWSIM     FORTRAN EXTENDED V 1.0               09/16/69              .22.29.09.

         90 SUP(J,L) =CT(J)
            ISUP(7,L)=0
            ISUP(6,L)=0
            GO TO 77
      C
      C                        SQUARE RADIUS OF PP FOR CHECKING
      C
        100 DO 110 I=1,NPP
            PPRAD(I)=DEM(5,I)*DEM(3,I)
            NMILLPP(I)=0
            DO 105 J=1,300
        105 MILLPP(J,I)=0
        110 CONTINUE
      C                           CALCULATE DISTANCE FROM EACH PP TO
      C                           EACH SAWMILL
            DO 150 I=1,170
            IF(ISUP(1,I).EQ.0)  GO TO 150
            DO 125 J=1,NPP
            D1(J)=(DEM(1,J)-ISUP(1,I))*3
            D2(J)=(DEM(2,J)-ISUP(2,I))*3
            D1(J)=IABS(D1(J))
            D2(J)=IABS(D2(J))
            R(J)=(D1(J)*D1(J))+(D2(J)*D2(J))
            IF(R(J).LE.PPRAD(J))140,125
        140 NMILLPP(J)=NMILLPP(J)+1
            NM=NMILLPP(J)
            MILLPP(1,NM,J)=I
            MILLPP(2,NM,J)=D1(J)+D2(J)
            ISUP(6,I)=ISUP(6,I).OR.MASK(J)
            ISUP(7,I)=ISUP(7,I).OR. MASK(J)
        125 CONTINUE
        150 CONTINUE
            PRINT 151,(NMILLPP(J),J=1,6)
        151 FORMAT(1H ,6I5)
            NM=NMILLPP(1)
            DO 154 K=1,NM
            PRINT 153, (MILLPP(N,K,1),N=1,2)
        153 FORMAT(1H ,I5,I10)
        154 CONTINUE
      C
      C                        WORK ON EACH PP SEPARATELY
      C
            DO 2000 I=1,NPP
            REWIND 1
            REWIND 2
      C                        SORT SUPPLY
            CALL SORT(I)  $ CALL PWSUP(I)
      C                        FIGURE DISTANCE TO EACH DEMAND CENTER
      C                        AND CALCULATE TOTAL AMT NEEDED
            JJ=DEM(5,I)
            IF(JJ.EQ.99)  160,155
        160 L=6
            DO 165 N=1,83
```

```
C
C                    COST BULK BARK
C
  944 K=2
      Y=TOTS(3)+TOTS(5)+TOTS(7)
      DO 950 J=3,7,2
      IF(Y.EQ.0.)  GO TO 949
      X=TOTS(J)/Y
      GO TO 948
  949 X=0.
  948 COST(11,K)=PCOST(1,5)*X
      COST(14,K)=PCOST(2,5)*TOTS(J)
      COST(18,K)=PCOST(3,5)*TOTS(J)
      K=K+1
  950 CONTINUE
C
C                     ADD INTERMEDIATE TOTAL COSTS
C
      DO 970 M=1,6
      DO 965 J=7,11
  965 COST(12,M)=COST(12,M)+COST(J,M)
      COST(17,M)=COST(13,M)+COST(14,M)+COST(15,M)+COST(16,M)
      PROCCST(M)=PROCCST(M)+COST(1,M)+COST(5,M)+COST(6,M)+COST(12,M)
     1+COST(17,M)+COST(18,M)
  970 CONTINUE
C
C                CALCULATE PROFIT
C
      L=1
      DO 980 M=2,12,2
      PROFIT(L)=TOTS(M)-PROCCST(L)
      L=L+1
  980 CONTINUE
C
C
      DO 990 J=1,6
      DO 985 M=1,18
  985 COST(M,7)=COST(M,7)+COST(M,J)
      PROCCST(7)=PROCCST(7)+PROCCST(J)
  990 CONTINUE
      PROFIT(7)=TOTS(13)-PROCCST(7)
C
C                      PRINT SATISFIED DEMAND AND COSTS
C
 1000 PRINT 1005, I,(DEM(J,I),J=1,3)
 1005 FORMAT (1H1,30X*SATISFIED DEMAND FOR PROCESSING PLANT *I5,* COORDI
     1NATE *2I3,* RADIUS *I3/)
      PRINT 1006
 1006 FORMAT(1H0,56X,*BULK BARK*37X*SAWDUST*/1H 17X,*PACKAGED BARK*,9X,
     1*DAIRY*,12X,*NURSERY*,11X*ORCHARD*,12X,*DAIRY*,12X,*NURSERY*,10X,
     2*GROSS*/1H ,*COUNTY*,9X,6(3X,*TONS*,8X,*SALES*),4X,*SALES*//)
 1010 DO 1025 MM=1,JJ
      N=MM+5
```

```
      IF(ICTY(1,N).NE.0)162,165
  162 DEM(L,I)=N
      L=L+1
  165 CONTINUE
      JJ=NCTY
  155 GET(1,I)=GET(2,I)=0.
      DO 200 J=1,JJ
      K = DEM(J+5,I)
C                  JJ=NO CTYS IN PP   K=CTY =
      DIS1 =(DEM(1,I)-ICTY(1,K))*3
      DIS2 =(DEM(2,I)-ICTY(2,K))*3
      ICTY(10,K)=IABS(DIS1)+IABS(DIS2)
      DO 170 M=4,5
      GET(1,I)=CTY(M,K)+GET(1,I)
  170 CONTINUE
      DO 180 M=6,9
      GET(2,I)=GET(2,I)+ CTY(M,K)
  180 CONTINUE
  200 CONTINUE  $ CALL PRDEM(I)
C
C                         TAKE CLOSEST MILL AT A TIME
C
      PRINT 201
  201 FORMAT(1H1,10X)
      NN=NMILLPP(I)
      TOTD=TOTB=0.
      IOVF=46
      DO 205 N=1,29
  205 TOTPP(N)=TOT1(N)=TOT2(N)=TOTALPP(N)=0.
C
      DO 202 J=1,29
  202 TEMP(J)=0.
C
C                        PROCESS BARK FIRST -- THEN SAWDUST
C
      PRINT 206
  206 FORMAT(1H1,20X,*PROCESS BARK*)
      IPROC=1
      ITITLE=10HBARK
      IYBARK=0
      KM=6
      NTR1=NTR2=0
  208 DO 500 JJ=1,NN
      J2=ISNOS(JJ)
      K=MILLPP(1,J2,I)
      IF(ITERR.NE.1)GO TO 207
      MM=SUP(KM,K).AND.MASK(I)
      IF(MM.LE.0)GO TO 297
C
C                         CHECK YEARLY PRODUCTION
C
  207 Y=DEM(4,I)
      IF(SUP(3,K).LT.Y)GO TO 280
```

```
PROGRAM     SAMSIM     FORTRAN EXTENDED V 1.0                 05/16/69           .22.29.09.
          DATA((NAMES(J,17),J=1,2)=10HTOTAL VARI,10HABLE COSTS)
          DATA((NAMES(J,18),J=1,2)=10HLOADING CO,10HSTS       )
          PRINT 1
        1 FORMAT(1H1*(EXECUTION STARTED*)
          DO 5 J=1,830
        5 ICTY(J)=0
C                   READ CARD - NO OF PROCESSING PLANTS  AND
C                              TO CHECK FOR OVERLAPPING TERR (ITERR=1)
       10 READ 15, NPP,ITERR
       15 FORMAT (2I5)
C
C                   READ PARAMETERS FOR EACH PP
C
          DO 30 I=1,NPP
          READ 20, ID,L,(DEM(J,I),J=1,5) ,DCONV
       20 FORMAT (A5,I1,3X,3I2,I10,I2,6F5,0)
          IF(ID.NE.5RPARAM.OR.L.NE.1)GO TO 35  $ IF(DEM(5,I).EQ.99)GO TO 30
          READ 25, ID,L,(DEM(J,I),J=6,40)
       25 FORMAT(A5,I1,2X,35I2)
          IF(ID.NE.5RCTY  .OR.L.NE.1)GO TO 35
          PRINT 31,(DEM(J,I),J=1,40)
       31 FORMAT(1H 3I3,I11,I3/1H ,35I2)
       30 CONTINUE
          GO TO 50
       35 PRINT 40
       40 FORMAT (1H1*ERROR IN ORDER OF PARAMETER CARDS*)
          CALL EXIT
C
C                   READ CTY NAMES ,COORDINATES AND DEMANDS
C
       50 NCTY=1
       52 READ 55,I,ICT
       55 FORMAT(I2,2I2,A10,4X,6F10.0)
          IF(I.EQ.99)GO TO 75
          NCTY=NCTY+1
          DO 60 J=1,3
       60 ICTY(J,I)=ICT(J)
          DO 65 J=4,9
       65 CTY(J,I)=CT(J)*DCONV(J-3)
          GO TO 52
C
C                   READ IN SUPPLY
C
       75 DO 76 I=1,1190
       76 ISUP(I)=0
          NMILLS=1
       77 READ 80, L, (ICT(I),I=1,5)
          IF(L.EQ.999) GO TO 100
       80 FORMAT (I3,X,2I2,12X,3F10.1)
          NMILLS=NMILLS+1
          DO 85 I=1,2
       85 ISUP(I,L)=ICT(I)
          DO 90 J=3,5
```

PROGRAM SAWSIM FORTRAN EXTENDED V 1.0 09/16/69 .22.29.09.

```
C
  235 IF(TOT1(29).GE.112500)  GO TO 250
      X=TOT1(29)+TEMP(29)
      IF(X.LE.113500)  GO TO 240
      Y=X-113500
      GO TO (236,239)IPROC
  236 Z=10.*30.*TDRIVE
      LOAD=LBARK
  237 M=Y/Z
      PCT=(1.0-M)/LOAD
      DO 238 M=1,29
      TOT2(M)=TOT2(M)+TEMP(M)*PCT
  238 TOT1(M)=TOT1(M)+(TEMP(M)-(TEMP(M)*PCT))
      NTR2=NTR2+1  $ NTRUCK2(NTR2)=K
      NTR1=NTR1+1   $  NTRUCK1(NTR1)=K   $   GO TO 247
  239 Z=10.*20.*TDRIVE
      LOAD=LSAW
      GO TO 237
  247 PRINT 248,K    $   GO TO 250
  248 FORMAT(1H0,*SAWMILL *I5* ON TRUCK 1 AND TRUCK 2*)
  240 DO 245 M = 1,29
  245 TOT1(M)=TOT1(M)+TEMP(M) $ NTR1=NTR1+1 $ NTRUCK1(NTR1)=K $ ITR=1
      ISUP(KM,K)=0
      GO TO 400
  250 IF(TOT2(29).GE.112500)GO TO 260
      X=TOT2(29)+TEMP(29)
      IF(X.GE.113500) GO TO 270
  252 DO 255 M=1,29
  255 TOT2(M)=TOT2(M)+TEMP(M) $ NTR2=NTR2+1 $ NTRUCK2(NTR2)=K $ ITR=2
  256 ISUP(KM,K)=0
      GO TO 400
  270 Z=X-113500
      Y=Z*.025
      GO TO(271,272)IPROC
  271 CDRIVB=CDRIVB+Y
      TCDRIV=TCDRIV+Y
      TCBARK=TCBARK+Y
      Y=Z/60.    $   IVBARK=3
      GO TO 273
  272 CDRIVS=CDRIVS+Y
      TCDRIV=TCDRIV+Y
      TCSAW=TCSAW+Y
      Y=Z/60.    $   IVSAW=3
      GO TO 273
  260 PRINT 265,K
  265 FORMAT (1H0* TRUCK 1 AND TRUCK 2 FULL ON SAWMILL NO.* I5)
      GO TO 290
  273 PRINT 275,K,Y
  275 FORMAT(1H0*TRUCK 1 FULL - SAWMILL * I5 *WILL NOT FIT IN TRUCK 2 -
     1OVERTIME PAID FOR *F5.1* HOURS*/1H ,*ALL OF MILL SUPPLY BROUGHT IN
     2 - FURTHER PROCESSING STOPPED*)
      GO TO 292
  280 PRINT 285,K
```

```
PROGRAM      SAWSIM    FORTRAN EXTENDED V 1.0                05/16/69            .22.29.09.

      3025  EXCESS(M)=0.
            GO TO 3002
C
C
C                         DEMAND SATISFIED ON SAWDUST
C
       350 IF(IYSAW.EQ.2)  GO TO 232
           Y=TOTD-SUP(4,K)
           X=GET(1,I)-Y
           IF(X.GE.300) GO TO 375
           PRINT 355,K
           IYSAW=1
       355 FORMAT (1H0*SAWDUST DEMAND SATISFIED ON MILL NO. *I5)
       360 PRINT 365,K
           GO TO 367
       365 FORMAT(1H0*SAWDUST PROD NOT INCLUDED FOR MILL NO. * I5)
       367 TOEXS=SUP(4,K)   $   GO TO 400
       375 PRINT 395,K
           IYSAW=1
           PRINT 380,X,K
       380 FORMAT(1H0,F10.2,* TONS OF SAWDUST INCLUDED FOR MILL *I5)
           LSAW=X/10.
           SAW=X
           TOEXS=SUP(4,K)-X   $   GO TO 233
       385 SAW=TOEXS
           LSAW=SAW/10.
       387 WRITE(1,348)ITITLE
           WRITE(2,348)ITITLE
           DO 389 M=1,29
       389 EXCESS(M)=0.
           IF(IYSAW.EQ.3)  GO TO 390
           IF(IYSAW.EQ.2)  GO TO 232
           IYSAW=2   $   GO TO 233
       390 IYSAW=2   $   GO TO 500
C
C                    PRINT TEMP -- COST FIGURES FOR 1 MILL
C
       400 IF(IOVF.GE.46)450,405
       405 DO 415 M=18,29
       415 TEMP(M)=TEMP(M)/60.
           DO 407 J=1,6
           L=IPR1(J,IPROC)
           M=IPR2(J,IPROC)
           PRINT1(J)=TEMP(L)
       407 PRINT2(J)=TEMP(M)
           WRITE(1,410)K,ISUP(1,K),ISUP(2,K),(PRINT1(M),M=1,6)
       410 FORMAT (1H ,3I3,I4  ,5X,F8.0,12X,F9.0,17X,F10.2,14X,F10.2,15X,F10.
          12,12X)
           WRITE(2,420)K,ISUP(1,K),ISUP(2,K),(PRINT2(M),M=1,6),ITR
       420 FORMAT(1H ,3I3,I4  ,4X,I7  ,12X,F8.1,3(10X,F8.1),12X,I1,6X)
           DO 425 M=1,29
       425 TEMP(M)=0.
           IOVF=IOVF+1
```

PROGRAM SAWSIN FORTRAN EXTENDED V 1.0 05/16/69 .22.29.09.

```
      PROGRAM SAWSIN(INPUT,OUTPUT,LU1,LU2,TAPE1=LU1,TAPE2=LU2)
      DIMENSION DFM(55,6),CTY(10,83),ICT(9),ICTY(10,83),CT(9),SUP(7,170)
     1,ISUP(7,170),D1(6),D2(6),R(6),PPRAD(6),NMILLPP(6),MILLPP(2,150,6),
     2ISNOS(150),BET(2,6),          MASK(6),TEMP(29),TOT1(29),TOT2(29),
     3TOTPP(29),NTRUCK1(50),NTRUCK2(50),IN(14)
      DIMENSION DCONV(6),TOTALPP(29)
       DIMENSION PRINT1(6),PRINT2(6),PRINT3(6),PRINT4(6),PRINT5(6),PRINT
     16(6),IPR1(6,2),IPR2(6,2),EXCESS(29)
      COMMON/B/DIS,SAW,BARK,CSAW,CBARK,CTRM,VTCOSTS,VTCOSTB,TVTCOST,
     1CDRIVS,CDRIVB,TCDRIV,TCSAW,TCBARK,TOTCOS,LSAW,LBARK,TMS,TMB,TOTLD,
     2TTRANSS,TTRANSB,TTRANS,TUTRS,TUTRB,TTUTR,TOTTS,TOTTB,TOTTIME
      COMMON/SORT/ISNOS
      COMMON/SUPPLY/SUP,NMILLPP,MILLPP
      COMMON/DEMAND/CTY
      COMMON/A/DEM,NCTY
      DIMENSION PCOST(3,5),SAT(13,42),SP(3),COST(10,7),TOTS(13),
     1PROCCST(7),PROFIT(7),NAMES(2,18)
      EQUIVALENCE(CTY,ICTY),(CT,ICT),(SUP,ISUP),(TEMP,DIS)
      TYPE INTEGER DEM,D1,D2,R,PPRAD,DIS1,DIS2
      TYPE INTEGER DIS
      DATA(MASK(4)=01000000B)
      DATA(MASK(1)=010B)
      DATA(MASK(2)=0100B)
      DATA(MASK(3)=010000B)
      DATA(MASK(5)=0100000000B)
      DATA(MASK(6)=010000000000B)
      DATA(TRFIXC=4450.)
      DATA((PCOST(I,1),I=1,3)=16227.,.1,.1.)
      DATA((PCOST(I,2),I=1,3)=461.,.0,06,0,10)
      DATA((PCOST(I,3),I=1,3)=1471.,.0,10,1.)
      DATA((PCOST(I,4),I=1,3)= 7631.,.13,14,0,30)
      DATA((PCOST(I,5),I=1,3)=  0.,.0,00,0,25)
      DATA((SP(I),I=1,3)=4,0,4.0,63,05)
      DATA((IPR1(L,1),L=1,6)=1,3,5,8,11,14)
      DATA((IPR2(L,1),L=1,6)=1,17,19,22,25,28)
      DATA((IPR1(L,2),L=1,6)=1,2,4,7,10,13)
      DATA((IPR2(L,2),L=1,6)=1,16,18,21,24,27)
      DATA((NAMES(J, 1),J=1,2)=10HRAW MATERI,10HAL         )
      DATA((NAMES(J, 2),J=1,2)=10H  DRIVER  ,10H           )
      DATA((NAMES(J, 3),J=1,2)=10H  VARIABLE,10H TRUCK     )
      DATA((NAMES(J, 4),J=1,2)=10H  FIXED TR,10HUCK        )
      DATA((NAMES(J, 5),J=1,2)=10HTOT INBOUN,10HD TRANS    )
      DATA((NAMES(J, 6),J=1,2)=10HINVENTORY ,10HHOLDING    )
      DATA((NAMES(J, 7),J=1,2)=10H  ALLOCATE,10HD FIX COST)
      DATA((NAMES(J, 8),J=1,2)=10H  SAWDUST ,10HFIX COST  )
      DATA((NAMES(J, 9),J=1,2)=10H  ALL BARK,10H FIX COST )
      DATA((NAMES(J,10),J=1,2)=10H  PACK BAR,10HK FIX COST)
      DATA((NAMES(J,11),J=1,2)=10H  BULK BAR,10HK FIX COST)
      DATA((NAMES(J,12),J=1,2)=10HTOTAL FIXE,10HD COSTS   )
      DATA((NAMES(J,13),J=1,2)=10H  SAWDUST ,10HVAR COST  )
      DATA((NAMES(J,14),J=1,2)=10H  ALL BARK,10H VAR COST )
      DATA((NAMES(J,15),J=1,2)=10H  PACK BAR,10HK VAR COST)
      DATA((NAMES(J,16),J=1,2)=10H  BULK BAR,10HK VAR COST)
```

```
 285 FORMAT(1H0*SAWMILL*I4 * DROPPED - PRODUCTION TOO LOW*)
     GO TO 500
 290 IDONE=1
 292 PRINT 295,K
 295 FORMAT (1H0,*SAWMILL *I4 * DROPPED -- DEMAND SATISFIED OR TRUCKS
    1FULL *)
     GO TO 3000
 297 PRINT 298,K
 298 FORMAT(1H0 *SAWMILL *I4 * DROPPED -- INCLUDED IN PREVIOUS PP*)
     GO TO 500
C
C                 WHEN DEMAND IS SATISFIED ON BARK
C
 310 IF(IYBARK.EQ.2)  GO TO 222
     Y=TOTB-SUP(5,K)
     X=GET(2,I)-Y
     IF(X.GE. 0) GO TO 330
     PRINT 315,K   $   IYBARK=1
 315 FORMAT (1H0,*BARK DEMAND SATISFIED ON MILL NO. *I5)
 320 PRINT 325   $   GO TO 340
 325 FORMAT (1H0*BARK PROD NOT INCLUDED FOR MILL NO. *I5)
 330 BARK = X
     LBARK = X/8.
     PRINT 315,K
     PRINT 335 , X,K
 335 FORMAT (1H0,F10.2,* TONS OF BARK INCLUDED FOR MILL *I5)
     IYBARK=1
     TOEXB=SUP(5,K)-X   $   GO TO 225
 340 TOEXB=SUP(5,K)   $   GO TO 400
 345 BARK=TOEXB
     LBARK=BARK/8
 347 WRITE(1,348)ITITLE
     WRITE(2,348)ITITLE
 348 FORMAT(1H0,135X/1H0,49X,*MILLS THAT COULD SUPPLY *A10,52X)
     DO 349 M=1,29
 349 EXCESS(M)=0.
     IF(IYBARK.EQ.3) GO TO 346
     IF(IYBARK.EQ.2)  GO TO 222
     IYBARK=2   $   GO TO 225
 346 IYBARK=2   $   GO TO 500
C
C               ADD INTO EXCESS
3000 IF(IYSAW.EQ.0)  GO TO 3010
3002 DO 3005 M=1,29
3005 EXCESS(M)=EXCESS(M)+TEMP(M)
     ITR=0
     GO TO 490
3010 IYSAW=4
     GO TO 450
3020  WRITE(1,348) ITITLE
     WRITE(2,348)ITITLE
     IYSAW=2
     DO 3025 M=1,29
```

```
      220 GO TO(221,230)IPROC
      221 TOTB=TOTB+SUP(5,K)
          IF(SUP(5,K).EQ.0.)  GO TO 500
          IF(TOTB.GT.GET(2,I))  GO TO 310
      222 BARK=SUP(5,K)
          LBARK=BARK/8
      225 TMB=LBARK*30.   $   TOTLD=TMB
          DIS=MILLPP(2,J2,I)
          TDRIVE=(DIS*2.)*1.5
          TTRANSB=TDRIVE*LBARK
          TTRANS=TTRANSB
          CBARK=LBARK*10.
          CTRN=CBARK
          VTCOSTB=(DIS*LBARK)*.6
          TVTCOST=VTCOSTB
          TUTRB=LBARK*10.
          TTUTR=TUTRB
          TOTTB=TTRANSB+TMB+TUTRB
          TOTTIME=TOTTB
          CDRIVB=(TOTTB*.05)
          TCDRIV=CDRIVB
          TCBARK=CBARK+VTCOSTB+CDRIVB
          TOTCOS=TCBARK
           IF(IVBARK.EQ.2)3000,235
C
C                        COST SAWDUST
C
      230 TOTD=TOTD+SUP(4,K)
          IF(SUP(4,K).EQ.0.)  GO TO 500
          IF(TOTD.GT.GET(1,I))  GO TO 350
      232 SAW=SUP(4,K)
          LSAW=SAW/10.
      233 TMS=LSAW*20.
          TOTLD=TMS
          DIS=MILLPP(2,J2,I)
          TDRIVE=(DIS*2.)*1.5
          TTRANSS=TDRIVE*LSAW
          TTRANS=TTRANSS
          CSAW=LSAW*20.
          CTRN=CSAW
          VTCOSTS=(DIS*LSAW)*.6
          TVTCOST=VTCOSTS
          TUTRS=LSAW*10
          TTUTR=TUTRS
          TOTTS=TTRANSS+TMS+TUTRS
          TOTTIME=TOTTS
          CDRIVS=(TOTTS*.05)
          TCDRIV=CDRIVS
          TCSAW=CSAW+VTCOSTS+CDRIVS
          TOTCOS=TCSAW
          IF(IVSAW.EQ.2)  GO TO 3000
C
C                       CHECK TO SEE IF GOES TO TRUCK 1 OR 2
```

APPENDIX E-1

Summary of Supply Data for Configuration No. 1

Supplying Mills of Bark

Mill No.	Coord	Dis	Tons	No. Loads	Cost/Raw Material	Var. Truck Cost	Cost of Driver	Total Cost	Total Time (hours)
40	4736	6	6577	822	8220	2959.20	2383.80	13563.00	794.6
37	4732	12	1392	174	1740	1252.80	661.20	3654.00	220.4
Total			7969	0	9960	4212.00	3045.00	17217.00	1015.0
Truck 1			7969	0	9960	4212.00	3045.00	17217.00	1015.0
Truck 2			0	0	0	0.00	0.00	0.00	0.0

Supplying Mills of Sawdust

Mill No.	Coord	Dis	Tons	No. Loads	Cost/Raw Material	Var. Truck Cost	Cost of Driver	Total Cost	Total Time (hours)
39	4636	3	1872	187	3740	336.60	364.65	4441.25	121.5
38	4735	3	4160	416	8320	748.80	811.20	9880.00	270.4
40	4736	6	11794	1179	23580	4244.40	2829.60	30654.00	943.2
37	4732	12	2496	249	4980	1792.80	821.70	7594.50	273.9
41	4840	21	1092	109	2180	1373.40	506.85	4060.25	168.9
Total			21414	0	42800	8496.00	5334.00	56630.00	1778.0
Truck 1			12094	0	24180	3267.00	2630.25	30077.25	867.7
Truck 2			9320	0	18620	5229.00	2703.75	26552.75	901.2

APPENDIX E-1

Summary of Supply Data for Configuration No. 1

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37	4732	12	1392	174	1740	1252.80	661.20	3654.00	220.4
Total			7969	0	9960	4212.00	3045.00	17217.00	1015.0
Truck 1			7969	0	9960	4212.00	3045.00	17217.00	1015.0
Truck 2			0	0	0	0.00	0.00	0.00	0.0

Supplying Mills of Sawdust

Mill No.	Coord	Dis	Tons	No. Loads	Cost/Raw Material	Var. Truck Cost	Cost of Driver	Total Cost	Total Time (hours)
39	4636	3	1872	187	3740	336.60	364.65	4441.25	121.5
38	4735	3	4160	416	8320	748.80	811.20	9880.00	270.4
40	4736	6	11794	1179	23580	4244.40	2829.60	30654.00	943.2
37	4732	12	2496	249	4980	1792.80	821.70	7594.50	273.9
41	4840	21	1092	109	2180	1373.40	506.85	4060.25	168.9
Total			21414	0	42800	8496.00	5334.00	56630.00	1778.0
Truck 1			12094	0	24180	3267.00	2630.25	30077.25	867.7
Truck 2			9320	0	18620	5229.00	2703.75	26552.75	901.2

APPENDIX E-2

Summary of Supply Data for Configuration No. 2

Supplying Mills of Bark

Mill No.	Coord	Dis	Tons	No. Loads	Cost/Raw Material	Var. Truck Cost	Cost of Driver	Total Cost	Total Time (hours)
93	3529	3	1531	191	1910	343.80	467.95	2721.75	156.0
91	3326	12	1114	139	1390	1000.80	528.20	2919.00	176.1
69	4028	15	1740	217	2170	1953.00	922.25	5045.25	307.4
73	3323	21	1740	217	2170	2734.20	1117.55	6021.75	372.5
Total			6125	0	7640	6031.80	3035.95	16707.75	1012.0
Truck 1			6125	0	7640	6031.80	3035.95	16707.75	1012.0
Truck 2			0	0	0	0.00	0.00	0.00	0.0

Supplying Mills of Sawdust

Mill No.	Coord	Dis	Tons	No. Loads	Cost/Raw Material	Var. Truck Cost	Cost of Driver	Total Cost	Total Time (hours)
93	3529	3	2746	274	5480	493.20	534.30	6507.50	178.1
91	3326	12	1997	199	3980	1432.80	656.70	6069.50	218.9
69	4028	15	3120	312	6240	2808.00	1170.00	10218.00	390.0
73	3323	21	3120	312	6240	3931.20	1450.80	11622.00	483.6
95	3024	27	312	31	620	502.20	172.05	1294.25	57.3
94	2931	27	324	32	640	518.40	177.60	1336.00	59.2
Total			11619	0	23200	9685.80	4161.45	37047.25	1387.1
Truck 1			8462	0	16900	5490.00	2640.00	25030.00	880.0
Truck 2			3156	0	6300	4195.80	1521.45	12017.25	507.1

APPENDIX E-3

Summary of Supply Data for Configuration No. 3

Supplying Mills of Bark

Mill No.	Coord	Dis	Tons	No. Loads	Cost/Raw Material	Var. Truck Cost	Cost of Driver	Total Cost	Total Time (hours)
70	3519	3	2247	280	2800	504.00	686.00	3990.00	228.7
73	3323	15	1740	217	2170	1953.00	922.25	5045.25	307.4
91	3326	24	1114	139	1390	2001.60	778.40	4170.00	259.5
93	3529	27	1531	191	1910	3094.20	1155.55	6159.75	385.2
Total			6632	0	8270	7552.80	3542.20	19365.00	1180.7
Truck 1			6632	0	8270	7552.80	3542.20	19365.00	1180.7
Truck 2			0	0	0	0.00	0.00	0.00	0.0

Supplying Mills of Sawdust

Mill No.	Coord	Dis	Tons	No. Loads	Cost/Raw Material	Var. Truck Cost	Cost of Driver	Total Cost	Total Time (hours)
70	3519	3	4030	403	8060	725.40	785.85	9571.25	261.9
73	3323	15	3120	312	6240	2808.00	1170.00	10218.00	390.0
74	3922	18	780	78	1560	842.40	327.60	2730.00	109.2
72	3817	18	312	31	620	334.80	130.20	1085.00	43.4
54	2921	21	624	62	1240	781.20	288.30	2309.50	96.1
98	3815	24	832	83	1660	1195.20	423.30	3278.50	141.1
91	3326	24	1997	199	3980	2865.60	1014.90	7860.50	338.3
87	4219	24	780	78	1560	1123.20	397.80	3081.00	132.6
48	2821	24	780	78	1560	1123.20	397.80	3081.00	132.6
47	3116	24	312	31	620	446.40	158.10	1224.50	52.7
95	3024	27	312	31	620	502.20	172.05	1294.25	57.3
93	3529	27	2746	274	5480	4438.80	1520.70	11439.50	506.9
89	4016	27	312	31	620	502.20	172.05	1294.25	57.3
55	2818	27	312	31	620	502.20	175.05	1294.25	57.3
50	2721	27	312	31	620	502.20	175.05	1294.25	57.3
92	2825	36	630	62	1240	1339.20	427.80	3007.00	142.6
Total			18190	0	36300	20032.20	7730.55	64062.75	2576.8
Truck 1			7580	0	15160	3997.80	2136.45	21294.25	712.1
Truck 2			10610	0	21140	16034.40	5594.10	42768.50	1864.7