PRODUCTION CAPACITY UTILIZATION IN THE SOUTHERN LOGGING INDUSTRY

by

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(ABSTRACT)

Daily production data were obtained from 22 independent contractors. The collected information included the contractors' estimates of their maximum production capacity and the actual production achieved. Explanations were requested to explain any difference between actual and achieved production.

Most frequent causes of lost production were: 1) adverse weather, 2) quotas, 3) moving. Other reasons for delays included mechanical problems, and labor problems. Median capacity utilization for the study period was 70%. The region of operation had a significant influence on capacity utilization: Contractors from the Piedmont had the highest capacity utilization (median of 81%), Coastal Plain (70%), and southern Appalachian (63%).

Rain had the most impact on contractors. Above average rainfall occurred over much of the region during the study period. Stricter environmental regulations are suspected to have increased the impact of rain on harvesting operations. Production quotas affected a number of loggers during the study, especially in the southern Appalachians. Capacity losses accounted for six to nineteen percent for these contractors. Overall, weather proved much more significant than quota.

A model was developed to estimate the cumulative cost of extra capacity in relation to the risk of wood outage at the consuming mill. The model could serve as a starting point for a better understanding of stump to mill wood flow.

Quality control statistical methods were adapted to analyze logging operations systems. Run charts, control charts, and cusum charts were used to measure variability in systems' production. Variation in production levels appear to be increasing with increased regulation. Elasticity has become essential for contractors to maintain profitability. High production during the relatively short periods of good weather and no quotas generated the margin necessary to sustain the contractors during periods of little or no production.

Findings suggested that long term production record should be maintained for a selected group of contractors. Better knowledge on the southern wood supply system sustainability and adaptability could be developed for use in operation and inventory management planning. An increased knowledge and a broader use of quality management tools should be considered in wood procurement.

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All my gratitude to the loggers and loggers' wives that took the time to deal with "the funny talking Canadian" and filled out the production cards on top of providing me with anecdotes on the southern logging industry and way of life. Your hospitality and friendship made me fall in love with the South.

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CHAPTER 1. INTRODUCTION

The southern logging industry's concern about the utilization of production capacity in the harvesting force has generated several investigations and research projects within the Industrial Forestry Operations (IFO) Research Cooperative at Virginia Tech. Laestadius'(1990) comparison of Swedish and southern wood-supply systems initiated discussions about the consequences of under-utilized logging capacity. Exhaustive documentation of wood harvesting costs followed Laestadius' work (Loving 1991). Loving concluded that excess logging capacity proved to be "the major weakness and potentially damaging characteristic of the current wood supply system."

The Evolution of Logging Operations

The evolution of mechanized logging operations has largely replaced the "three men and a truck" operations and created a level of stability. Productivity increases compensated for the relative stability of delivered wood prices during the transition from labor-intensive to capital-intensive systems in the 1960's and 1970's. In other words, while the contract rates per ton of wood remained constant in nominal dollars, the increasing quantity of wood produced allowed the logger to clear a similar profit per unit time in constant dollars. Contractors achieved the productivity increases necessary to sustain a financial position by using more efficient and productive equipment. Technological innovation was the key to profitability. Loving (1991) stated that the logging industry seems to have reached a technological plateau. Although new technology will continue to be developed and commercialized, the marginal efficiency of continued investment in current technologies is diminishing.

Development of new equipment is not driven exclusively by production increases and the future will likely see environmental and ergonomic improvements. As the limits of current machinery are approached, it may be time to look at other ways of improving actual wood supply system efficiency.

Maintaining Profitability by Means of Technical Efficiency

Logging costs follow inflation, logging rates often do not because of competitive pressure within the harvesting force and pressure from wood purchasers to keep raw material costs low. A net profit, in current dollars, has to be twice as large today as ten years ago (assuming a 7% inflation rate) if the contractor is to have the same purchasing power. If the margin per ton has remained the same in nominal dollars, the contractor will have had to double production to offset inflation.

Example:

If a logger netted \$10,000 in 1983, \$20,000 must be netted in 1993:

$\$10{,}000 * (1+0.07)^{10} = \$20{,}000.$

Net profit (N) is equal to margin per ton (P) times the output (O): $N = O * P$

If $N_{1993} = 2 * N_{1983}$, given P constant:

$O_{1993} = N_{1993}/P_{1993}$ or $2 * N_{1983}/P_{1983}$

Equal nets were achieved by increasing technical efficiency rather than price.

Recently operating costs increased as a result of the extra care needed to conform to environmental regulations. In challenging economic times, increasing contractors' margin per ton is difficult for procurement organizations. If productivity rates have reached a plateau, it should now be evident that keeping total profits constant represents a considerable challenge. Past gains came from the "hard" dimension of the system, i.e., the equipment. Future gains may come from the "soft" dimension of the system. This dimension includes management, labor, and technical application of available equipment.

The Business of Logging

Improving the system may require focusing on long term benefits by taking steps to improve the business environment of independent contractors. Quotas and other efficiency inhibitors that restrict the best entrepreneurs' production have to be justified. It is commonly acknowledge that the raw material cost across the South varies with furnish type and source. Sawmill residue chips are usually the least costly. Gatewood[1] is next, and wood purchased by the mill procurement and harvested by contractors is the most expensive. Long-term contracts with commercial suppliers such as independent chipmills, may further complicate wood procurement. Raw material source predictability usually varies inversely with cost. Sawmills may shift from two shifts to one if the market softens. Gate wood suppliers may move to a competitor, a different market, or prove unable to function in periods of adverse weather. Primary contractors are expected to be the most dependable suppliers.

Rewarding predictability and dependability by allowing primary contractors to produce and placing less expensive sources, such as sawmill chips, on quota is hard to justify, especially in periods of reduced profit margins. Absorbing limited amount of short term costs could result in long term savings. The process of selection is a constant one and most be handled carefully and thoughtfully. Independent contractors that have adopted recent equipment refinements are less vulnerable to severe weather. Well

[1]Wood delivered to the mill by suppliers who have no contractual relationship with the purchasing company.

equipped loggers, when backed by a perceptive purchasing organization, should be able to sustain regular wood flow under all but exceptional conditions. This will require the industry to focus on dependable contractors. The selection process will be at the expense of weaker contractors, those risky producers costing the forest industry both money and credibility[2]. "Professional" loggers are needed by the industry to adapt to the constraints of a new business and regulatory operating environment. In a fair market environment, good contractors will reveal themselves making selection easier.

The industry benefits in the long run from financially healthy, well-equipped, progressive loggers. The cost of innovative equipment and methods to adapt to our ever-changing social and operating needs is significant. Only well established loggers can be expected to have the resources to support such activities. Best Management Practices (BMP), voluntary in some states and mandatory in others, and other environmental restrictions keep raising challenges to harvesting firms (Cubbage and Lickward 1991). Well established contractors are the industry's best bet to meet these challenges. Marginally profitable loggers will be among the last to conform and will have difficulty adapting to new requirements. Progressive loggers need increased production and stability, this would require allocating a larger share of the wood order to them. The trend toward fewer, more dependable, and more productive producers will parallel the trend noticeable elsewhere in the economy. The contractor size needed by the industry has to be defined. A mill's harvesting force will consist of a variety of business types, sizes, and capabilities to match the characteristics of the procurement area.

A smaller number of better equipped producers will make procurement planning easier in terms of matching operations, tracts, and seasonal conditions. A good knowledge of the logging force's capacity

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[2]Credibility is used in this context as the positive perception the general public has of a logger, considering him as a professional earning his living in a thoughtful way. In a near future, credibility may become one of the most valued assets of an independent contractor.

for handling different stand qualities, hauling distances, and weather conditions, should allow a better match of contractor, environment, product, and demand. The ability of loggers to move to a new tract and resume production in a minimum of time, is a characteristic of modern systems that may be under-appreciated.

The forest industry has invested heavily in efforts to improve finished product quality and the efficiency of its daily operations. Signs commonly found in chip mills summarizes their objectives to improve safety, quality, cost, and production.

It is interesting to attempt to establish a parallel between the message to chip producers and the requirements of forest harvesting. What is asked of the independent contractor? They are expected to safely produce quality raw material in sufficient quantities at a reasonable price while given only partial control over the factors that most influence their cost and performance such as raw material and market stability. When the cost of total quality in forest harvesting is better documented, incentives can be applied to achieve those goals.

Production quotas and adverse weather are considered to have the most impact on Southern logging operations. The two are closely related, and interact directly - as weather delays increase quota delays tend to decrease. Only detailed daily information concerning the operating environment can provide sufficient understanding of these interactions. If the common hypothesis that the wood harvesting force has been overbuilt to allow for a safety margin in case of prolonged adverse weather is true, there is room for improvement. Crisis situations may only arise infrequently but it usually result in the addition of extra capacity that is then carried for prolonged periods. What weather does not claim from the extra capacity, limiting quota will. Reduced wood orders become the only available mechanism for capacity reduction.

Determining if excess capacity exists is the first step in solving what may be a major problem. Wood supply systems are extremely complex because of the number and variety of players; legal restrictions on competition and cooperation; diversity of goals among mill management, procurement organizations, chip suppliers, logging contractors, landowners, and regulatory agencies.

Study objectives

This project validates and extends Laestadius' (1990) and Loving's (1991) findings by surveying a selected group of logging contractors to determine true production capability and to document forces that cause variation from that capacity.

This research focused on the capacity of independent mechanized contractors operating in the Coastal Plain, Piedmont, and southern Appalachian regions of the Southeastern United States. General objectives were to:

1) Verify capacity utilization ratio of southern independent contractors obtained in previous studies.
2) Relate production capacity levels to geographic, climatic, and economic conditions.
3) Compare the purchasing company's estimate of available production capacity with those of the contractor force.
4) Explore the effects of procurement philosophies[1], number of markets, and weather patterns on capacity utilization.

[1] Two wood procurement philosophies are represented in this research: direct wood purchase, and indirect purchase.

CHAPTER 2. LITERATURE REVIEW

The southern wood-supply system inventories capacity to keep a low inventory of wood. The Swedish wood-supply system inventories wood to keep a low inventory of capacity.

Laestadius, 1990

The costs of excess inventory are well documented, the cost of excess capacity is not.

Loving, 1991

The last comprehensive look at the southern wood supply system was by the Battelle Institute in the early 1960's (Hamilton et al, 1961). Battelle investigated the factors affecting pulpwood production costs and technology. Among other conclusions, the negative impact of rain on productivity was identified and quantified. It is not the objective of this project to parallel Battelle's work; the region, the industry and analytical science has changed since then. The project is intended to be an update on managerial and environmental factors affecting production.

The Isoquant Graph

Projects to gather information on the actual state of the southern wood-supply system have recently been conducted at Virginia Tech by the Industrial Forestry Operations Research Cooperative. Laestadius (1990) used a microeconomic tool, the isoquant graph, to illustrate the difference between Sweden and the southern United State in regard to inventory. A wood-supply system may opt for various combinations of unutilized wood inventory and harvesting capacity to deliver wood to the mill digester for the same cost (any point on the isoquant curve) (Figure 2.1).

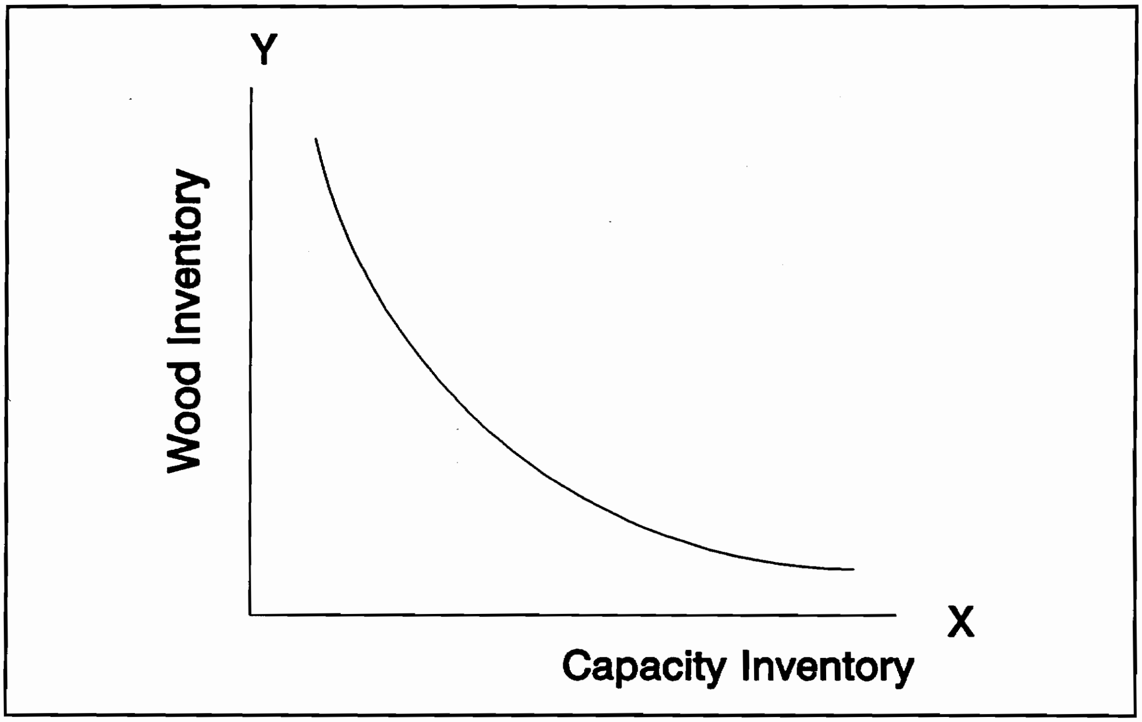

Figure 2.1. An isoquant curve; the same wood supplied using different inventory levels in the mill yard (round-wood and chips) or in the forest (loggers).

Laestadius (1990, p.116) best delineated how each wood-supply system operates:

> "A mirror-image bias exists: the southern system emphasizes the measurement and minimization of wood inventory cost, while the Swedish system prioritizes the measurement and minimization of idle-capacity cost".

Depending on climate, available work force, managerial goals, natural resources, and equipment spread, each procurement organization will find its own optimum combination along a given cost curve. Southern procurement organizations own the inventoried wood and are held accountable for it; on the other hand, independent contractors own the production equipment and must pay for idle capacity. Idle capacity is external to the procurement organization. This could explain the difficulty of evaluating real production cost. Laestadius believed that both the Southern and the Swedish wood-supply system are producing at equilibrium points on the isoquant map that is far from optimum. The possibility of reducing idle capacity deserves consideration.

The Cost of Idle Capacity

A complete study of logging cost components was needed to investigate the cost of idle capacity. Loving (1991) gathered financial information for a better understanding of expense type and timing which confronted mechanized independent loggers. The study also facilitated understanding of the relationship between a logger's profitability, and the procurement philosophies and strategies of the purchasing organization.

A logger facing high fixed costs, mainly on equipment, because of idle capacity has no other choice than to account for and include the cost of that unproductive capability when negotiating a contract price. As a result, part of the cost due to idle capacity returns to the procurement organization that fixes the production quota. Loving (1991, p.130) verbalized this idea:

> "Therefore, the cost of excess logging capacity is passed from the company to the independent contractor in the short term. But the wood consumer ultimately pays for the cost of logging capacity in ways which are not easily accounted".

It is arguable that all the cost of excess capacity returns to the wood consumer. Ultimately everyone in the system is believed to absorb part of the cost. The ways in which these costs are distributed are not always obvious or even traceable in dollars.

A contractor attempting to reduce costs by running older, somewhat unreliable equipment is less likely to be able to respond to poor weather conditions or quick changes in wood orders. An A.P.A. study in the late 1960's[1] correlated high production to low labor turnover, low absenteeism, and low accident rate (A.P.A. 1968). Two decades later, it is interesting to test the correlation of high-production contractors with low negative impact on the environment and safe trucking practices. In a study aimed at identifying managerial and operational characteristics of "safety successful" logging contractors, Sluss (1992) linked high production rates to lower accident frequencies:

> "The contractors were similar in terms of harvesting equipment and crew size, but were able to produce at higher rates while maintaining lower accident frequencies."

Crew stability and experience were suspected of having the most influence on accident severity and frequency.

Next to in-woods operations, trucking is a major safety concern for the forest industry. Trucking is affected by variability in production: during high demand anything that will run and pass inspection will be pressed into service. Contractors will be hesitant to invest in new equipment without a foreseeable long term demand for the extra capacity. Quality trucking contractors are fully committed. The additional demand can only be met by running old equipment or relying on less reliable trucking contractors. Truck accidents often involve the general public, therefore, any unsafe action may have tremendous consequences. For many communities the most visible sign of forest harvesting is the numerous log trucks using the county roads. Green and Jackson (1992) found that mechanical failures were a contributing factor in 10% of accidents involving log trucks and in 8.8% of accidents involving logging tractor-trailers, as compare to only 3.2% for other heavy trucks. Maintaining good equipment helps production and contributes to a positive community perception of the logging industry. Professional loggers should take special care of their hauling equipment as they are the most visible entity of their enterprise, "trucks are your (the loggers') ambassadors to the public" (Stuart 1992).

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[1]The project was designed to create an objective evaluation program to detect reliable loggers ready to invest in high-production machinery and capable of managing them.

Faced with increased pressure from regulating agencies, the forest industry needs community support. Ronan et al. (1970) evaluated attitudes in a rural Georgia county towards wood harvesting and found that community leaders recognized the importance of forest operations to the local economy but did not recognize logging as one of the more desirable occupation. Despite mechanization and obvious working condition improvements[2] logging is still not considered "glamorous". Public recognition of logging contractors as skilled business people with well developed safety and environmental awareness may be a way to modify this unfavorable perception. A suggested action from the 1970 study was to emphasize to the public that successful loggers need to be skilled entrepreneurs. The industry should be able to state that the producer follows practices which have been identified and defined by sound research techniques as being most appropriate for the stand and site.

To encourage the contractor to purchase new, high-performance equipment, procurement organizations might have to relax quotas to allow loggers to take full advantage of the possible increased production[3] (Green and McNeel, 1991). When mills reduce wood deliveries, the only alternative left for loggers is to decrease production. As expressed by McNeel (1988):

> "These limits on wood production, usually termed quotas, reduce the cash flow from an operation, increase the 'per unit' cost of operating, and force the logger to operate at a reduced capacity. When the logging system consistently works below capacity, cash flow begins to affect equipment purchase decisions. The logger remains in a state of flux, producing at an unprofitable level and unable to replace worn-out equipment".

In its current form, the southern wood supply system imposes restrictions on technical change. Elasticity, or the ability to respond and adapt to surge situations, has been highly valued, and influenced the development of new processes. Machinery or technology that requires high equipment utilization

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[2]Labor can now retire as forest worker.

[3] To illustrate this the authors mention the incapacity of many loggers to benefit from the higher production rates of sawheads due to production quotas.

ratio by mean of system balancing can be economically disadvantaged when harvesting in the South. An otherwise adequately designed machine to perform in other regions of the world may never overcome the low quota periods, or as Stephenson (1987) put it:

> "Concepts which simply required a dependable productive 40 hours work week to control fixed cost were at a disadvantage under production quotas."

The actual harvesting system in the South is the product of a long adaptation to its environment. Until foreign equipment manufacturers understand the dynamics of this system, introduction of unsuited machines will continue to fail.

Stuart et al. (1992) used production data collected from a sample of southern loggers and assumed that the average weekly production was the level at which the producer covered all expenses and realized a minimum return on equity. they estimated that many loggers were producing below their break-even level for prolonged periods of time[4]. Thus, it may be hypothesized that the state of flux or unprofitable production level mentioned by McNeel (1988) occurs on a regular basis.

To survive in such an unpredictable and changing business environment, loggers must be able to adapt quickly to any change in the system at the expense of long- or even mid-term planning. As Haggard (1981) mentioned, "A contractor should be expected to employ normal strategies such as reserving easily logged tracts for winter harvesting, and saving timber close to access roads to offset the effects of weather". In their business management handbook for eastern timber harvesting, Vodak et al. (p.166, 1983) recommend the following: "purchase tracts far enough in advance to prevent interruptions in production allow for a greater flexibility when moving from one location to another." While this relates

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[4]More details on this analysis are provided in Chapter 5.

to common sense in harvesting planning, contractors relying on others to purchase their lumber often have no idea where the next tract is located until the very last day of production.

Production Elasticity

The capability of a logger to adapt quickly to a given situation is closely related to production elasticity. In classical microeconomic theory, elasticity is a measure of sensitivity of one variable to changes in another (Pindyck and Rubinfeld, 1989). Applied to forestry, Loving (1991) defined elasticity as a contractor's capacity to vary weekly production to meet shifts in market demands without adding or idling machines or labor. A contractor may be either upwardly or downwardly elastic. A logger that cannot significantly depart from the system's median production level is said to be inelastic. An equipment-intensive logger with new machinery will be upwardly elastic. Such a contractor can easily increase production in periods of high demand. However, this type of logger has less flexibility to get through a long period of low wood orders. A labor-intensive contractor, one who runs older, paid-off equipment, will usually be downwardly elastic. This type of organization has difficulty handling a major increase in production rate but has the ability to survive longer during periods of low wood orders. Procurement organizations need a mixture of these two producers types (Stuart, 1992). Loving noted that, if an upwardly elastic system was favored during the 1960's and 1970's, it is now a different situation:

> "The rather flat conditions in the late 1980's and early 1990's seem to be favoring those which are downwardly elastic".

Loving also explored the cost to the contractor of production quotas imposed by the mill to stabilize woodyard inventory at a low-level. The analysis indicated that wood procurement organizations were paying for low inventories in the woodyard by indirectly paying for loggers' elasticity through higher contract prices. The cost of elasticity may be several times the cost of carrying slightly larger inventories. While the cost of elasticity is difficult to assess, Loving estimated in a case study that increasing the capacity utilization of a logging contractor from 51% to 61%, could increase the logger's revenue by $109,565, saving the purchaser $54,787. The study assumed an initial annual production level of 24,214 cords, and revenues in 1989 dollars.

Summary

The prevailing wood supply system in the South is the result of a long adaption to the physical environment, social characteristics of the inhabitants, and the long term business relationships between producers and buyers. The legal requirements of separation between the independent contractor and the contracting organization may make it difficult for each party to understand the other's requirements. The distance between the wood consuming industry and the forest worker is not measurable in miles only. The purchaser and the supplier do not always share a common understanding of the wood supply system's capacity and variability. Southern loggers are expected to vary production levels according to seasonal weather patterns, demand fluctuations for wood and paper products, and natural catastrophes. This study documented the importance of these factors. Like a living organism, the system's adaptation to a perturbation is difficult to predict. Base line observations collected experimentally will serve to build a holistic analysis of the wood supply system.

CHAPTER 3. METHODS AND PROCEDURES

Five companies cooperated in this study. The independent contractors chosen represented a cross-section of those suppliers that the companies' procurement group regarded as dependable, with good reputations among landowners, labor, and peers. It was suggested to the cooperators that loggers with good bookkeeping habits and an interest in innovation would be desirable. Over 25 loggers' names were forwarded for consideration. A group of 24 agreed to cooperate, thirteen were involved in Loving's study (1991), and all but one of the previous participants who where approached accepted the opportunity to participate in the second phase of the project.

Data Collection

The loggers were asked to record daily information about their production and general operation. A tally card (a copy is provided in appendix A) was designed to be simple to complete while still covering all vital aspects of production. The qualitative part of the logger's card involved a brief description of weather conditions and other factors that may have affected their daily productivity. The quantitative information included the logger's estimate of the maximum production that could be achieved if no external or internal factors were to slow production. Stand quality, ground roughness, and distance to market were regarded as unchangeable tract characteristics, consequently, loggers were instructed to consider these in their estimate. This value was then recognized has the logger's capacity. Contractors were asked to record their actual daily production. If actual and estimated production were different, explanations or reasons for the difference were requested. Reasons or causes were categorized on the tally form as quota, weather, mechanical problems, labor problems, and "other". Space was allocated on the back side of the form for comments and detailed explanation. Each form was designed for one six day work week. Pre-stamped envelopes were distributed for the return of completed cards.

Data were entered on a spreadsheet (Boreland 1992) as received. Maximum and actual production were compared to obtain a ratio. Causes of lost production were categorized as:

1) Quota: Daily production lost due to quota imposed by the wood-supply organization;

2) Weather: Daily production lost due to adverse weather conditions. Direct causes (rain, excessive temperature) or indirect (road conditions);

3) Moving: Production lost to moving equipment from one tract to another, or to moving the deck within the tract;

4) Mechanical: Production lost due to equipment problems;

5) Other: All other factors affecting production. In the eventuality of this category being too frequent, details were requested.

Where applicable, the procurement forester working with the contractor was asked to provide an estimate of the logger's capacity. Like the loggers, foresters were required to give an estimate of the effect of each external factor affecting production. A weekly tally sheet (Appendix B) was made available to the forester. Information collected were compared with the loggers' figures to verify accuracy or credibility of the estimates. Potential differences between loggers' and foresters' estimates and between each estimate and the actual production was tested using the non-parametric Wilcoxon's rank sum test (Hollander 1973).

A monthly newsletter (Appendix C) was used to maintain continuous communication with all study cooperators. The newsletter's objectives were to return information on a regular basis to maintain interest in the study, provide loggers with a constant supply of cards and pre-stamped envelopes, and remind all participants to return completed cards and tally sheets. Production graphs of all loggers for which production figures had been forwarded to the university were included in the newsletter.

The procurement forester's weekly estimate of the logger's productive capacity was included in the spreadsheet, and compared with the logger's estimate and actual production. This data organization provided the flexibility necessary to identify a change in production pattern as a response to external stimuli.

Interviews were conducted with the loggers. Using Loving's format (Loving 1991), questions were designed to learn more about loggers' view on the wood business, quota situation, safety, BMP's, equipment strategy, and other business-related questions. A cost analysis was performed for individuals who provided accounting records.

Daily rainfall information was obtained from the National Oceanic and Atmospheric Administration (NOAA) to document the impact of adverse weather on logging operations. Total monthly rainfall was compared with historic averages. Monthly production lost to rain was graphed against total precipitation received.

Analytical Tools

Down time was monitored to verify previous research on capacity utilization (Laestadius 1992, Loving 1991, Hamilton et al. 1961). A utilization ratio was computed for each contractor studied by dividing estimated maximum production by actual production as obtained by field observations. A bar chart was produced to illustrate the computed values.

All causes contributing to differences were evaluated and expressed in percentage. Pie charts provided an effective way to show the importance of each of the factors in relation to the others.

A run chart, often called Shewhart chart (Adam and Ebert 1989), proved to be an useful tool to analyze daily variability of the loggers' production and departures from estimated maximum capacity. Run charts are also useful to detect broad production patterns.

Cusum charts, control charts (Duncan 1986), cumulative probability distributions, and various histograms were also produced. More details on each of these charts will be given as they are used in following chapters.

Expected Outcomes

The capacity utilizations of loggers were compared. Forces affecting production were identified and quantified. Approaches for increasing the wood supply system efficiency by increasing the utilization ratio were identified. Unproductive practices were highlighted and alternatives suggested. Suggestions were made concerning ways to stabilize week to week production variation while preserving desirable positive or negative elasticity.

Case studies were developed for cooperators who submitted complete financial records and were used to prepare an economic model for various levels of capacity utilization. The model was used to partially define the cost of idle capacity over a range of production levels.

CHAPTER 4. PRODUCTION CAPACITY

"For every complex question there is a simple answer,

and it is wrong."

H.L. Mencken

Introduction

Production capacity, the maximum amount of output that can be produced, of an active logging force is difficult to compute or evaluate. Changes, most of them minor, some more significant, are always taking place in the logging industry. In the era of company crews, capacity utilization was an important management tool to evaluate the overall system performance. When logging operations shifted to independent contractors, the producer and the buyer were legally separated. The wood purchasing organization was restricted to having concern for, but could take no interest in the producer's economic survival. Wood was sometimes taken from every producer that could deliver it. As new technological developments increased the productivity of mechanized loggers, capacity started to overbuild. Several southern companies are using production quotas to control the flow of wood going through the mill gate (Laestadius 1990). Under such a system, most loggers have their wood deliveries significantly reduced. Quotas allow companies to influence business decisions of a logging contractor. These contractors need to plan for the recurrence of low quota period, wet weather, and demand surges. Wet weather and quotas result in lost revenues, which can only be compensated for by over production during surge periods. Facing these stochastic factors, loggers will frequently carry extra capacity to capitalize on favorable market conditions.

Thus, extra capacity varies annually for a single producer, as well as between producers within the same procurement area. Traditional sources of variability are weather (rain, heat), societal traditions (holidays, hunting season), economic (movement of contractors in and out), and mill consumption. Long-term contracts, chipmills, sawmills, and exports are some of contemporary sources of variability affecting the wood supply system.

Loving (1991) reported an overall logging capacity utilization of 51 to 59%. Capacity utilization was slightly higher in the Coastal Plain regions (59-67%), lower in the mountains (40-48%), and about the norm in the Piedmont (53-59%). The results were obtained by comparing the logger's highest sustainable weekly production recorded[1] in the past years with their production at the time of the study.

The utilization ratio computed in the present study is not based on the historical highest production level, but rather on the logger's and procurement forester's daily estimates of the maximum capacity. The maximum capacity level was expected to increase for favorable tracts and decrease for tracts with unfavorable characteristics. The ratio obtained with this approach (relying on loggers' and foresters' estimates and taking into account tract characteristics as well as hauling distances) was expected to be higher than one obtained by comparing the average production level with the past best sustainable production. A reliable estimate of the loggers' maximum capacity will be indispensable to further analysis of the wood supply system.

System utilization is a composite measure affected by machine reliability, job organization, and the working environment (Stuart 1990). It is culturally based, reflects the loggers' and procurement

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[1]Loving was not interested in the "heroic" production level, one obtained in a 16 hour day, but rather in the production level loggers could maintain for several weeks given the opportunity.

organizations' business philosophies, and it is often evaluated by "rules of thumb". Given these premises, trends can be identifiable only by studying a large number of loggers. The 23 harvesting contractors participating in the study allow for the identification of such trends.

Several alternative methodologies can be used to evaluate production capacity. The most appropriate for this problem are the mechanistic and the organic.

The Mechanistic Approach to System Evaluation

In the mechanistic approach the system is viewed as a linear sequence of machines. Working together, they transform the initial material into the intended state (Laestadius 1990). Under this methodology, the system is divided into its elements, and the performance of individual elements are studied in a wide range of working conditions. Then, outputs for individual components can be predicted and linked through simple addition, allowing simulation or other methodology to form or project a system output. When applied to a production system, the resulting capacity utilization is a function of each machine availability and performance. The method requires a certain rigidity or stability.

Machine performance is usually predicted using averages of parameters such as stand density, skidding distance, site trafficability, and so forth. Predicted performance derived from time studies should only be used when the same sequence of activities occur under the same conditions as when the data were collected. Otherwise, in the best case, results are only good approximations. These projections are often far from the observed values. Additional assumptions and manipulations are necessary to balance machines. The mechanistic approach to system evaluation usually involves taking the production of the most limiting element as production for the entire system or make the operation so "cold" that integration into a functional system is virtually meaningless. This approach has commonly been applied to large harvesting organizations such as company organization and environments where large machine inventories can be maintained.

The Organic Approach to System Evaluation

Like a living organism, the Southern wood supply system adapts to its environment and reacts to changes in ways that are not always easily predictable. These changes are numerous since operations are contractor controlled and take place over a large area composed of diverse logging conditions. A change in one input will trigger a series of actions that may destabilize the system. The instability may cause another group of participants to take an action which may restore stability in some parts of the system but increase instability in others. A cause and effect relationship is not always obvious.

In the Southeast, the typical harvesting system is usually composed of all operations necessary to get wood from stump to mill. Capacity utilization of the system is not as affected by individual machine availability as by weather condition, market demand, number of competing and cooperating producers, and road quality. All of these factors may vary greatly within a whole procurement area. Variation in individual machine availability is usually overcome by the use of spare machine, redeployment of other equipment or changing tracts. Loggers can usually adapt to a wide range of stand composition and tract quality, as well as a reasonable hauling distance variations. The organic approach to system evaluation was retained for this analysis because the study was designed to evaluate how the system and its components reacted to forces affecting utilization, rather than predict a performance level.

An attempt to define a single, fixed, level of production capacity may ignore both the system's variability and the sources of that variation. It may be better to define the range of "maximum production capacity" levels for a given logging force given the needs of the procurement organization. Loggers with production elasticity have the capacity to vary their capacity according to market demand and weather conditions. In the simplest case, these contractors have two maximum production levels: 1) a long term sustainable level, i.e., months, 2) a short term sustainable level to be used in crisis situation, i.e., weeks or days. These two levels should be identified for as many loggers as possible in a procurement organization and used in appropriate circumstances to optimize the purchaser benefits and the suppliers revenue. Ignorance of these two levels may lead to unnecessary use of "outside" suppliers in high demand periods, and may plunge some contractors into critical financial situations in periods of low wood order.

This study focused on developing a technique to define these levels for a variety of contractors. Data collection focused on system rather than machine performance. Special sources of variability were identified and investigated. A general understanding of the causes of variability in wood flow and the nature and effect of tactics employed by loggers and procurement personnel to accommodate this variability is thought to yield more information on the southern wood supply system than a complex regression function could.

Methods

Loggers were asked to estimate their daily capacity level. These estimates incorporated stand quality and composition, site trafficability, equipment available, and the usual labor force. Capacity was expected to change between tracts and within a tract as skidding distances increased or stand composition changed. Friday's estimated capacity was often lower than other days because time was reserved for maintenance.

Saturdays were considered as a bonus day. Most crews will work on any Saturday they are allowed; this extra day is used to recoup time lost to rain or for other reasons. If an attempt was made to produce, the values were added to the data base. If the crew was not called out and no wood was produced, the whole day was discarded and this "unutilized capacity" was not taken into account in the analysis.

The analysis depended on the logger's estimates of their capacity. Overestimated maximum production could seriously bias the results. To verify the logger's estimates, the procurement forester working with the contractor was asked to provide a weekly evaluation of the logger's capacity. A distribution-free Wilcoxon signed rank test was performed to detect any difference between the logger's and the forester's estimates. The null hypothesis was that the logger's estimates were smaller than or equal to the forester's estimates (H_0: Logger < = Forester). The alternate hypothesis was that the logger's estimates were larger than the forester's indicates against an estimation bias (H_1: Logger > Forester). The null hypothesis was rejected for seven of the thirteen contractors ($\alpha = 0.2$). The fact that some logger's estimates tended to be higher than the forester's did not necessarily imply an over estimation on their part. Rather, it may reflect a difference of opinion or reveal that there was no common understanding of the logger's expected capacity. For example, in some locations where loggers were strictly regulated by wood order, any production over the long term wood order was considered by some procurement foresters as being in excess of normal capacity level.

A second investigation was performed to check on the logger's estimate by computing the ratio of the days the logger met or exceeded the estimated capacity by the total days worked. If the contractor met or exceeded his estimated maximum capacity 1/3 or more of the worked days, the estimates were to be considered valid. Loggers proved to have reasonable estimates. The results[2] of the Wilcoxon signed

[2]All loggers did not have a procurement forester to provide a weekly estimate.

rank test for a significant difference between the estimates, and the ratio of days with production at the maximum level (when necessary) are provided in table 4.1. An example of close agreement between the logger's and the forester's estimate is provided in Figure 4.1; There are weeks for which the logger's estimates were higher than the forester's and weeks for which the opposite is true. In both cases, the two estimates are not more than 125 tons (five truck loads) apart. Alternatively, an example of a disagreement between the two estimates may be seen in figure 4.2. This logger's estimates were almost always higher than the forester's. The logger's values seem reasonable since estimated capacity was met or exceeded 36% of the worked days. In this case it was found that the forester based the estimate of maximum capacity on the average wood order regardless of tract characteristics.

Table 4.1. Wilcoxon Signed Rank to compare loggers' and foresters' estimates of maximum capacity.

Loggers	H_o:Logger <= Forester p-value	Ratio Days @ Max/All days
101	0.36	n/a
102	0.23	n/a
104	0.95	n/a
105	< 0.01	0.34
202	< 0.01	0.44
203	0.01	0.43
206	< 0.01	0.60
301	0.37	n/a
302	< 0.01	0.57
303	0.97	n/a
305	0.35	n/a
306	0.01	0.53
403	< 0.01	0.36
404	< 0.01	0.55

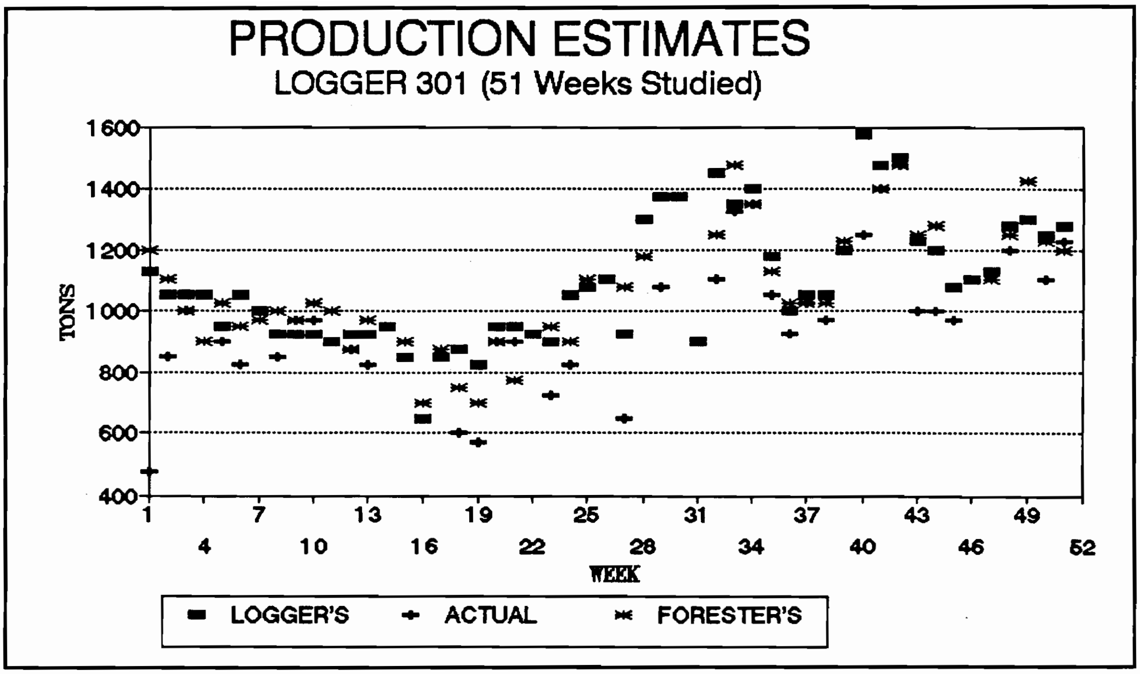

Figure 4.1. Comparison between logger 301's and the procurement forester's estimates.

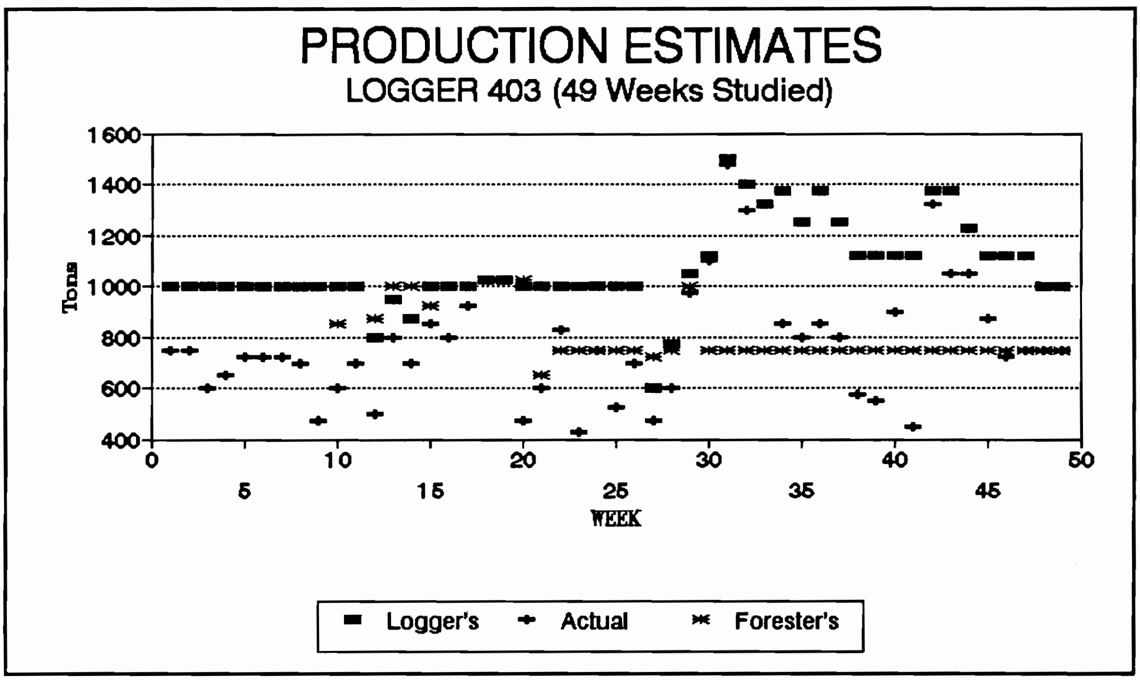

Figure 4.2. Comparison between logger 403's and the procurement forester's estimates.

Results

Utilization Ratio

Greater variation in production capacity was observed for loggers who ran two crews and switched equipment between them. Equipment was usually moved as a temporary measure to adapt to specific changes in market or tract. The utilization ratio achieved the intended objective of measuring capacity utilized because capacity increases were matched with increases in achieved production. Loggers with less equipment flexibility showed less variability in their estimates. For these loggers, variations were most often explained by tract characteristics.

Loggers' capacity utilization ratio.

The capacity utilization ratios for the 22 loggers studied is shown in Figure 4.3. The highest ratio is 91% for logger 301 and the lowest is 54% for logger 401. A box and whiskers plot of the population indicate a symmetric distribution around a median value of 70%. Two moderate outliers was detected in the upper range.

Capacity utilization per region

Loggers were scattered in five physiographic regions: Coastal Plain, Piedmont, Sand Hills, Appalachian Valleys and Ridges, and Sand Mountain. The logger from the Sand Hills was included in the Piedmont and the one from Sand Mountain was included with the Appalachian. The average and median ratio for each of the three regions is displayed in Figure 4.4.

The Appalachian loggers had the lowest overall average utilization with a median ratio of 63%. Coastal Plain loggers had an overall capacity utilization of 70%. Piedmont loggers had the highest overall capacity utilization. The median was 81% with a moderate outlier at 55%[3]. All three distributions were slightly skewed to the left.

A Wilcoxon rank sum test was used to test for significant regional differences ($\alpha = 0.1$). Utilization for the Piedmont loggers was found to be significantly greater than that of the Coastal Plain (p-value = 0.065) and Appalachian loggers (p-value = 0.045). Coastal Plain utilization was significantly higher than the Appalachian crews as well (p-value < 0.001).

[3]This outlying logger operated in a very mountainous tract for several months on the Piedmont's northern edge.

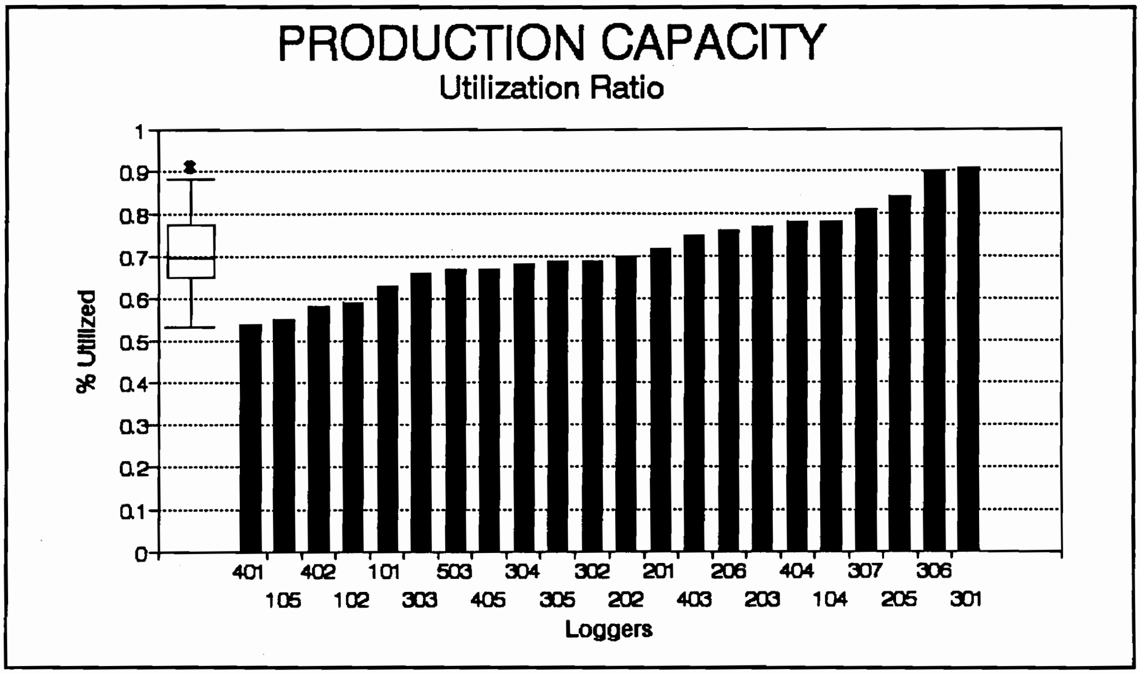

Figure 4.3. Capacity utilization ratios for all loggers studied.

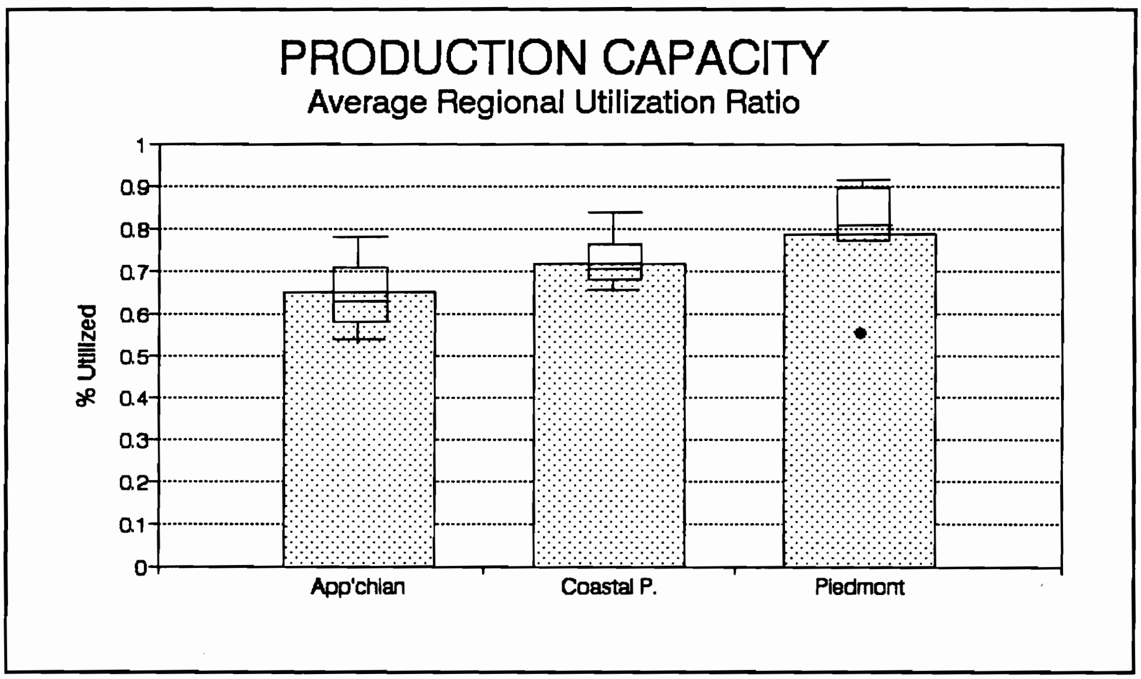

Figure 4.4. Capacity utilization per region.

Wood procurement approach: Direct purchase versus Brokers.

The level of capacity utilization for loggers on the basis of the type of wood procurement organization is shown in Figure 4.5. Similar levels of performance were found for both approaches with the exception that none in the dealer group were found to have an utilization ratio lower than 67%. A two sided Wilcoxon rank sum test failed to detect a significant difference between the two groups (p-value = 0.32). The small number of loggers relying on dealers precluded definite conclusions.

Number of delivery points

It was hypothesized that serving a number of delivery points increases market opportunities and helps increase or stabilize capacity utilization. The capacity utilization ratio of loggers sorted by the average number of markets they delivered to every week is shown in Figure 4.6. The highest median value (highest % of capacity utilized) was found for the group of loggers with three or more delivery points. Results from a Wilcoxon rank sum test indicate significantly ($\alpha = 0.1$) smaller utilization ratios for the loggers with less than two weekly markets compared with those having two or more ($p = < 0.001$). Loggers with three or more weekly markets also had a significantly higher utilization than loggers with two markets ($p = 0.036$). All loggers involved in the study were delivering most of their production to one regular purchaser. Only a constant demand from the main consumer seemed to guarantee high utilization level. Secondary consumers may simply provide the additional markets necessary to absorb the five to ten percent additional capacity that makes the difference between a tolerable and a great week.

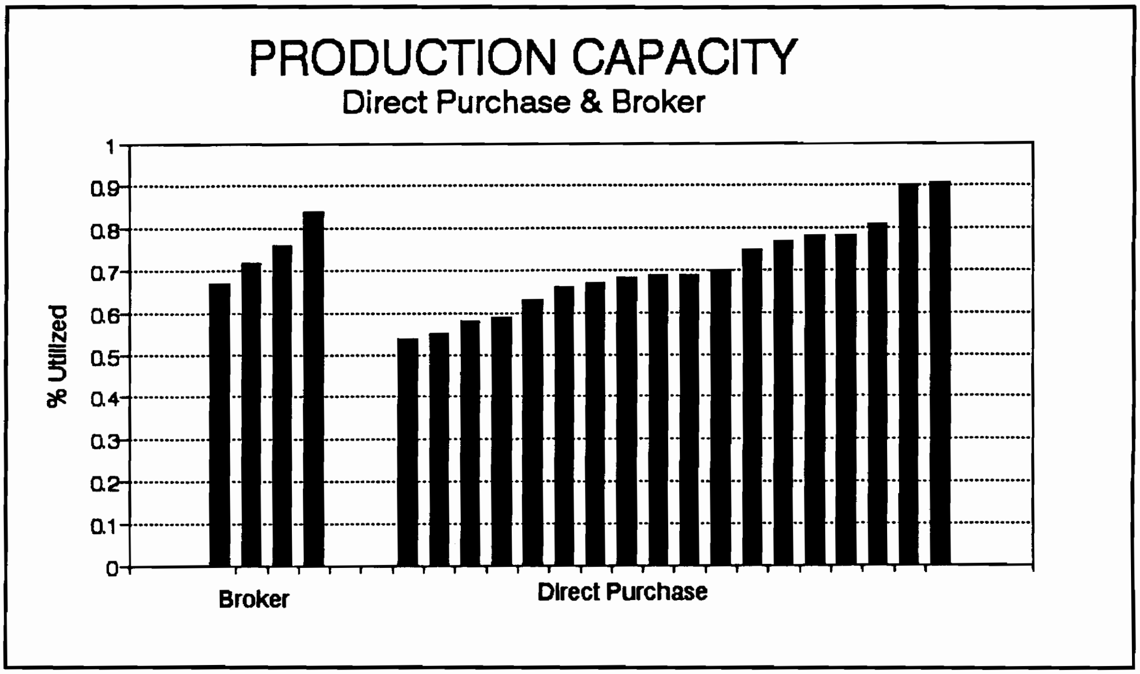

Figure 4.5. Wood procurement approach: Direct purchase and broker.

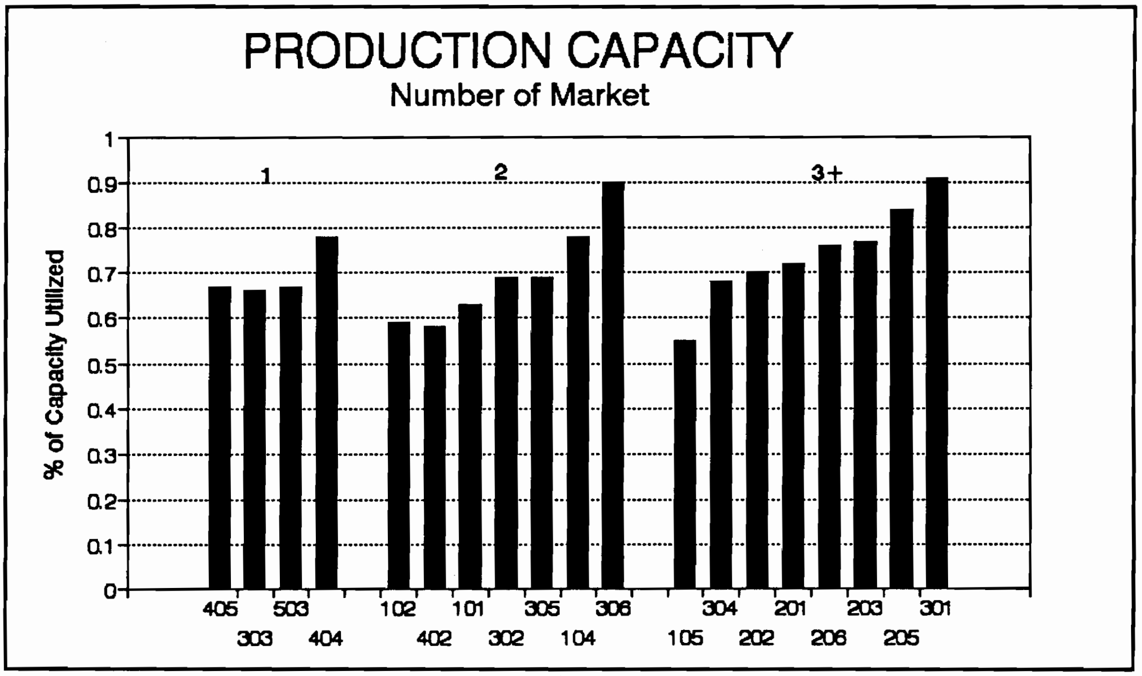

Figure 4.6. Average weekly number of delivery points.

Causes of Lost Production

Five major causes for lost production were identified: Weather, quota, mechanical breakdown, moving, and other[4]. Weather had the greatest impact during the study. Quotas came second.

Weather

Weather was, without doubt, the most significant cause of lost production during this study. Regulation aimed at maintaining water quality (BMP's) may worsen the impact of adverse weather on production by forcing loggers into idleness more frequently. The impact of adverse weather on logging activities is discussed in chapter 6.

Weather and quotas are closely linked. Wood supply organizations often justify overcapacity in logging by the unpredictability of wet and dry periods. In its actual state the system will over produce in absence of adverse weather if no restrictions are imposed, quotas are used to reduce the system productivity until increased capacity is needed. Loggers may stay on quotas for long periods of time during a drought year. In the eventuality of frequent rainfalls production is reduced and quotas are not needed. For both cases loggers will maintain utilization below their capacity.

Quota

Quotas imposed by the procurement organization determine the maximum quantity of wood to be purchased from a logger during a given period of time. When quotas are imposed, production is reduced to a fraction of the maximum capacity. Contractors are particularly sensitive to quotas and the way quotas are assigned. Successful contractors have the impression that their allowable production

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[4]The "Other" category includes miscellaneous downtime such as labor problem, long unloading delays at the delivery point, and traffic accident.

levels are lowered to subsidize the less efficient loggers. This is especially true if the quota for the less productive contractors represent a higher percentage of their capacity. A logger reported that his production was cut from 75 loads to 12, while someone else in the same area was cut from 40 to 30. This logger stated: "*We can't get to a perfect (quota) system but if at least everybody were to be affected the same way, then the best would not pay for the others.*" There may have been good and rational reasons for the wood supply organization to impose these different quota levels that had nothing to do with subsidies. The key features were that the contractor did not understand the differential, and the wood procurement organization felt it was unnecessary to explain their activities. This example of quota allocation does not reflect all situations.

There are as many methods for allocating quota as there are companies. Some companies use deliveries during the worst of the winter months as a basis. This strategy rewards those who produce under adverse conditions by allowing them to produce more during favorable conditions. A second strategy is to reduce everyone's production by a fixed percentage. Although this seems equitable, it may in fact favor downwardly elastic contractors. Those loggers with lower fixed payments are better prepared to suffer cutbacks. Other quota strategies may reward contractors who purchase special equipment such as a tracked feller buncher or wide tired skidder. A procurement organization may chose to favor contractors who agree to perform special services such as thinning, hardwood logging or salvage operations. Other strategies may favor wood which arrives with no procurement effort (gatewood). Some quota systems restrict all contractors to the same number of loads per week, others take wood from all producers until the yard is full and then all wood purchases stop.

Quotas have a perverse effect on loggers who rely on contract hauling. The trucking sub-contractors specialize operations to match the production level most regularly demanded by the purchasing mill; they do not want to absorb the variations. Loggers find plenty of available trucks when they are on quota, and face a truck shortage when demand is high. It is difficult for these loggers to be upwardly elastic and to capitalize on periods of high demand to increase their cash flow. Therefore, they must have the equipment to closely match their median production level. If this level is too low it becomes difficult for them to invest in equipment.

There is an important distinction between a quota and a wood order. While quotas are unpredictable in occurrence and may represent any fraction of a logger's capacity, wood orders are usually a guaranteed minimal volume to be purchased. Stable wood orders allow the loggers to plan for this minimum level of production. If the weekly wood order is not cumulative, i.e. what is lost one week cannot be make up by an increased wood order the following week, loggers will still need to carry considerable extra capacity to achieve high production levels when demand surges so they have the opportunity to at least average their long-term wood order. Low wood orders have similar negative effects as quotas in terms of capacity utilization.

One of the organizations cooperating in the study has taken measures to stabilize contractors' weekly production. Quotas are now uncommon because of the partnership relation that was established between suppliers and the purchaser. A logger, contracting with this company as a preferred supplier, reported that on some occasions extra capacity existed and stated: "*Sometime I could use one or two extra trucks, but then I'd be done too early with my yearly quota. I rather like working at a constant rate year round instead of being idle for two months.*"

Mechanical

Mechanical downtime also keeps loggers from achieving their full capacity utilization. The overall importance of this factor, compared to weather and quota, was found to be small for the group of contractors studied. Most loggers lost less than 2% of their capacity to mechanical problems. A significant amount of production lost due to mechanical reasons may indicate older and less reliable equipment. New equipment undergoing a shakedown or that is being utilized for a new application may also suffer considerable downtime. A logger who has constant losses due to mechanical reasons will likely have difficulty in maintaining high production during surges in demand.

The equipment developed for the southern industry has emphasized reliability and ease of maintenance and repair over sophistication. The common presence of multiple machines of the same type within the system and the retention of older machines as spares, also contributes to a reduction in down time losses.

Moving

Moving the equipment from one tract to another, especially if it is done during the work day, may result in significant losses. The production loss associated with moving is influenced by the distance between the tracts and the frequency of moves, which, in turn, is a function of tract size, road standards, and the contractor's production capacity. Moves triggered by adverse weather or changing wood orders are especially damaging because they are hard to plan for. Contractor 306[5] had high production losses due to moves but the losses were recovered by being able to resume production on an accessible tract. The number of moves each logger made during the study period are reported in table 4.2. The percentage of these moves justified by BMP's and weather is provided. The median percentage of moves motivated by weather and BMP's is 22%.

[5]See chapter 6.

Table 4.2. Total number of moves recorded and percentage due to weather or BMP's.

Logger's I.D	# of Moves (# of weeks studied)	Moves Due to Weather or BMP's	%
101	11 (53)	2	18
102	21 (54)	4	19
104	5 (25)	2	40
105	14 (48)	3	21
201	12 (49)	2	17
202	7 (50)	2	35
203	11 (51)	1	9
206	9 (30)	2	22
301	9 (54)	0	0
302	26 (43)	12	46
303	31 (53)	17	55
304	31 (51)	10	32
305	27 (47)	8	30
306	39 (39)	24	62
307	11 (47)	2	18
401	8 (51)	2	25
402	n/a	n/a	n/a
403	5 (43)	1	20
404	3 (35)	2	67
405	5 (24)	1	20
503	7 (13)	4	57

Other

Exceptional unloading delays at the mill, tract availability, and labor shortage constituted the most frequent delays and were classified under the "Other" category in the following analysis.

Geographic Differences

The importance of each of these factors was documented. Loggers were segregated by physiographic region to isolate the environmental influences on production capacity. The proportion of time lost was compared and the percent capacity lost to weather, quota, and other calculated (Figures 4.9, 4.10, and 4.11) to reduce the effect of differences in the businesses' production capacity.

Appalachian

Weather was the most important cause of lost production for the Appalachian loggers (Figure 4.7), although the impact varied greatly from contractor to contractor. Contractor 102 lost 27% of his capacity while 404 lost less than 5%. This region is the only one where all participating loggers were affected by quotas. At the beginning of the study, from June to September 1992, quotas accounted for almost all of the downtime. In the fall of 1992 and the winter of 1993, quota losses were replaced by rain, amplifying the earlier mentioned relationship of these two factors. As seasonal drying occurred most contractors were back on quotas by late spring of 1993.

Piedmont

Weather, again, was the major influence on capacity (Figure 4.8). The effect differed greatly between contractors. Only two loggers within the Piedmont region were affected by quotas and the effect was minimal. Again, quotas were imposed in the dry summer of 1992, removed during the wet winter conditions, and reinstalled in the drier spring of 1993. For all these loggers weather was the major obstacle to higher utilization. Logger 306 had few losses due to rain. This logger's geographic location and strategic planning (more details in chapter 6) explain part of this performance.

Coastal Plain

The largest number of contractors involved in the study are operating in the Coastal Plain. As shown in Figure 4.9, weather was the most limiting factor during the study. Median losses to weather were 23% with a range of 15 to 30%. Effects of weather were more consistent than in previous two regions, perhaps because topography of the area is so uniform that it is difficult to move away from weather effects. Some loggers reported production lost to quotas early in the study, but this quickly disappeared as abundant rainfall modified the need to impose production quotas.

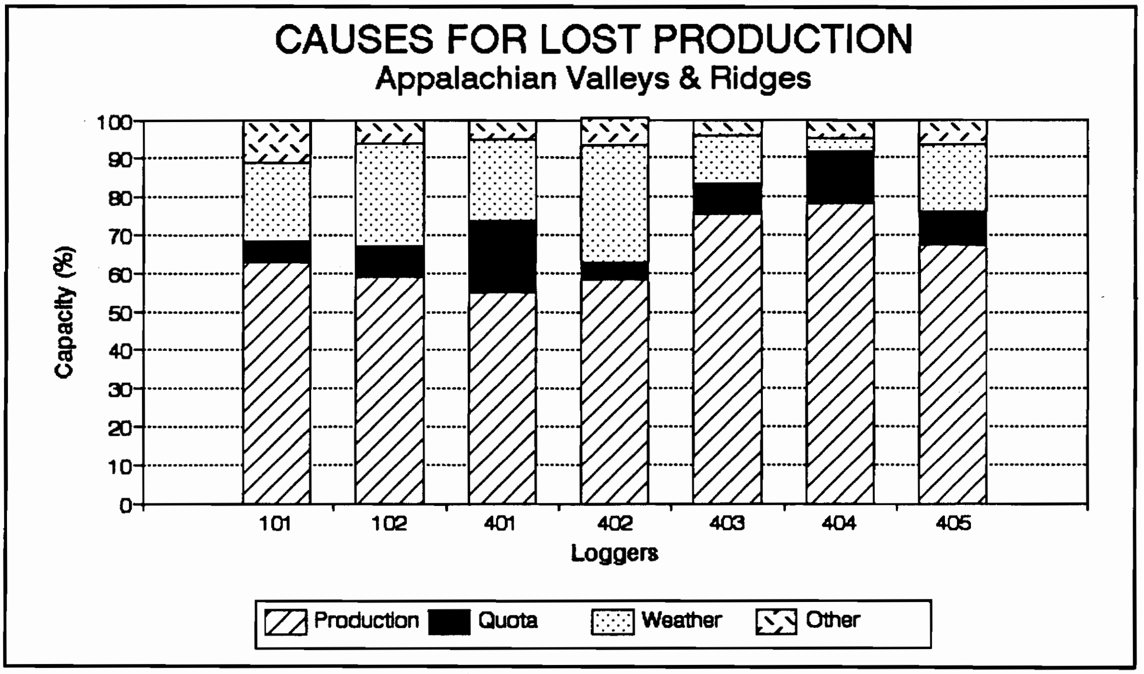

Figure 4.7. Causes for lost production in the Appalachian valleys and ridges.

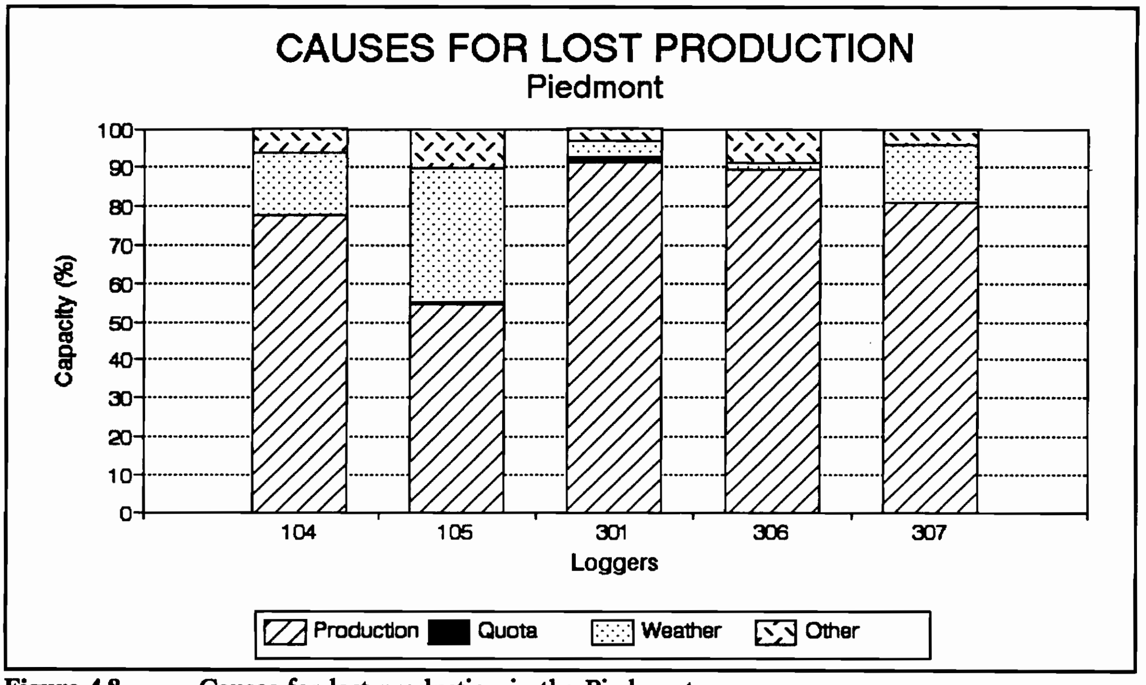

Figure 4.8. Causes for lost production in the Piedmont.

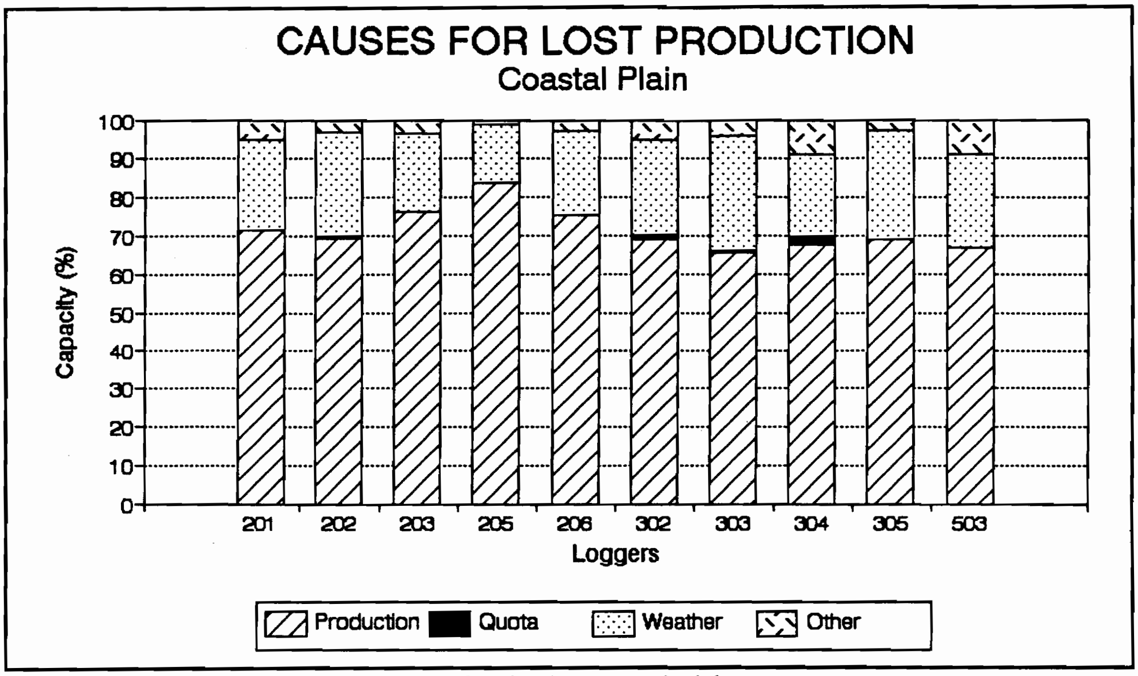

Figure 4.9. Causes for lost production in the Coastal Plain.

Total Cost of Excess Capacity

Wood supply organizations frequently justify keeping more contractors than necessary on the basis that the additional capacity may be needed if the weather conditions cause wood shortages. Contractors justify keeping more equipment than their wood order justifies because they generate their profits during, and immediately after periods of bad weather (by being upwardly elastic). Keeping extra capacity is analogous to maintaining a fire department in a small town. You do not need it often, but when you do, the need is desperate. With a fire truck on every block, very little property would be lost to fire but fire suppression costs would be excessively high. At the other end, with no fire suppression capacity at all, main street could be lined on both sides by chimneys and ashes.

Figure 4.10 is a model of this theory when applied to wood procurement. Assuming that the cost of excess capacity increases proportionally with the amount of idle capacity, minimal cost is located at the intersection of cost of extra capacity function with the cost of wood shortage function. If ideal knowledge were available it would be simple to define the cost function for extra capacity. The cost of wood outage is a risk function and must be defined for each mill. Its slope and location depend on the geographic and market conditions prevailing in the operating region. Models of this type are generally structured so that one input is linear. In this case the cost of extra capacity maintained by the logging force has been linearized, which caused the combined change in the reduction of cost due to wood shortage. Each unit spent in excess capacity buys less protection against outage.

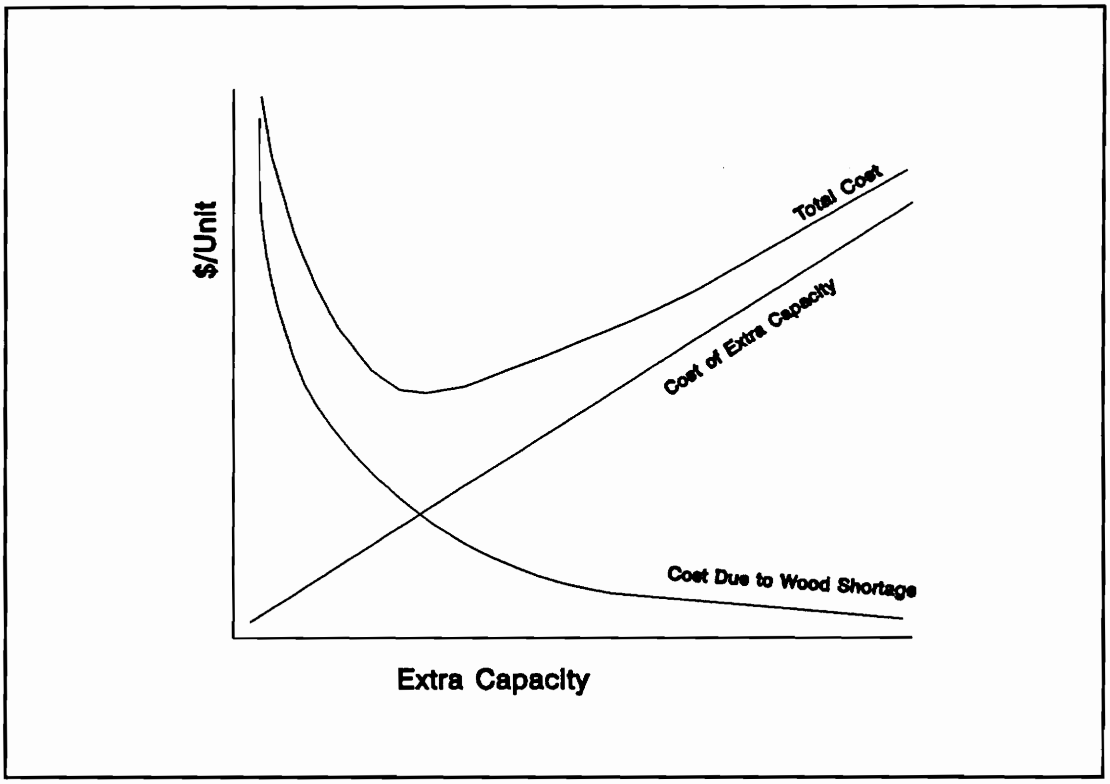

Figure 4.10. Total cost of excess capacity in relation with wood shortage occurrence and amount of extra capacity.

This theoretical model can be used to conceptualize the influence of environmental factors. For example stricter BMP regulation would increase the operating cost for a logger who wishes to maintain the same capacity utilization (Cubbage and Lickwar 1991). The excess capacity cost function would shift to the left. The risk function would shift to the right since the probability of running out of wood increases, and the cost of buying on outside market increases as well. Consequently the overall total cost function increases. The new extra capacity equilibrium point could move to the right or left depending on the risk function's slope.

Total Cost of Excess Capacity Example

Using the data collected from loggers and making some assumptions on the cost of wood shortage, an example was builded to test the theoretical model. While some over or under estimations might have been made, the selected values provide adequate insight to illustrate the interaction between idle capacity and wood shortage potential.

Scenario:

1. The purchasing organization needs 800,000 tons of round wood annually;
2. The desired logger can produce 100,000 tons/year (415 tons/day, 240 days/year) when working at full capacity (100%);
3. At 50% capacity utilization, the logger's revenue is $12.25/ton and the operating costs are $700,000/year ($14.00/ton);
4. Total operating costs increase by 5% for each increase of 10% in capacity utilization;
5. Wood outage costs the purchasing company $1,000,000/day (Fixed costs and lost sales);

Table 4.3. Cost of idle capacity.

Utilization	Annual cost	Production	Unit Cost	Revenue	Profit Margin	Cost of Idle Capacity
(%)	($)	(ton/year)	($/ton)	($/ton)	($/ton)	($/ton)
50	700,000	50,000	14.00	12.25	-1.75	5.05
60	735,000	60,000	12.25	12.25	0.00	3.32
70	771,750	70,000	11.02	12.25	1.23	2.09
80	810,300	80,000	10.12	12.25	2.13	1.19
90	850,800	90,000	9.45	12.25	2.50	0.52
100	893,300	100,000	8.93	12.25	3.32	0.00

Table 4.4. Pulpmill's wood outage cost.

Logging Capacity Utilization	Pulpmill's Risk of Outage	Cost of Outage	Cost of Outage
(%)	(Days)	($/year)	($/ton)
50	0	0	0.00
60	0.25	250,000	0.31
70	0.50	500,000	0.62
80	1	1,000,000	1.25
90	2	2,000,000	2.50
100	4	4,000,000	5.00

Table 4.5. Total cost of idle capacity.

Capacity	Cost of Idle Capacity	Cost of Wood Outage	Σ
(%)	($/ton)	($/ton)	($/ton)
50	5.05	0.00	5.05
60	3.32	0.31	3.63
70	2.09	0.62	2.71
80	1.19	1.25	2.44
90	0.52	2.50	3.02
100	0.00	5.00	5.00

Using values from Tables 4.2, 4.3 and 4.4, cost function of excess capacity, wood shortage, and total cost of excess capacity were graphed (Figure 4.8). The suggested level of idle capacity to minimize total cost was 20% (or 80% of capacity utilization). The total cost function reached its minimum at this point. This example corroborated the suggested theoretical model.

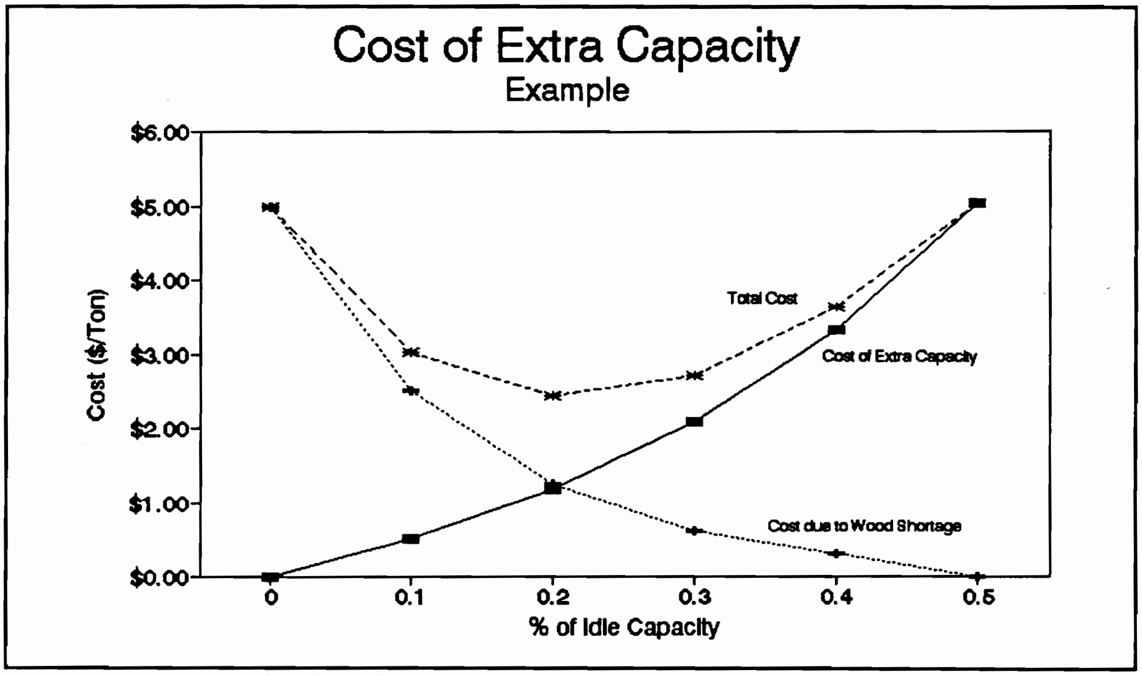

Figure 4.11. Cost function of excess capacity as computed in the example.

Conclusion

Rain is the primary cause of inventory fluctuation in the South. Lack of evapotranspiration in the winter makes it even more acute. Wood is available (no single stumpage owner can halt operations); logging, transportation and processing are so widely distributed that the threat of labor action or other forces that might otherwise disrupt operations in other countries is absent; and seasonal variability, is much less severe than in climates with true winter or monsoon seasons.

Temperature has become much less of a concern as operations become more mechanized and physical work has been replaced by machines operated from a heated or air conditioned cab. When it rains, first woods roads and then the forest soils force cessation of operation and inventories drop: the least weather proof operations cease activities first, the most last. More and more capacity is shut down as the rainfall continues. When the wet weather ends, capacity comes back on line in reverse order. The more weather proof contractors may have an advantage because they can exploit days in the early stages of recovery when the mill gates are wide open and few contractors are on the roads. Inventories refill, at an accelerating rate, as more capacity comes on line. Eventually, inventories will overfill and operations will be shut down by quotas[6]. The order and the extent of shut downs caused by quotas may or may not be as rational and driven by external considerations as those driven by excessive rain and the level of sophistication and investment by the individual logger: loggers can purchase equipment adapted to perform in adverse weather conditions, it is difficult to plan for quotas. The weather resistant operation competitive advantage over the more weather dependent is shown in Figure 4.12. The degree of weather proofing a contractor has is function of several factors. First, the stumpage he has lined up can be well or poorly drained. Second, the equipment used may operate with high flotation or narrow tires. Road quality within the tracts is a third factor affecting production in wet weather. Crew willingness to work in adverse climatic conditions is another factor.

The current system has few control mechanisms other than quotas. The quota system is sufficiently unstructured to allow a degree of arbitrariness necessary to empower both parties and to satisfy the American legal system. A firm can arbitrarily put a "tight" quota on a contractor and that contractor can arbitrarily chose to sell his services elsewhere. Different degrees of independence exist between contractors and firms, thus quota policies are often different between organizations.

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[6]Quotas have to be imposed by the procurement organization now for lack of *sufficient rain* (as awkward as this expression may sound).

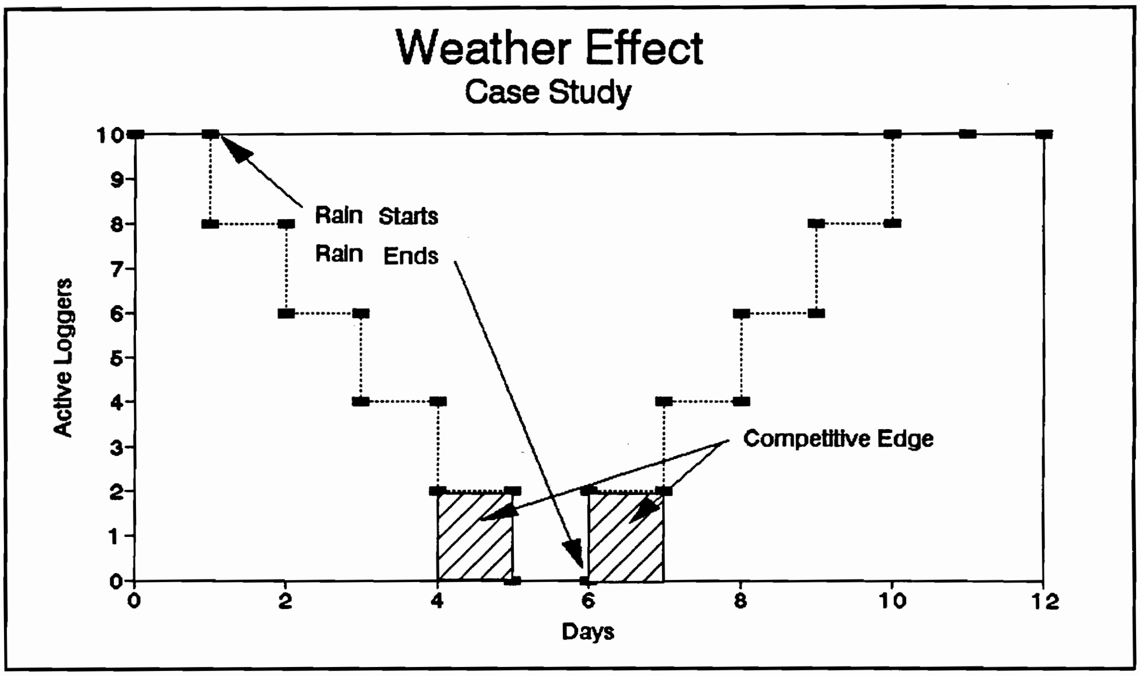

Figure 4.12. Weather resistant loggers' competitive advantage.

Realistically, full utilization of capacity is not an obtainable goal for the logging industry because weather will always be a significant source of delays and mechanical breakdown will continue to be unavoidable even with proven technology. But the application of improved machinery will allow the system to operate in a more robust manner with regard to adverse weather.

All regional differences in capacity utilization obtained by Loving (1991) were verified: Coastal Plain and Piedmont loggers both were found to have higher utilization ratios compared to the Appalachian loggers. Higher capacity utilization values than those estimated by Loving may be explained by the intensity and the level of detail in the data collection process used for this study.

Production lost to quotas was a special case compared to other causes of lost production. It is the only factor over which the procurement organization has absolute control. Quotas are often justified by a need to distribute a reduced wood order to all producers. When used as a short term measure, benefits may surpass costs. On the other hand, chronic or recurrent quotas are symptomatic of an industry with too many producers. Recent trends in other industries indicate a desire to reduce the number of suppliers. Deming (1986) reports the case of General Motors, where attempts to cut their production costs lead to a reduction in the number of suppliers. Economies of scale were realized, but most of the gains came from joint efforts in their drive for quality resulting in lower prices. Multi-year contracts were considered to reward the suppliers for their cooperation with GM in its cost-cutting objectives. Reducing the number of suppliers will promote accomplishments toward teamwork which may yield even greater benefits.

Companies are naturally reluctant to commit most of their round wood needs to fewer loggers. A surplus of producers encourages competitiveness. Retained loggers may be uncomfortable in a preferred supplier relationship. Being dependent on a single company can have negative consequences if negotiations get difficult (Liden,1988). Obviously an equilibrium of needs and guarantees will have to be secured on each side. Anti-trust regulations and the federal requirements regarding independence of contractors (A.P.A. 1988) may restrict the formal links between loggers and companies sometimes found in other countries. A symbiotic relationship already exists between the purchaser and the producers. The following quote was often repeated in the study by both loggers and foresters: "*They've been good for me in the past, so once in while I'll do something for them even if it costs me a little money.*"

CHAPTER 5. PATTERNS OF PRODUCTION

"There is usually a limit on how good things can get,

but no limit on how bad they can become."

W.B. Stuart

Introduction

According to Deming (1986), "A process has a capacity only if it is stable." While reserving judgement concerning the appropriateness of this quote to forestry, methods based on Deming's philosophy and statistical quality control tools have found their way into a wide range of economic sectors (Scherkenbach 1988, Boswell 1992, Jarrett 1993). Forest operations should not be excluded. Quality management concerns are getting much attention even though legal constraints governing independent contractors have slowed the progression of these management tools into procurement. The number and diversity of suppliers contracting with a mill, the fact that logging firms contract with several mills, and the complexity of the legal and operational criteria regulating the logging business as a whole make coordination more than control the key to successful operations (Stuart et al. 1993).

With the appearance of even more regulation systems such as OSHA (Occupational Safety and Health Act) (A.P.A. 1992), BMP's (Cubbage and Lickwar 1991, Hawks et al. 1993), and CDL (Commercial Driver's Licensing) (Shaffer 1990), the future harvesting contractor, land owner, and the consuming mill may be forced to develop better channels of communication. Quality management tools may provide a way to monitor the business environment and establish a common understanding of each party's needs and obligations. The first step of a quality improvement program must be devoted to developing an understanding of the system. At this stage descriptive statistics are used to collect information concerning system behavior. All statistics dealing with the average are of little use until the process is brought under control. The difficulty of individualizing the effect of a single factors in forest harvesting and the rapidity of technological changes (at least in comparison with other industries) hinder analyses of such processes. Graphical representations are crucial to the process definition and attempts to bring the system, or even components of the system into some form of control.

Deming (1986) cites a number of advantages to bringing a system under statistical control. First, the cost of the system is predictable because the performance can be predicted. The system's capability is measurable and communicable. Output regularity is essential. Thus, statistical control should work well with the "just in time" inventory mode of the southern forest industry. Just in time delivery follows naturally when a whole system is in statistical control (Scherkenbach, 1986). A system with predictable performance offers the best opportunity to maximize productivity and profits. Relationships between the producer and purchaser are greatly simplified when the system is in control. Finally, without statistical control it is difficult to measure the effect of change on the system.

Bringing forest operations under statistical control as defined in plant operation[1] might be difficult due to the nature of these activities. Nevertheless, the application of simple tools would yield interesting results in an environment heading for increased regulation.

[1]There is a degree of manufacturing control that the shop floor engineer may achieve that cannot be emulated in a forest environment.

Monitoring the Operations

Because uniformity is impossible in any process, key questions in control and quality analysis are "How much variation exists?" and "What can I do to control the nonuniformity of the processes?" (Adam and Ebert, 1989). Both questions can be partially answered through use of simple graphical techniques, run charts, cusum charts, and control charts. Duncan (1986) defined control charts as a statistical process aimed at studying and controlling repetitive processes. Brought to light by Shewart (1931), control charts are a valuable tool for establishing a target level of production, helping management take necessary action toward achieving this level, and serving as measurement tools to judge overall goal achievement.

Run Chart

Daily production data provided by the loggers supplied a basis for further graphical analysis. Figure 5.1 is an illustration of simple run chart used to get a general overview of the contractors experience. The thick dark line represents the logger's estimated maximum daily capacity. The thin dotted line represents his actual production. The daily variation of both lines becomes evident and a general production pattern with periodic highs and lows is exposed. Differences between the two lines can be easily spotted.

C-Charts

Adding control limits (Figure 5.2) to a run chart creates an excellent tool to identify significant variation in the process. A control chart (c-chart) is a simple way to graphically expose events that may be less obvious in a column of numbers. Control charts help to quickly detect variation in production. Once detected, variability should be analyzed to determine if it was due to chance alone or some assignable cause (Daniel and Terrell, 1989).

For the study, two approaches were used to establish control limits. The first, and most traditional approach, used the average as the standard. The upper control limit (UCL) is fixed at three standard deviations above the average and the lower control limit (LCL) is fixed at three standard deviations below. The results of this approach when applied to logger 301's daily production are shown in Figure 5.2. The three standard deviations method provides limited information. The variability in production was so great that any level of production between 0 and 420 tons per day was "in control". No exceptionally good or bad days were indicated. Because of the great variability in logging, and because Gaussian distributions cannot always be expected, an alternative was needed.

A second technique was specifically developed for this study. Instead of control limits based on standard deviation, the UCL and LCL are defined by converting the distribution into an ogive. Desired control limits are then established based on distribution shape and operational characteristics. The ogive or cumulative probability distribution is a simple and efficient way to convert data into percentages. The ogive form of logger 301's daily production for the 54 weeks of the study is presented in Figure 5.3. The ogive's shape is typical of a fairly normal distribution. The lower control limit was fixed at 25 tons (or one truck load) because that represents the minimal production level for a harvesting contractor. It also exposes the bimodal nature of the distribution (shut down vs. produce). The upper limit was fixed at the maximum "expected" production level for this contractor. Three hundred tons seemed a reasonable upper limit based on the logger's past production records and harvesting equipment used. In this example 93% of the observations fell between the upper and lower limits. Including the minimal production level (25 tons) caused the control limits to be asymmetrical about the mean of 200 tons per day.

Both techniques were applied to all loggers involved in the study. Table 5.1 compares the control limit locations and gives the number of outliers for each approach. The average and median daily production is provided. Limitations of the standard approach are evident, limited useful information is obtained. In all cases the lower limit equals zero (negative production values are not acceptable) and the upper limits is fixed at three to four times the mean daily production. In their normal state, loggers' harvesting systems have too much variability to be analyzed with the three standard deviation technique. Outliers can be detected using an ogive and setting the lower control limit at 25 tons (one truck load) and the upper limit at the 98 percentile. With this method UCL were usually set within twice the value of the median daily production. The number of observations below the LCL indicated each logger's sensitivity to wet weather and the number of days lost to quota.

When transferred to a run-chart, control limits become signals to the contractor and the contract manager to investigate the cause of an exceptional observation: common causes, those on which the management has control on, or special causes, those for which little can be done to avoid. A c-chart with ogive-defined control limits is presented in Figure 5.4. Several special causes can be identified to explain the lower outliers. Rain stopped this logger's production for four days. Holidays and quotas (common cause) caused three and five of these unproductive days respectively. Some exceptional production days were observed around the 200th day. These were attributed to the use of a new machine, favorable in-woods conditions, and short hauling distances. This production level should be noted by the procurement organization as this logger's emergency maximum capacity level.

Table 5.1. Comparison between the three standard deviation and ogive approach to set control limits.

		Three Standard Deviations			Ogive		
Loggers	Avg (Med)	LCL	UCL	# of Outliers	LCL	UCL	# of Outliers[1]
101	95 (100)	0	273	0	25	200	4/48
102	139 (175)	0	454	0	25	300	5/79
104	163 (175)	0	437	0	25	300	3/24
105	155 (175)	0	521	1	25	375	5/74
201	243 (250)	0	735	0	25	600	2/43
202	201 (250)	0	555	0	25	325	3/53
203	345 (375)	0	923	1	25	650	4/35
206	185 (200)	0	528	0	25	375	6/33
301	200 (200)	0	417	0	25	300	7/15
302	199 (250)	0	628	0	25	425	5/58
303	280 (360)	0	890	0	25	600	3/83
304	418 (450)	0	1122	0	25	850	6/37
305	249 (275)	0	733	0	25	450	2/30
306	182 (200)	16	349	4	25	275	3/4
307	143 (150)	0	314	0	25	200	2/23
401	114 (125)	0	407	0	25	275	4/83
402	101 (125)	0	347	0	25	225	5/90
403	155 (150)	0	368	0	25	275	6/20
404	124 (125)	0	290	0	25	200	1/16
405	138 (175)	0	550	0	25	275	1/24
503	222 (250)	0	611	0	25	400	1/15

[1] The first value represents the number of outliers above the UCL, the second outliers below the LCL.

Cusum

Cusum (cumulative sum) charts are useful instruments for detecting trends in a series of observations (Duncan 1986). Variation from a standard[2] are summed for each observation. An example of an average based cusum is shown in Figure 5.5. Contractor 301's daily average for the 54 weeks studied weeks was 200 tons. This average was subtracted from each day's production reported by the logger. The remainder, negative when production was below average, positive when production was above average, was added algebraically. The plotted cumulative difference reveal general trends. A prolonged negative slope indicated that the logger has produced below the standard for a prolonged period of time. The opposite was true for a positive slope and usually meant a better cash flow for the logger. From a practical point of view, prolonged periods (several months) at a decreasing production rate should be avoided. As shown in Figure 5.5 logger 301 had a negative slope for the first half of the study. A logger in such a situation has to seek financial aid or use savings to survive until productivity improve. In the case of logger 301, the shift from a negative slope in the first half (around day 120) of the year to a positive slope in the second half was caused by the use of a more productive feller buncher. Logger 401 (Figure 5.6) had a more preferable pattern, periods above or below the average were not prolonged.

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[2]The standard can be the distribution's mean, mode, median, or any other parameter of interest.

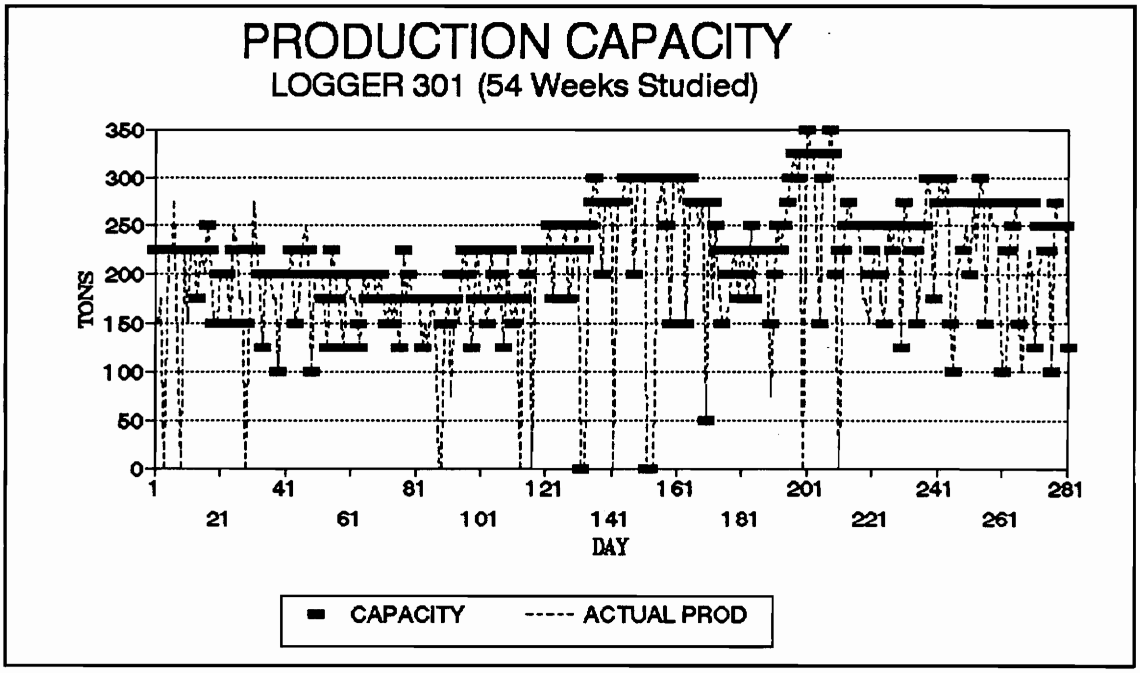

Figure 5.1. Run chart of logger 301's estimated maximum capacity and actual daily production.

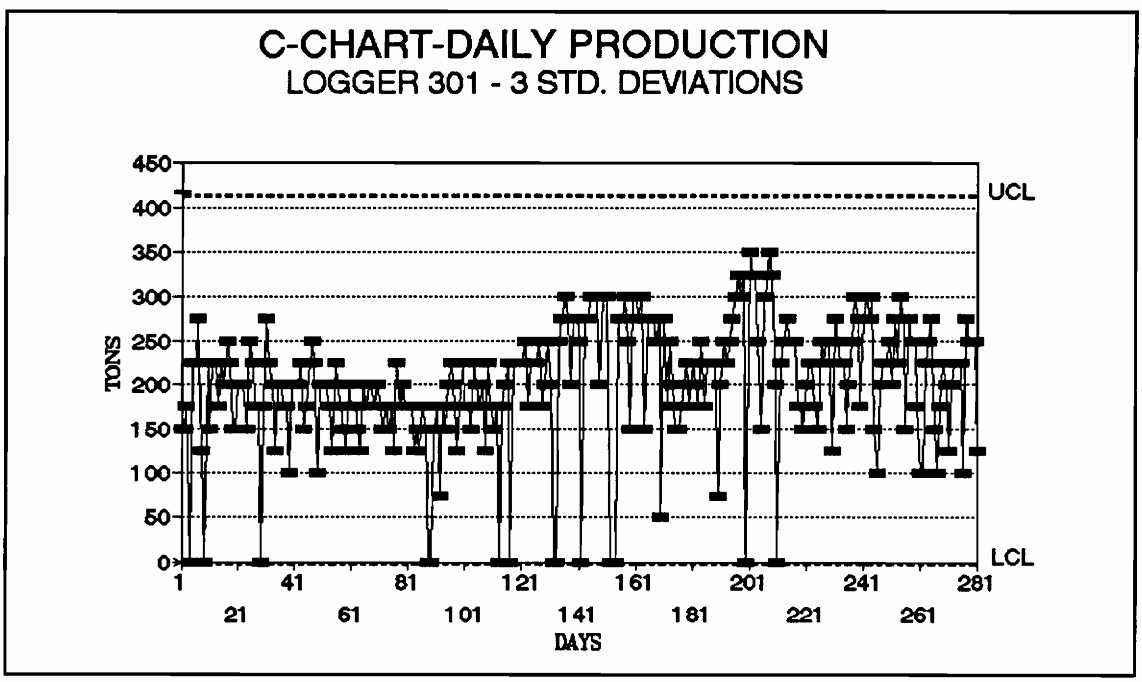

Figure 5.2. Logger 301's three standard deviation based c-chart.

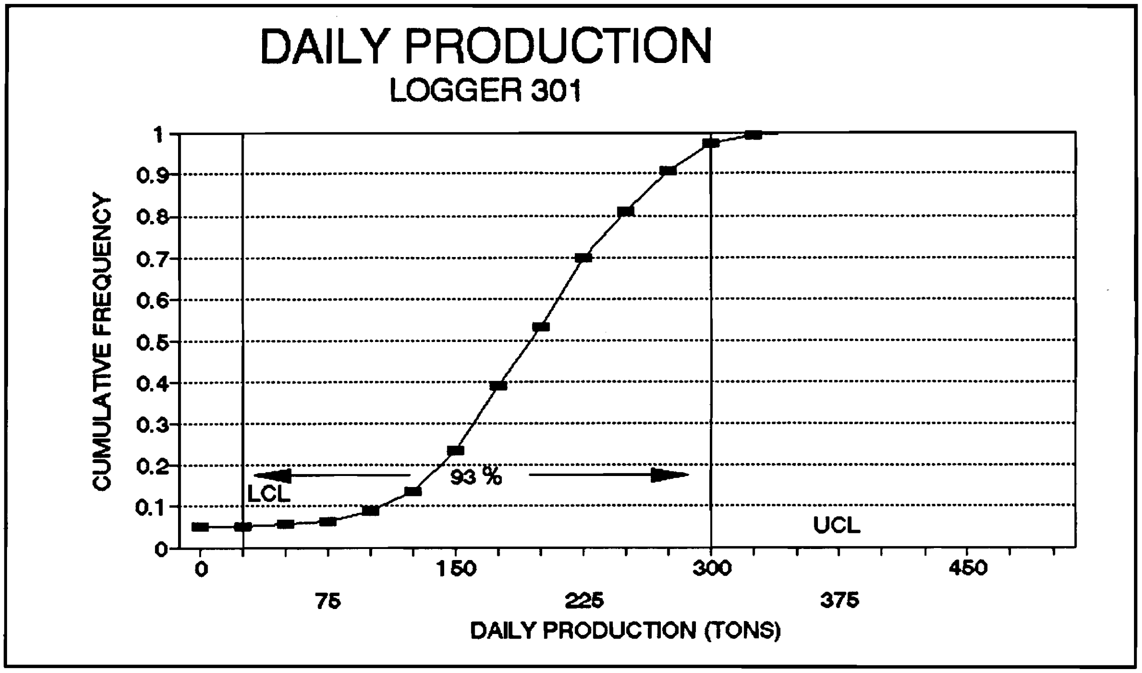

Figure 5.3. Logger 301's daily production distribution transformed to an ogive.

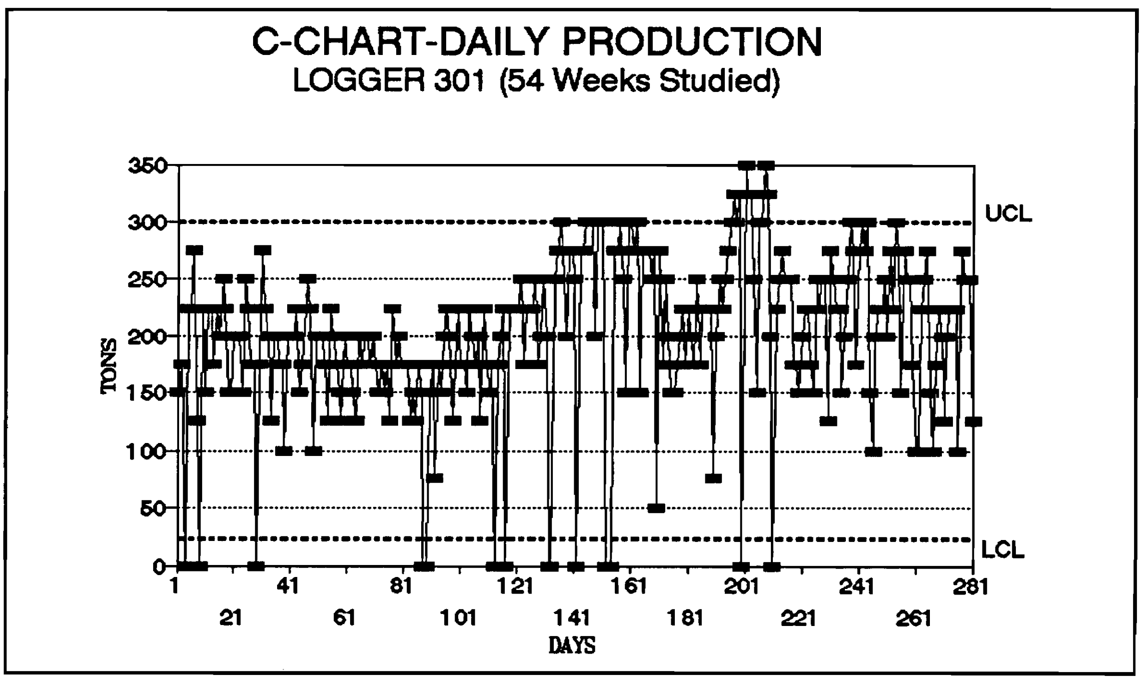

Figure 5.4. Logger 301's c-chart with ogive defined control limits.

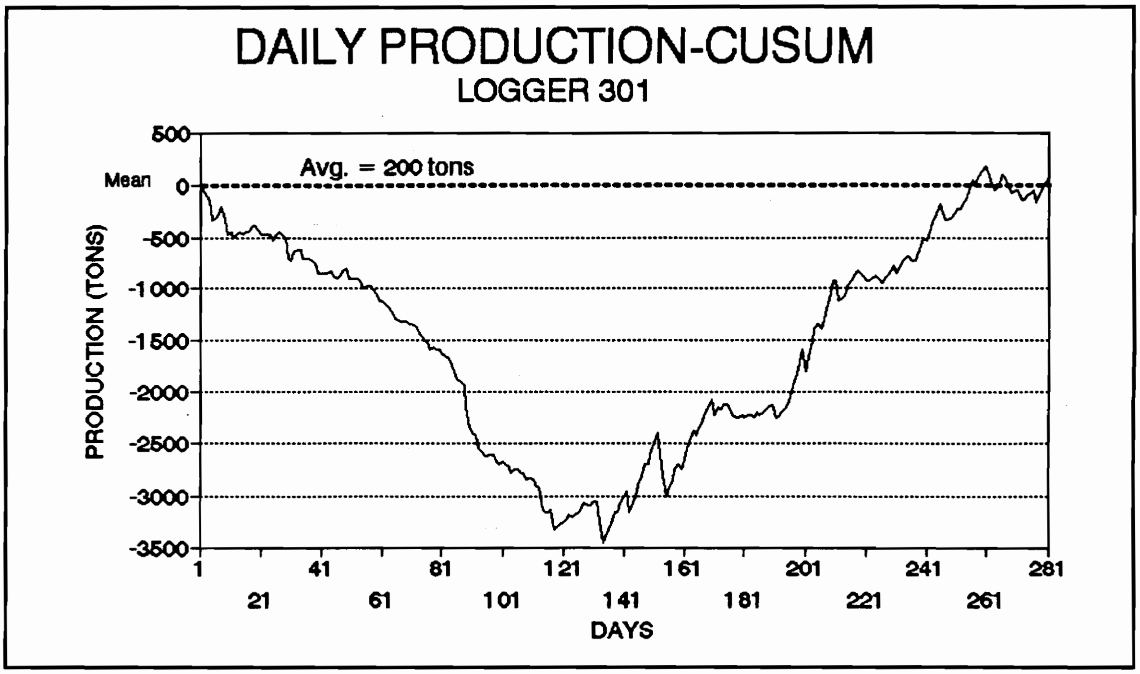

Figure 5.5. Contractor 301's average based cusum.

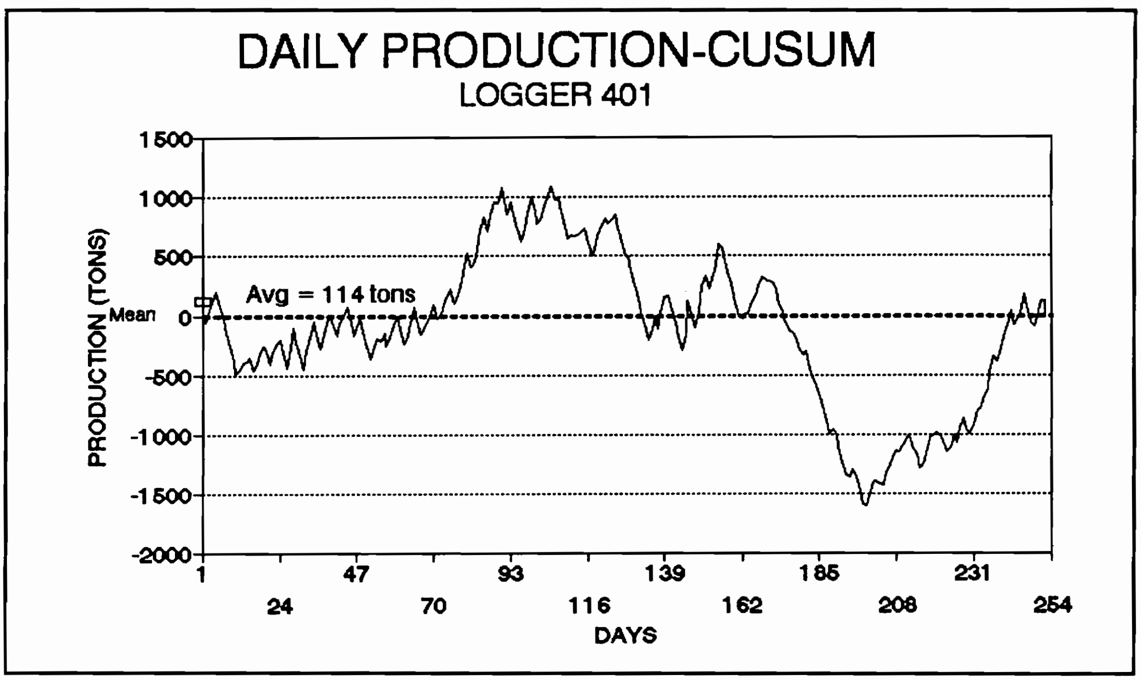

Figure 5.6. Contractor 401's average based cusum.

Long Term Follow Up

Production records for the past five years were available for five loggers in the study. This unique data base offered an opportunity to study production trends dating back to 1988 from a weekly basis.

Weekly Variability

The variability and trends in each contractors weekly production are summarized in Figures 5.7 through 5.16. For all five loggers, the first year is characterized by less variation - smaller amplitude - than the last four years. Loggers 101, 102, and 303 seem to have experienced increased variation while maintaining stable median weekly production (Figures 5.7, 5.9, 5.15). Interviews with these loggers revealed that their production capacity remained unchanged during this period, and different or additional productive machinery was not added. Data presented in table 5.2 confirmed that their average weekly production remained fairly stable. Logger 301 increased production and variabilty remained high (Figure 5.11). Logger 302 maintained similar variability while suffering a decrease in median weekly deliveries (Figure 5.13).

Logger 101 and 102, in 1992, remained at the same production level as in 1988. Box plots values (Figures 5.8 and 5.10) confirmed a constant increase in variation with stable median values. Logger 102 had distributions for the last two years that included weeks with no production; these were now a part of the distribution, previously a week with no deliveries constituted a variety. This was reflected by the lower whisker of the box plot being located on the x axis (zero). In other words, weeks with out production were not unusual.

Logger 301 bought a new feller buncher in 1992 and had a major increase in weekly production capacity. This is reflected by a higher median in the box plots (Figure 5.12). For the first time since 1989 zeros are considered as outliers to the distribution. Major reductions in utilization due to quotas in 1990 and 1991 were not repeated in 1992.

Hurricane Hugo seems to have created an opportunity for logger 302 to have his best year in 1990. On the other hand, 1992 represented his worst year on record. His annual average (Table 5.2) and median show a reduction in weekly deliveries. For the first time since the study started, zeros are not considered as outliers (Figure 5.14).

Logger 303 returned to his 1988 production level after low production from 1989 through 1991. As for previous loggers, contractor 303's box plots values (Figure 5.16) show great variation and lower whiskers frequently set directly on the no production level.

Even if annual average and median weekly deliveries remained fairly stable, these figures did not entirely confirm stable capacity. It is possible that increased capacity did not translate to increased production. The interviews confirmed that yearly differences are due to changes in utilization rather than increased or decreased capacity. Logging contractors seemed to have been forced into inactivity more frequently during the last two or three years. The reason may be stricter BMP regulations amplifying the effect of weather, or managing total fiber needs through increased use of quota on round wood deliveries. In both cases, the loggers adjusted by producing more when condition were favorable and consequently, variability increased. Elasticity became essential to stay in business.

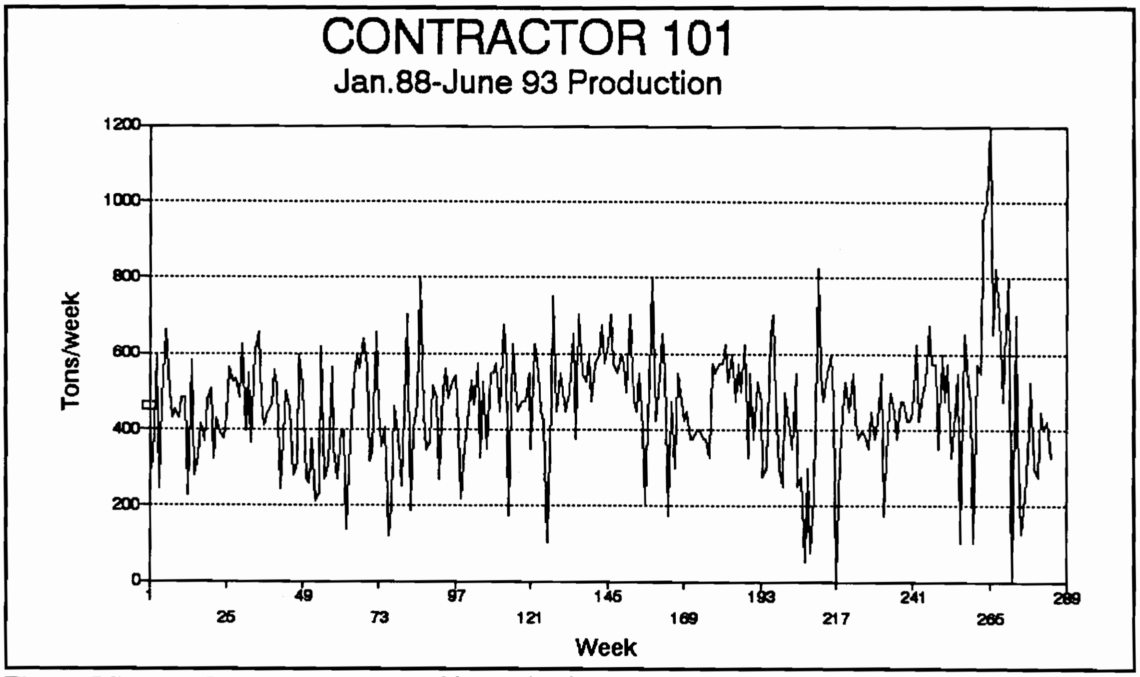

Figure 5.7. Contractor 101's weekly production.

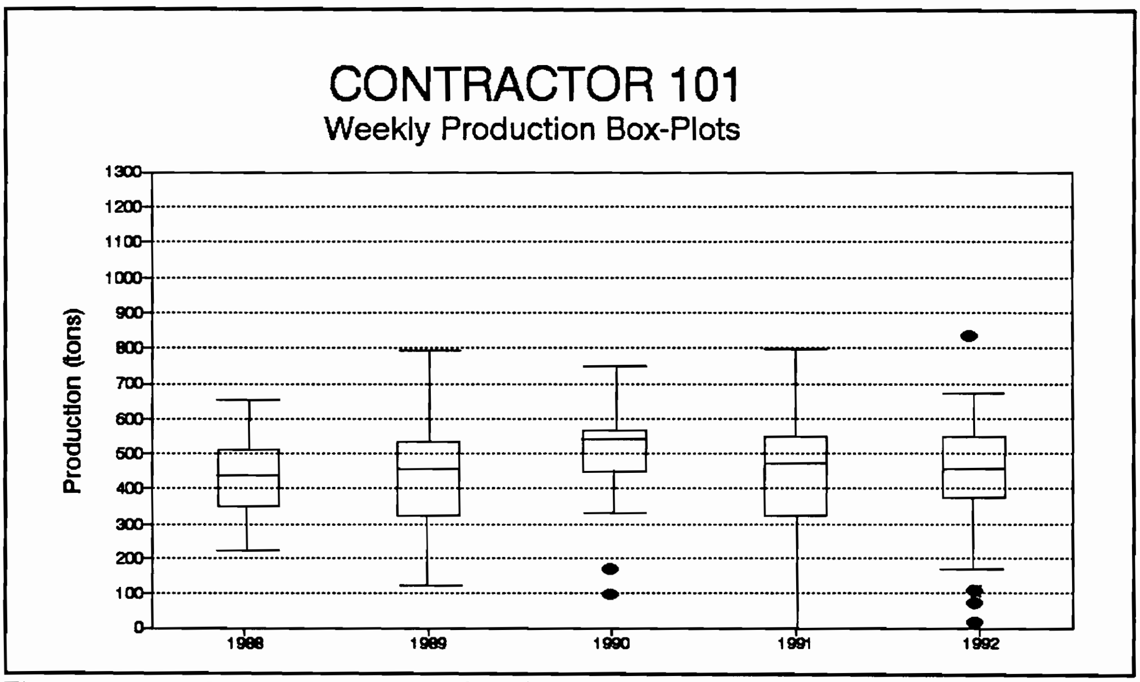

Figure 5.8. Contractor 101's annual weekly production box plots for 1988 through 1992.

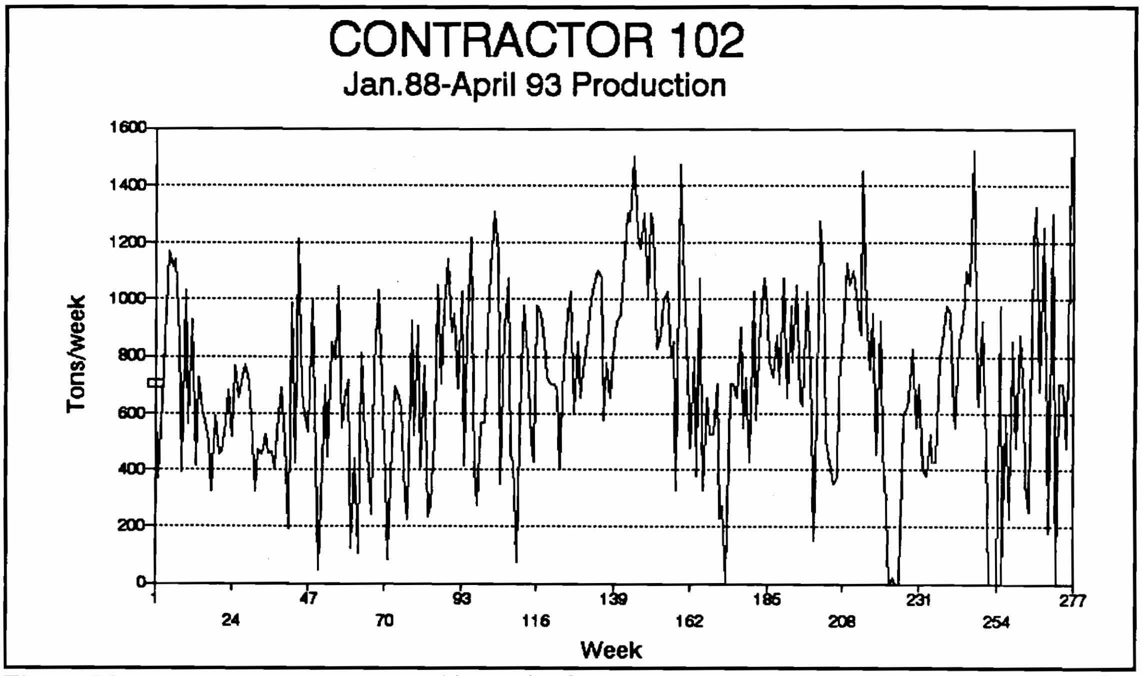

Figure 5.9. Contractor 102's weekly production.

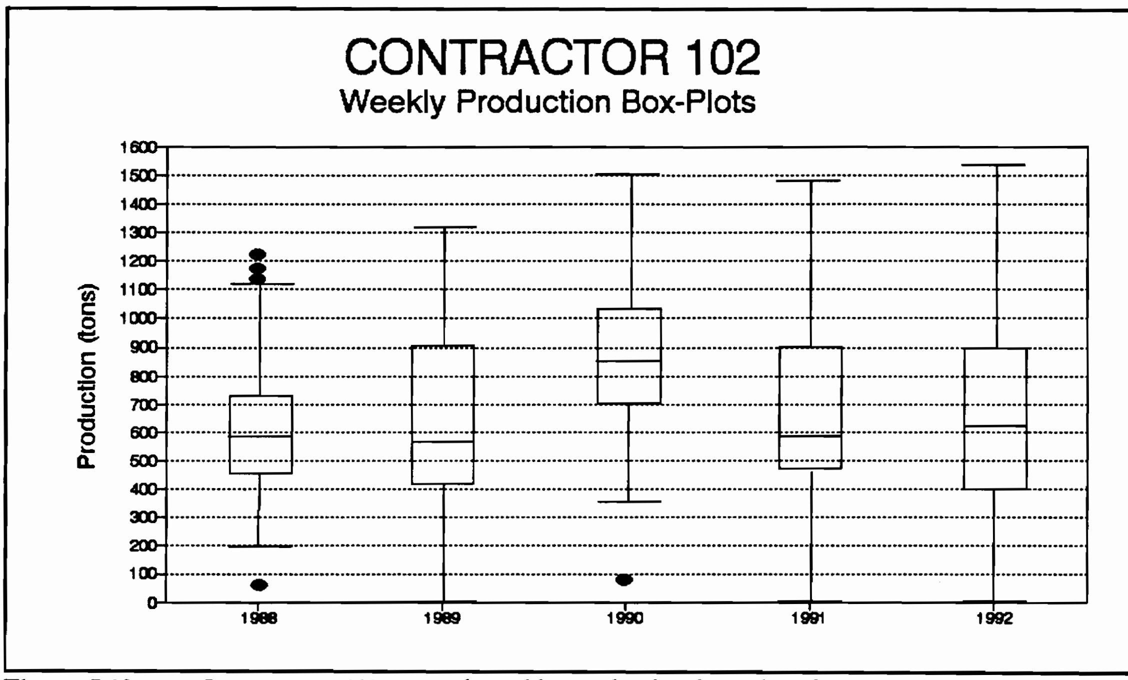

Figure 5.10. Contractor 102's annual weekly production box plots for 1988 through 1992.

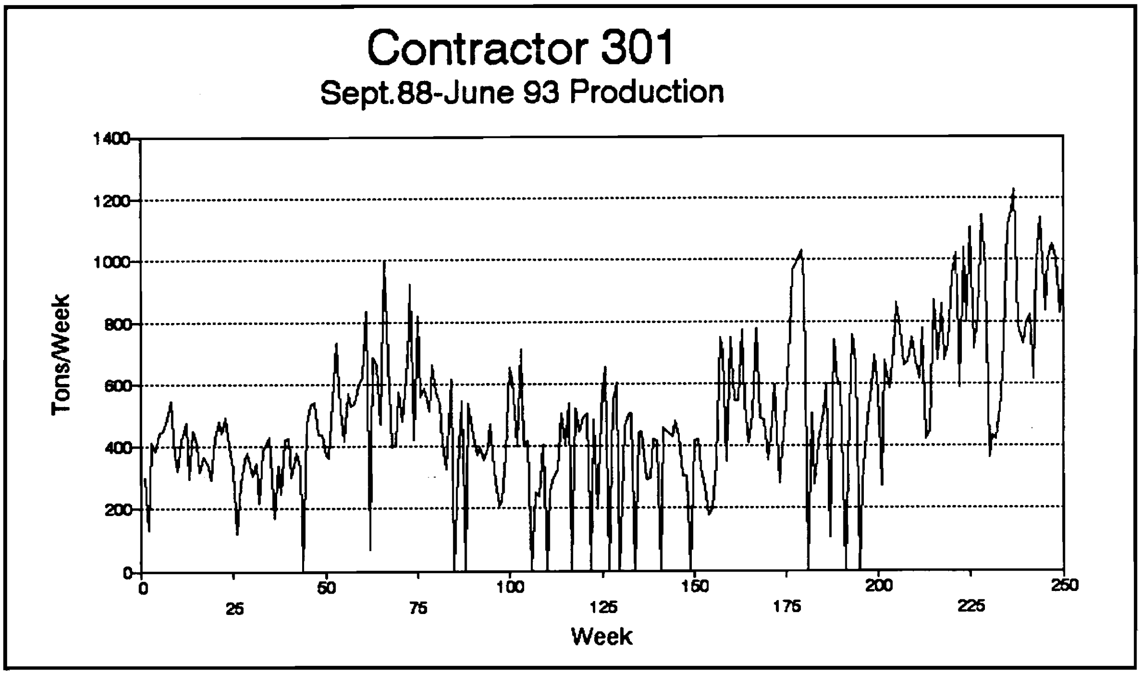

Figure 5.11. Contractor 301's weekly production.

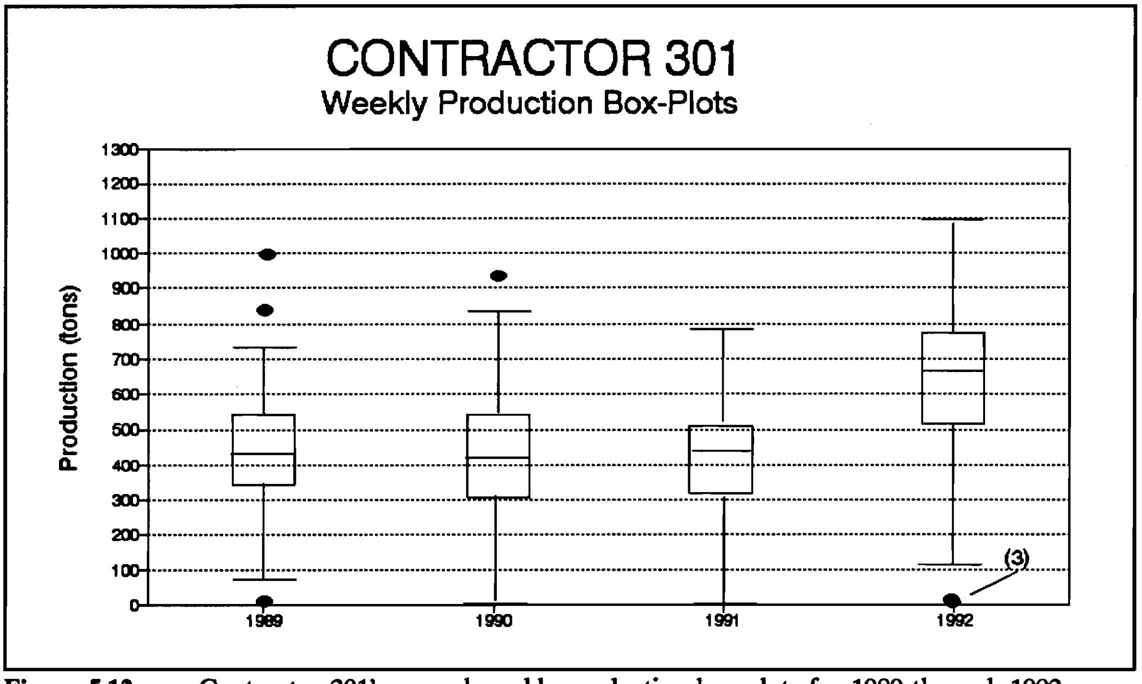

Figure 5.12. Contractor 301's annual weekly production box plots for 1989 through 1992.

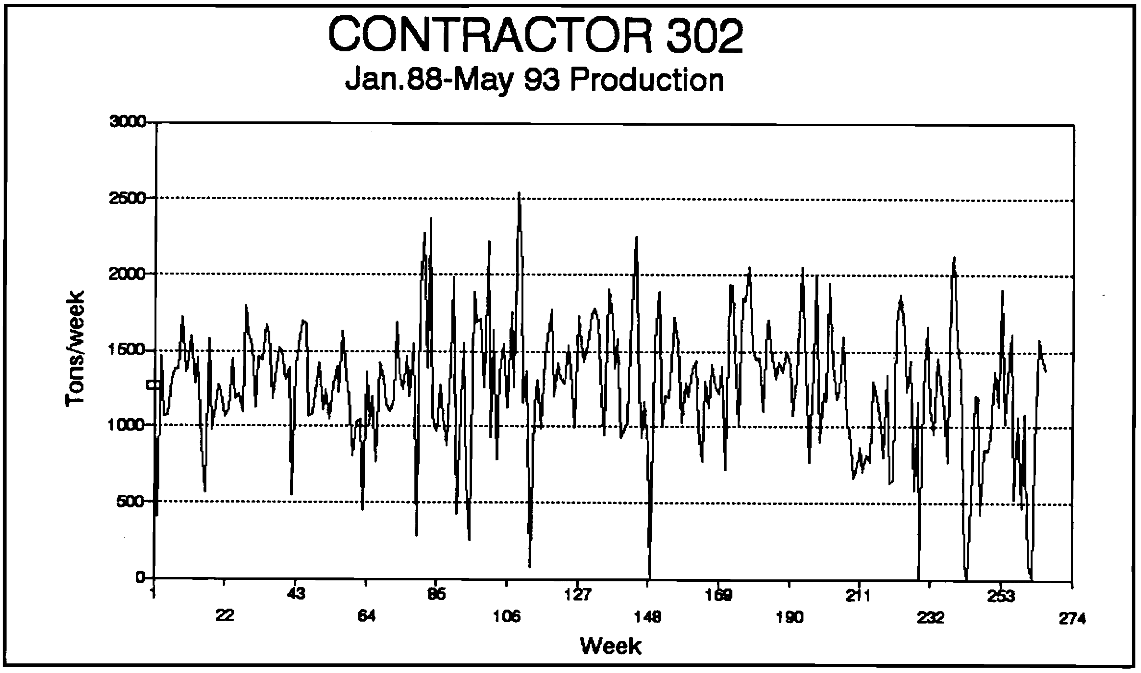

Figure 5.13. Contractor 302's weekly production.

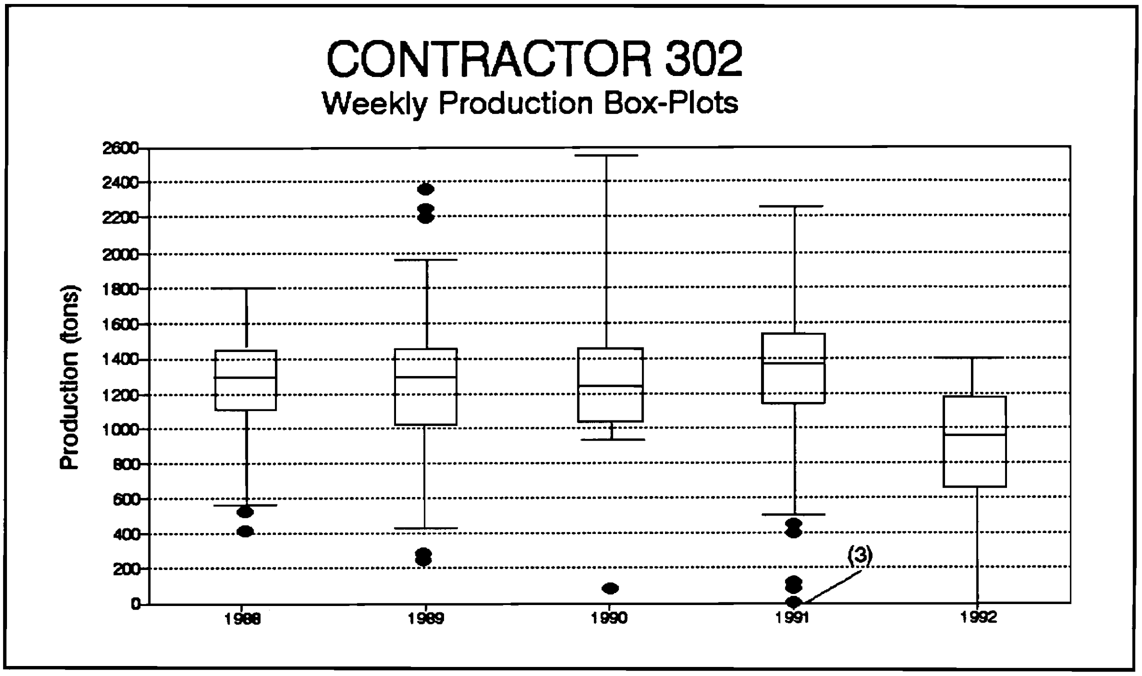

Figure 5.14. Contractor 302's annual weekly production box plots for 1988 through 1992.

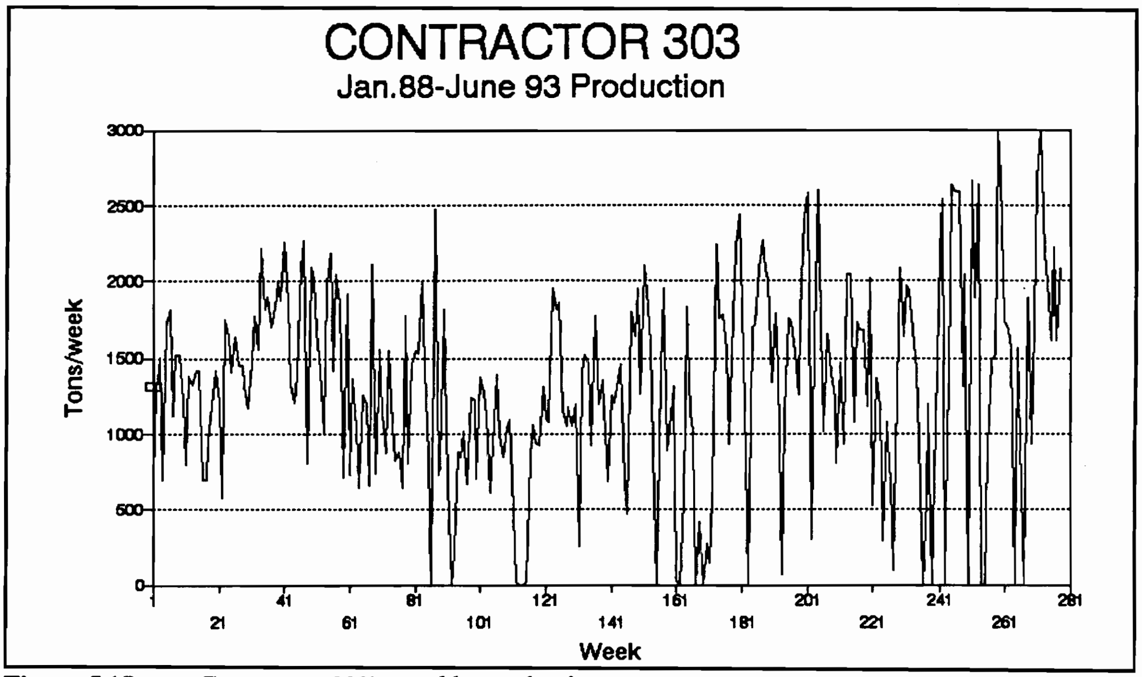

Figure 5.15. Contractor 303's weekly production.

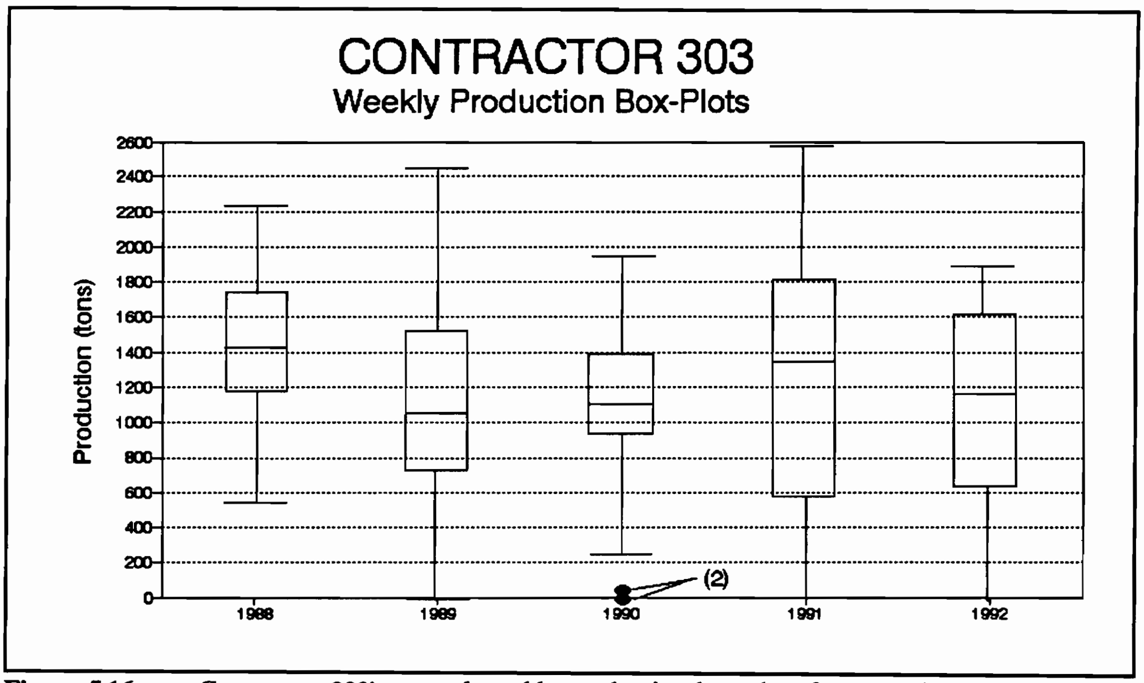

Figure 5.16. Contractor 303's annual weekly production box plots for 1988 through 1992.

Table 5.2: Average weekly production for 1988, 1989, 1990, 1991, and 1992.

LOGGER	AVERAGE PRODUCTION (Tons/Week)				
	1988	1989	1990	1991	1992
101	441	422	518	447	447
102	663	662	868	701	643
301	385	435	412	413	638
302	1293	1264	1434	1347	1114
303	1472	1162	1099	1285	1405

Average Based Cusum

As previously described, an average based cusum may serve to indicate trends in weekly delivery over an extended time horizon. Assuming the average represented the level at which a producer covered all expenses and realized a minimum return on equity, then crossing the line to the negative side represents a deficit and money from previous periods needed to be available to make it through the hard times. Two workable solutions exist given that a state of no variation is impossible to achieve.

The first is to have short positive and negative runs[3] alternating regularly. Therefore a logging contractor does not have to build large cash reserves against the eventuality of a prolonged low production period. Loggers 101, 102, and 302 (Figures 5.17, 5.18, and 5.20) had a general cusum pattern that followed this "workable situation". By comparison loggers 301 and 303 (figures 5.19, and 5.21) have a cusum pattern with prolonged periods below and above the average. The second solution arises when

[3]A run is at least six consecutive observations below or above the standard.

the occurrence of these periods can be planned. It is the loggers' responsibility to ensure sufficient cash reserves in anticipation of down periods. Loggers 301 and 303 both seemed to have prolonged periods of unequal length so it was difficult for them to prepare for the downturns in round wood demand.

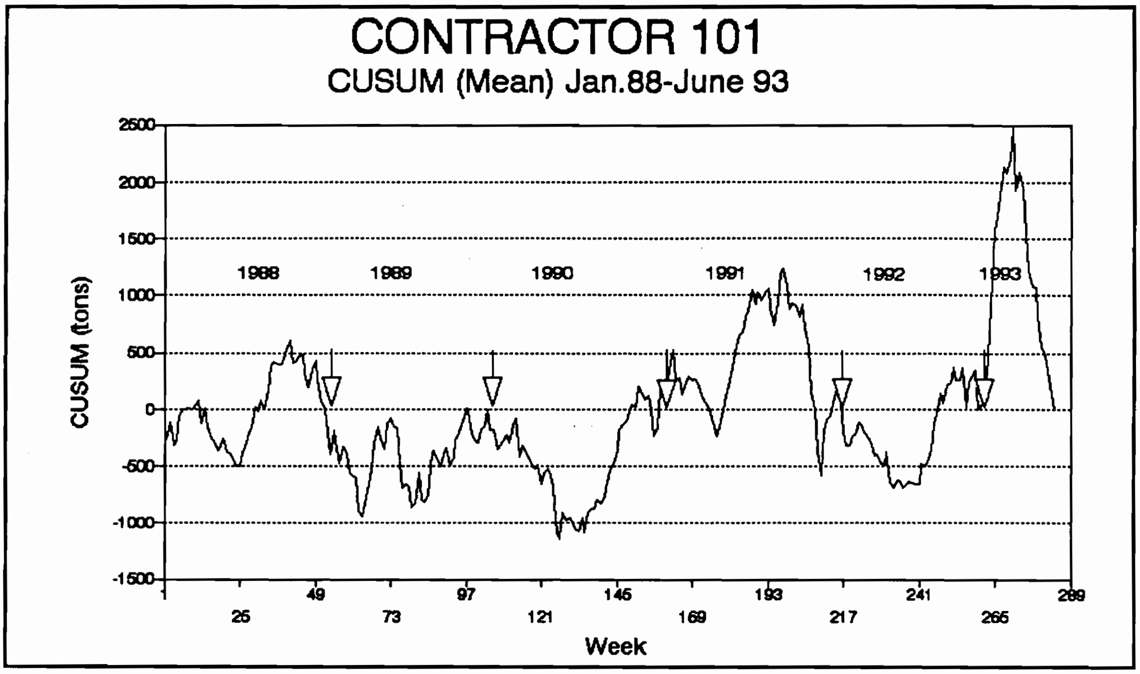

Figure 5.17. Contractor 101's average based cusum (5 years).

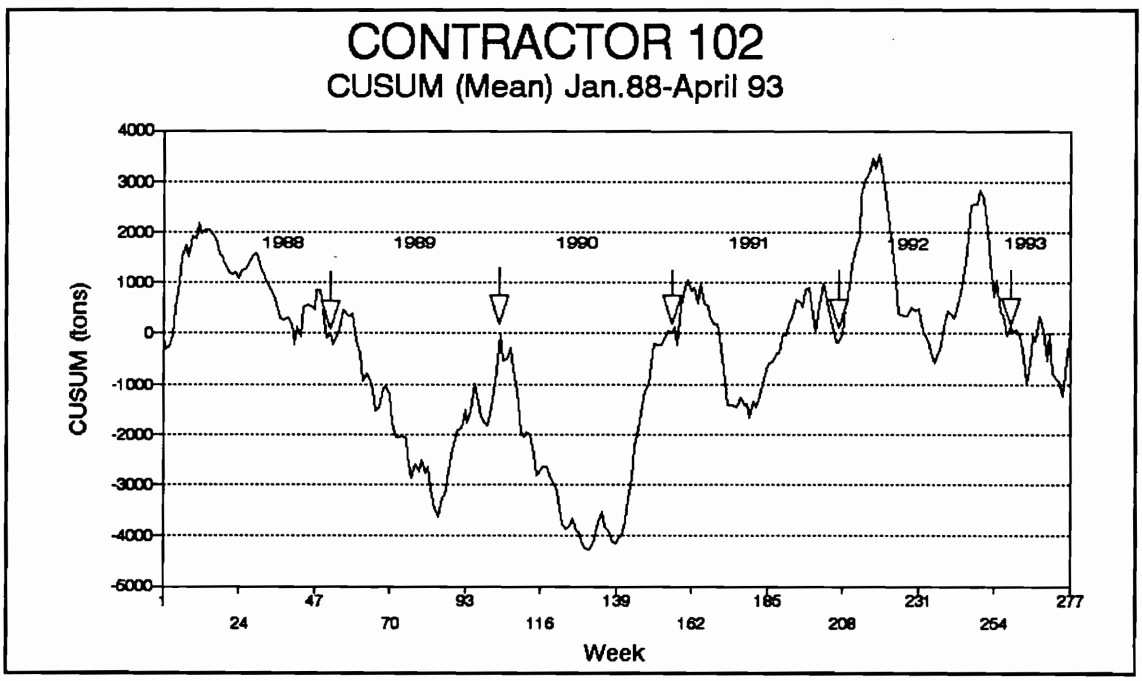

Figure 5.18. Contractor 102's average based cusum (5 years).

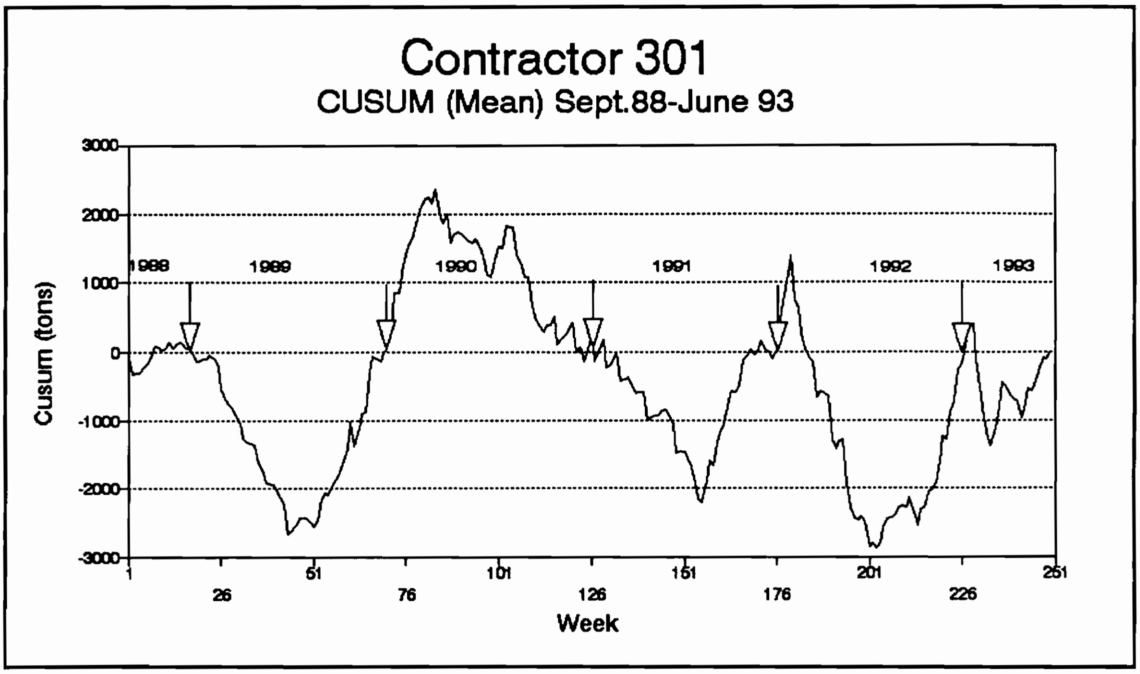

Figure 5.19. Contractor 301's average based cusum (5 years).

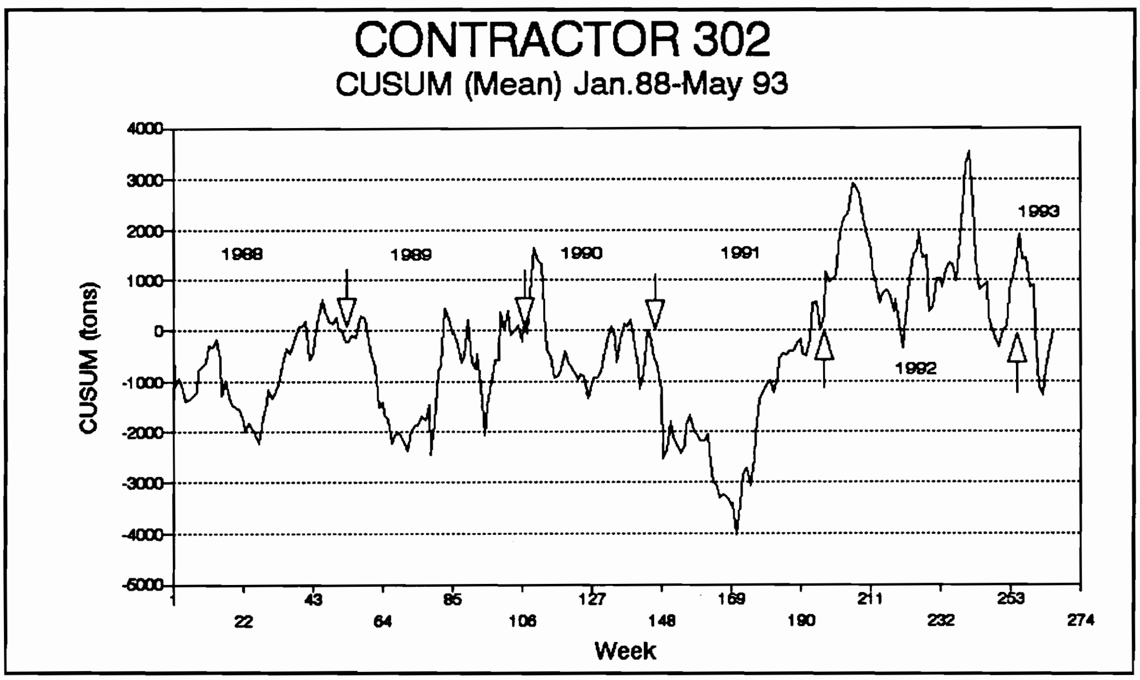

Figure 5.20. Contractor 302's average based cusum (5 years).

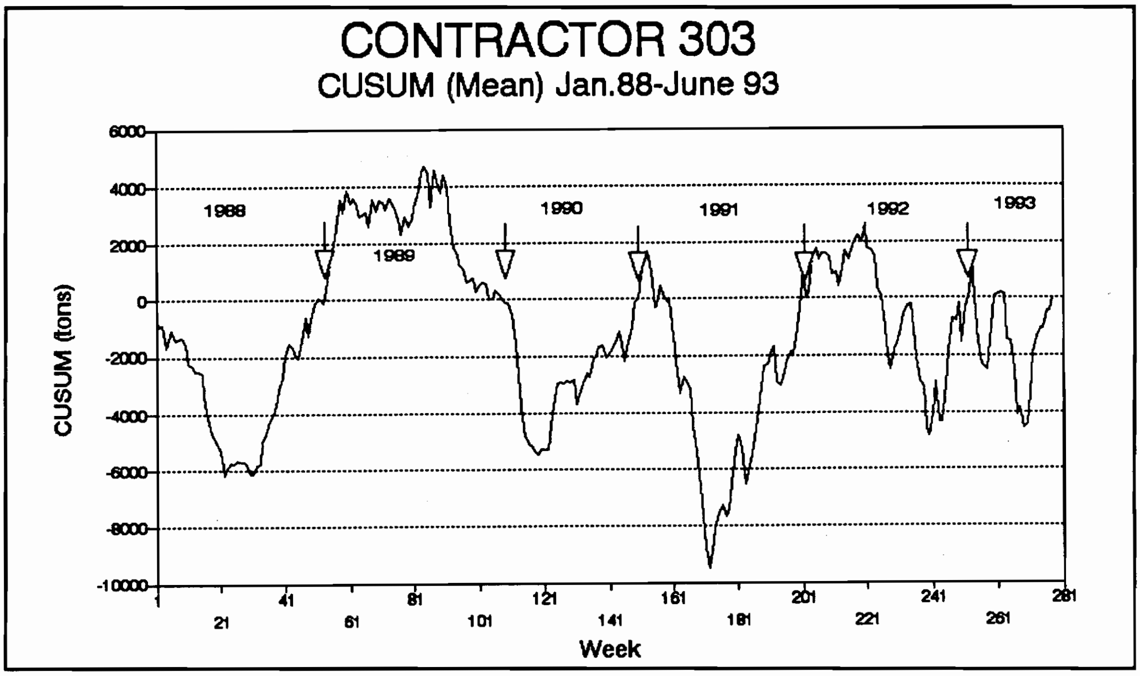

Figure 5.21. Contractor 303's average based cusum (5 years).

Cusum based capacity index

A capacity index can be obtained by using the bound between the third and fourth quartile. This value marked the level of production the contractor achieved or exceeded 25% of the time (Figure 5.22 - 5.26). It served as a measure of the system's sustainable capacity given relaxed constraints (wood orders and favorable weather). This capacity index may also indicate the system's underutilized capacity. The index was recalculated each year to account for possible yearly variation. The value at which the downward line stops is the total capacity lost over the last 4 to 5 years because the system was unable to sustain a 75% capacity utilization.

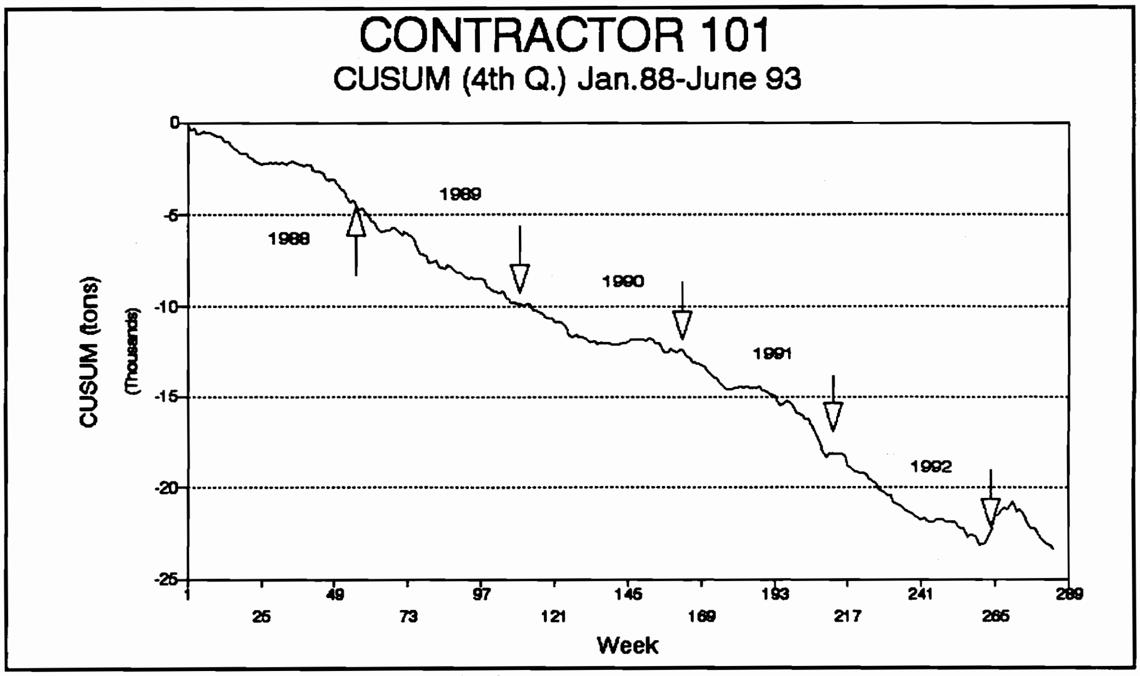

Figure 5.22. Contractor 101's capacity index.

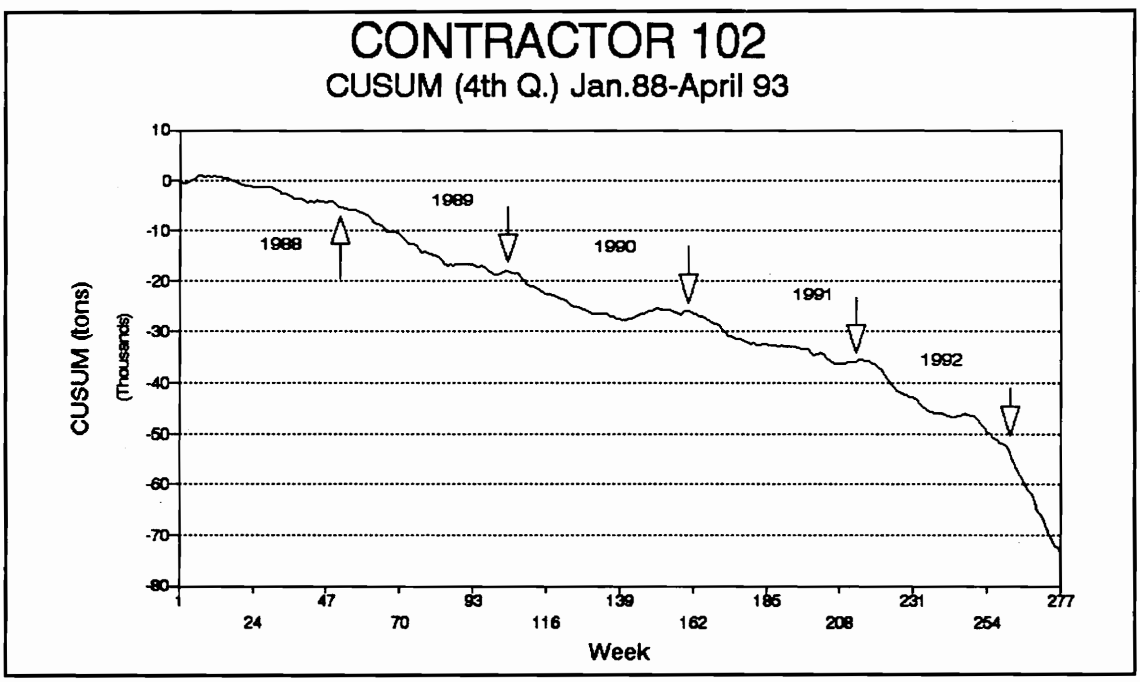

Figure 5.23. Contractor 102's capacity index.

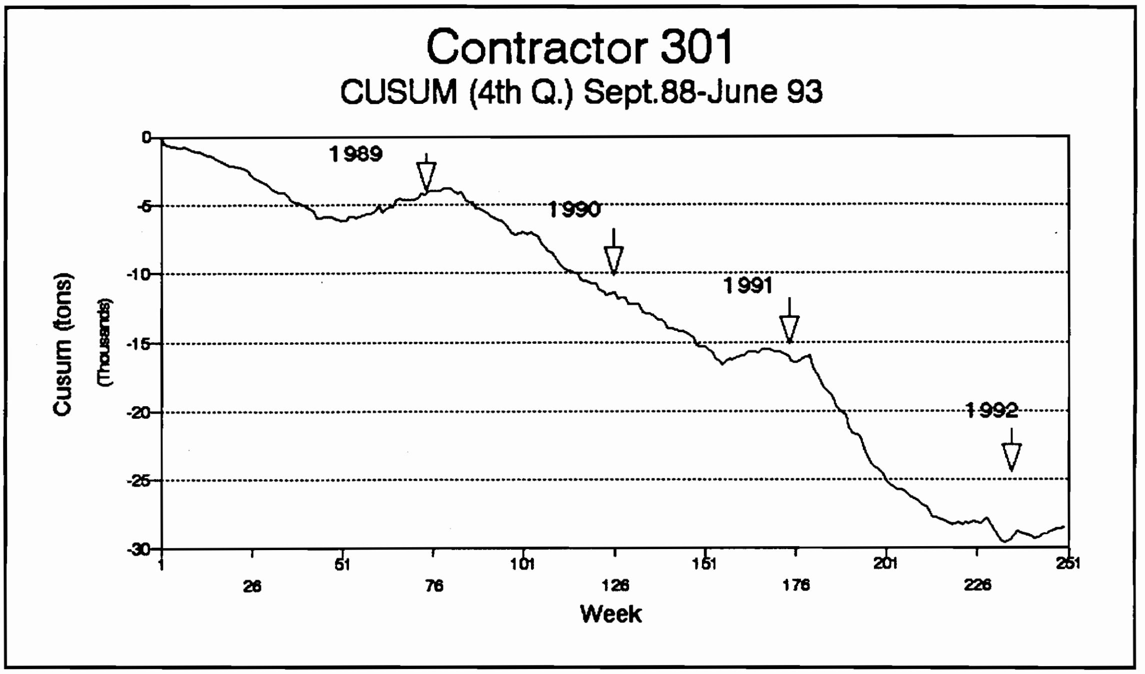

Figure 5.24. Contractor 301's capacity index.

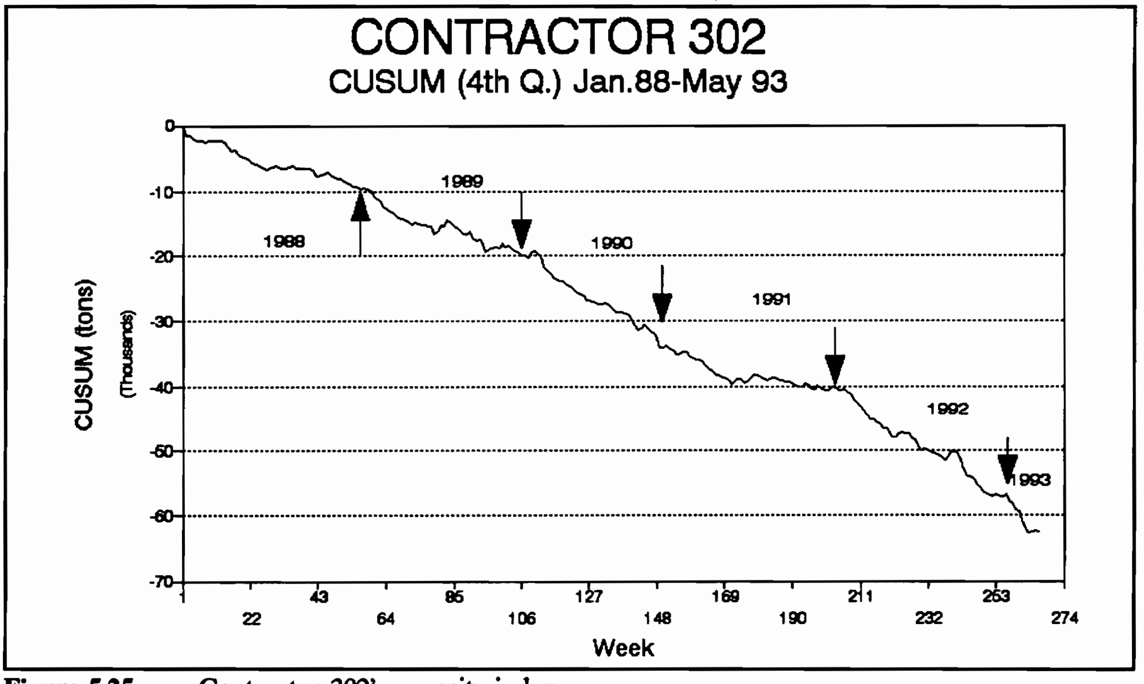

Figure 5.25. Contractor 302's capacity index.

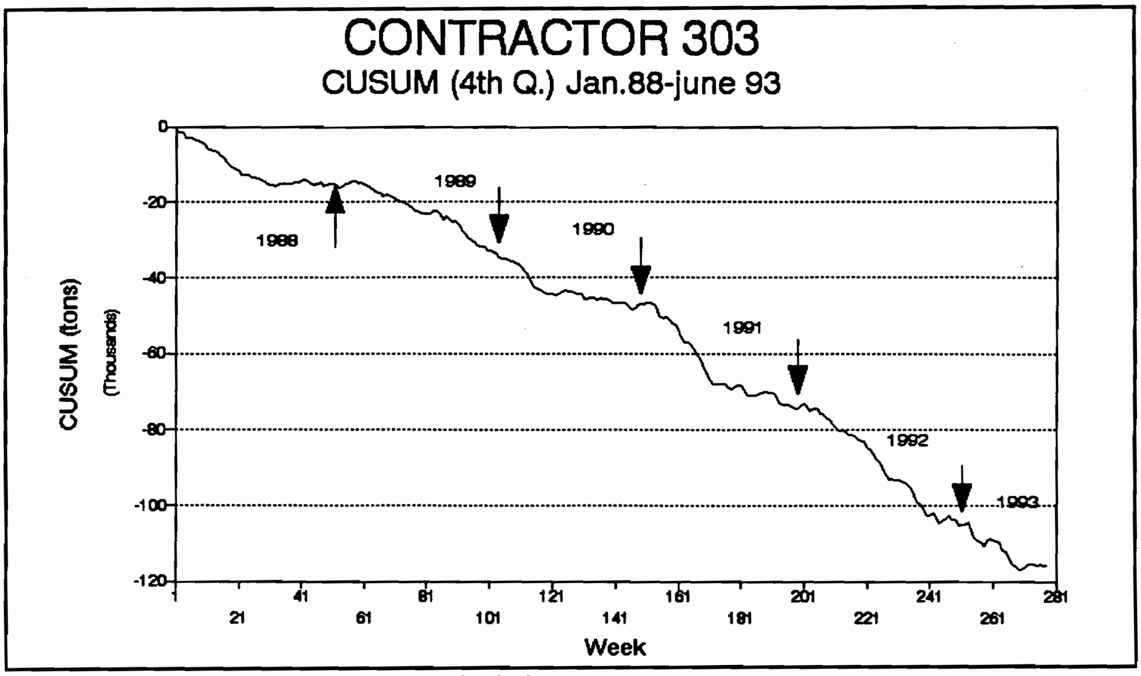

Figure 5.26. Contractor 303's capacity index.

Conclusion

This chapter presented simple tools that could be used to more closely monitor harvesting contractor performance. The long used rule of thumb and the "last year average" approach conveys a great risk of misperception. The information to build control charts and cusum charts has been collected for years in scale houses, on settlements sheets, purchasing organizations' computers, and loggers' records. Few in depth analyses have been done with those data. The possible benefits obtainable with these techniques, and their proven usefulness in other fields should motivate their utilization in wood procurement.

Production charts may serve in production goal setting for individual loggers delivering to an organization. Each logger's maximum production capacity and the condition that permitted it can be traced. They represent a reliable source of information on the inventory of production capacity for an entire wood procurement area. Justification regarding loggers' variable quotas or changing wood orders may get simpler. The information recorded with these techniques is a valuable source to document the impact and cost of new policies such as the BMP's[4]. Over all, these techniques should help ease communication, document variability, and remove some of the "averaging" in wood procurement.

Weekly production variability seemed to be increasing. Loggers were forced to be upwardly elastic to achieve high production levels when conditions were favorable to maintain the same annual production average as in previous years. Weeks with no production have gotten so frequent that they were often considered part of the distribution.

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[4]Data collected for this study proved useful in the South Carolina Forestry Association attempt to estimate cost of BMP's on wood harvesting.

CHAPTER 6. WEATHER EFFECTS

"Brume sur la montagne,
reste dans ta cabane.
Brume dans la vallée,
va travailler."

(Fog on the ridge,
stay in your lodge.
Fog in the valley,
will do great work today.)
Canadian proverb

Introduction

Adverse weather conditions for logging in the South are usually caused by rain. High humidity levels, wind, or extreme temperatures, while annoying, seldom affect productivity of logging crews. The occurrence of snow, sleet, and glaze storms is so rare across most of the region that these events are regarded as adventures rather than problems. High water tables and poor road conditions have a much greater effect on production. A study initiated to document the causes and cost of lost production for modern loggers provided an opportunity to explore the impact of weather on modern, fully mechanized harvesting contractors.

Historical

The impact of rain on logging productivity in the Southeast has been considered a stochastically occurring burden on the industry, an unchangeable factor with which one need learn to live . This is reflected by the scarcity of comprehensive studies on the subject in the literature.

The 30 year old Battelle (Hamilton et al. 1961) report on factors affecting pulpwood production costs and technology in the Southeast is a rare case of large scale research on the subject. Two effects of precipitation were identified by Battelle: the immediate loss of production when logging crews stopped all production due to heavy rain fall, and the lingering effect caused by the inundations of poorly drained harvesting sites. Both were found to have greater impact during the winter months. Evapotranspiration is less during the dormant season, it takes longer for a tract to dry after winter rainfall. The report concluded that in the period from 1955 to 1960, a rain had an effect on that day's deliveries and a lesser influence on the next day's receipts. The effect was minimal after two working days. The "bobtail" truck was a major component of the wood supply system of that era. These three-men-and-a-truck systems were extremely mobile, having the ability to change tracts to accommodate the weather. It was suspected that the long term effect of rain depended on the topographic characteristics of a tract, the region, and the temperature.

Battelle also reported that the time of the day when precipitation occurred had a great influence on production. Rain early in the morning, when the crew was deciding whether or not to work had the greatest effect. The whole day could be lost. Rain in the afternoon or after the crew started work might reduce total output by diminishing traction and hauling speed but some wood could still be delivered. It is worth noting that the Battelle Institute had foreseen the situation where over capacity could build up in trying to overcome the wet periods:

> "If producers are added to the system to meet demand during such shortage, and because weather is reducing production, the producer force could be considerably overbuilt."

The authors then go on by mentioning the consequence of such response by the system:

> "During subsequent periods of better weather, the work week of producers may have to be reduced in order to support all the producers that have been brought into the system."

The quota system to limit production was identified.

In the 30 years since Battelle's report, much has been done to reduce the southern wood supply system's vulnerability to adverse weather. Most of the improvement came not by strategic redefinition of the system but rather as a result of mechanization[1] (Stuart pers. comm. 1993), which has, to a certain extent, aggravated the situation of production overcapacity.

Current

This project offered the opportunity to investigate the impact of adverse weather on today's highly-mechanized/high-production loggers. The loggers provided detailed information concerning their daily production, factors which influenced the level of production, and what their production capacity would have been without downtime. The daily production information provided by the loggers, paired with detailed regional weather reports from the National Oceanic and Atmospheric Administration (NOAA) allowed for a comprehensive analysis of weather effects on logging.

Field Study

Data collection started in May 1992. As the study progressed, adverse weather became the main obstacle to stable production. Most of the participants agreed half way through the winter that it was one of the wettest rainy seasons in memory. The amount of precipitation that fell in each of the areas for the duration of the study is summarized in Table 6.1. While confirming above average precipitation for many months the rainfall data shows that rains were not truly exceptional, only a few monthly totals lay outside three standard deviations of the mean rainfall for that month over the period for which records have been kept.

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[1]As Stuart pointed out (Stuart pers. comm. 1993), much of the mechanization efforts of the last decade have been directed toward making jobs more weather independent.

The impact of BMP's and weather is closely linked to the soil type and topography. The physiographic region in which each logger operated is shown in Table 6.2. These loggers operated in the same general area for most of the study period, a regional soil and relief survey provided details to complement the weather reports. Total monthly precipitation alone could certainly not explain all the differences in production levels of Sand Hill and Coastal Plain loggers. When studying weather effect, a minimal soil and topographic description is indispensable.

A run of several months of above average precipitation, especially during the winter season, usually indicates a period of extremely high water tables. The Atlanta station recorded a run of seven months where the rainfall ranged from slightly above average to double the normal amount. Consequently this region had little time to drain or dry, and logger 101, 102, 105, 401, and 405 all located north of Atlanta showed major losses to weather (Table 6.3). In general, rain had a negative effect on production mainly because of its persistence, particularly between October and December 1992. The negative impact of rain may have been worsened by the increased attention paid to BMP's. Several loggers mentioned that they had to halt operations to avoid running afoul of rutting BMP's in conditions where only a year ago they would have keep on producing.

General trends

Each logger had an individualized strategy to deal with adverse weather. Strategy may be dictated by the region of operation (soil, topography), quality of the road network, financial obligations to be met, procurement organization, availability of wet weather tracts, equipment at hand, and BMP's.

All loggers were affected by adverse weather (Figure 6.3). Rain was the major cause of unproductive time for most. The extent to which they were affected and the ways they adapted were not uniform. In general, contractors from the Southern Appalachian region suffered the heaviest capacity losses, in some cases half of which was due to weather, half to quota. Contractors from the Piedmont and Coastal Plain lost less time but the majority of that time was due to weather. Logger 306 from the Sand Hill region lost only 10% of his estimated capacity. This was the only producer for whom weather was not the most important cause of delays.

There was important variation among loggers of the Piedmont region. Loggers 301 has been doing exceptionally well with only 9% of capacity lost. Logger 105 stands out from the group with a 47% loss of capacity. Because this contractor was operating in areas that extends to both the Southern Appalachian and the Piedmont it was difficult to classified the exact region.

Table 6.1. Total rainfall (in inches) and departure from average.

STATION		1992								1993						Σ
		May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	
Centreville AL	Prec'n	1.1	2.2	6.7	8.2	5.0	1.9	8.3	6.8	5.5	3.6	3.7	3.8	3.9	2.7	63.4
	Δ Avg.	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Huntsville AL	Prec'n	2.5	10.6	6.1	3.4	5.9	2.6	5.2	6.0	4.5	2.8	7.9	3.5	8.3	1.5	70.7
	Δ Avg.	-2.2	+6.9	+1.1	+0.3	+1.9	-0.3	+1.0	+0.6	-0.7	-2.1	+1.3	-1.4	+3.2	-2.6	+7.0
Athens GA	Prec'n	1.5	4.4	4.1	6.2	5.7	2.8	8.3	5.7	4.4	5.0	7.4	2.7	3.2	1.4	62.8
	Δ Avg.	-3.3	+0.4	-1.0	+2.6	+2.1	+0.1	+4.9	+1.6	-0.2	+0.6	+1.9	-1.3	-1.1	-2.6	+4.7
Atlanta GA	Prec'n	1.7	4.1	9.0	5.0	8.6	2.8	10.0	6.4	3.9	4.4	5.7	2.8	4.9	6.0	75.3
	Δ Avg.	-2.3	+0.7	+4.3	+1.6	+5.4	+0.3	+6.6	+2.2	-0.8	-0.4	0.0	-1.5	+0.6	+2.5	+19.2
Wilmington NC	Prec'n	7.6	7.0	3.2	13.6	2.2	3.1	7.1	4.5	5.8	3.0	6.3	5.8	2.8	3.7	75.7
	Δ Avg.	+3.3	+1.4	-4.3	+6.9	-3.5	+0.1	+4.0	+1.1	+2.0	-0.7	+2.5	+2.9	-1.6	-2.3	+11.8
Charleston SC	Prec'n	5.1	6.2	4.4	9.6	3.0	4.9	5.7	1.5	8.9	3.1	5.8	2.7	3.0	3.7	67.4
	Δ Avg.	+0.7	-0.3	-3.0	+6.5	-1.9	+2.0	+3.6	-1.6	+5.5	-0.2	+1.5	+0.1	-0.7	-2.7	+9.5
Columbia SC	Prec'n	1.9	6.4	2.2	9.6	4.6	4.2	4.0	3.3	7.5	3.1	6.0	1.6	3.0	0.7	58.1
	Δ Avg	-1.9	+1.9	-3.2	+4.1	+0.4	+1.7	+1.5	-0.2	+3.1	-0.2	+1.2	-1.7	-0.7	-4.1	+1.9
Chattanooga TN	Prec'n	2.0	8.9	5.3	3.1	4.7	4.5	5.9	5.6	5.2	3.7	7.4	3.3	3.4	1.6	64.6
	Δ Avg.	-2.0	+5.6	+0.8	-0.3	+0.4	+1.6	+1.7	+0.5	+0.3	-1.1	+1.37	-1.0	-1.0	-1.9	+5.2
Lynchburg VA	Prec'n	6.0	1.9	3.3	1.5	4.1	1.8	5.6	3.5	4.1	3.6	7.0	3.6	2.2	2.3	42.3
	Δ Avg.	+2.3	-1.6	-0.6	-2.2	+0.9	-1.6	+2.7	+0.3	+1.3	+0.6	+3.5	+0.5	-1.7	-1.1	+3.3

Table 6.2. Physiographic region and soil type.

LOGGERS (Per Land Resource Region)	Topography and Parent Materials
1) Southern Piedmont 104, 105, 301, 307	Relief: Gently rolling to hilly. Acid and basic crystalline rocks. Relief: Sloping to hilly. Schists.
2) Southern Appalachian Ridges and Valleys 101, 102, 401, 403, 404, 405	Relief: Gently rolling to steep. Limestone, shale and sandstone. Relief: Rolling ridges and steep slopes. Sandstone, shale and cherty limestone.
3) Sand Mountain 402	Relief: Gently sloping to steep mountain slopes. Sandstone, limestone and shale.
4) Southern Coastal Plain 201, 202, 203, 205, 206	Relief: Gently sloping ridges and steep slopes. Marine sand, sandy clay and clay. Relief: Gently rolling. Marine sand, sandy clay and clay.
5) Coastal Plain 302, 303, 305 304 503	Relief: Nearly level to gently slopping. Marine sand and sandy clay. Relief: Nearly level to gently slopping. Marine and sandy loam sediments. Relief: Level to sloping. Sandy coastal plain sediments. Relief: Nearly level to gently sloping. Marine sand, sandy clay & clay. Relief: Nearly level. Marine sediments. Relief: Nearly level to gently sloping. Clay and marine sediments.
6) Sand Hills 306	Relief: Gently sloping to hilly and broken. Sandy and loamy Coastal Plain sediments.

Table 6.3. Impacts of weather on studied loggers.

LOGGER #	REGION	% OF CAPACITY LOST	% LOST TO RAIN
101	Appalachian	37	56
102	Appalachian	41	65
401	Appalachian	46	43
403	Appalachian	25	52
404	Appalachian	22	16
405	Appalachian	33	54
104	Piedmont	22	73
105	Piedmont	45	76
301	Piedmont	9	43
307	Piedmont	19	77
402	Sand Mountain	42	72
306	Sand Hill	10	17
201	Coastal Plain	28	84
202	Coastal Plain	30	88
203	Coastal Plain	23	84
205	Coastal Plain	16	94
206	Coastal Plain	24	89
302	Coastal Plain	31	81
303	Coastal Plain	34	86
304	Coastal Plain	32	66
305	Coastal Plain	31	91
503	Coastal Plain	33	75

Go/No-Go

A majority of loggers have a distribution of daily production that is bimodal, with one peak at zero - days with no production - and a second peak at their most frequent production level. These two peaks also represent two distinct business states: a go, and a no-go level. The go level covers every day when the logger attempts to produce; The crew is called out and the equipment is running, both fixed and operating costs must be covered by production. In the no-go condition the logger does not attempt to produce. There are no revenues, but the expenses are also considerably reduced.

If the bimodal characteristic of these distributions is ignored when calculating an arithmetic average as a measure of job potential, the value obtained will fall between the two modes, a level that the contractor seldom achieves (Figures 6.1 - 6.3). A procurement organization attempting to establish a production goal for their logging force should be careful to avoid inappropriate application of the average.

Loggers with upward elasticity had a distribution that was skewed to the high end. The upward elasticity was the result of sufficient excess capacity to increase production when the opportunity was presented. The loggers with this characteristic usually pushed their operation to a maximum production level when conditions permit. These high production days allowed them to recoup the losses suffered on the days lost to bad weather. Logger 302, 303, and 304 were good examples of this characteristic (Figures 6.1, 6.2, and 6.3). Approximately 30% of the available productive days were totally lost for these contractors and each had maximum sustainable production levels of 150 to 175% of their modal production.

Contractors 302 and 303 had similar distributions of days lost to rain (Figures 6.4 and 6.5). Contractor 304 had recently invested heavily in new high flotation equipment to aid compliance with BMP's. Faced with high payments, the contractor could not remain idle for long. This logger tended to "fight" adverse conditions more than the other two by working on days where they stayed home. Consequently there were a large number of days worked where production fell short by four to ten loads (Figure 6.6).

Weather Resistant Loggers

Some loggers were not as affected by rainfall as others. Differences may be explained by less rain or fewer heavy storms, different soil composition, strategic planning, or a combination of all these factors.

Logger 306 operated in South Carolina's Sand Hills, and did not lose a single day due to adverse weather[2] (Figure 6.7). The deep sandy soils of the region drain rapidly, and strategic planning played an important role. Forest roads usually crossed valleys and low areas and would not allow hauling in wet conditions; The roads "went out" before the woods became inoperable. To circumvent this problem, logger 306 was provided with several tracts to move among. Frequent changes allowed maintenance of production. This logger moved the operation 39 times in 39 weeks. Moves resulted in loss of one to seven loads on those days when weather conditions precipitated a move (Figure 6.8).

Of all loggers studied, contractor 301 had the most constant production output (Figures 6.9 and 6.10). This contractor operated in the Piedmont and had a couple of weeks on quota in the summer, before he was allowed to produce wide-open. During wet periods output was close to estimated capacity. Availability of winter tracts in the operating area may, in part, explain the excellent performance.

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[2]Four days were lost to holidays.

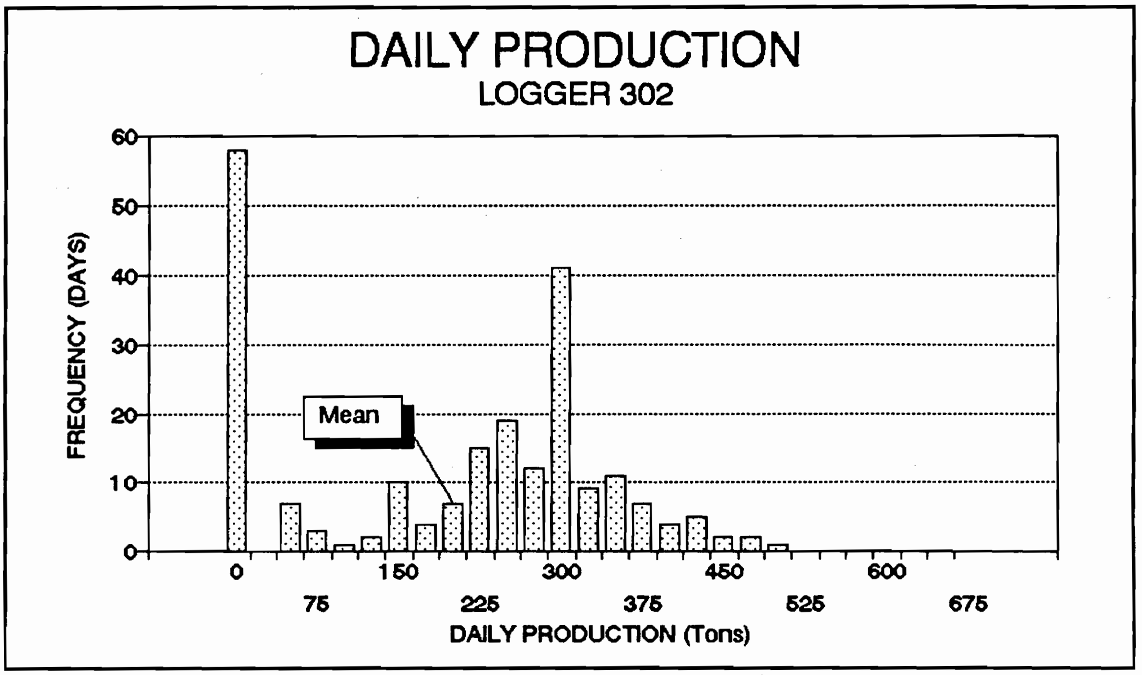

Figure 6.1. Logger 302's daily production frequency distribution.

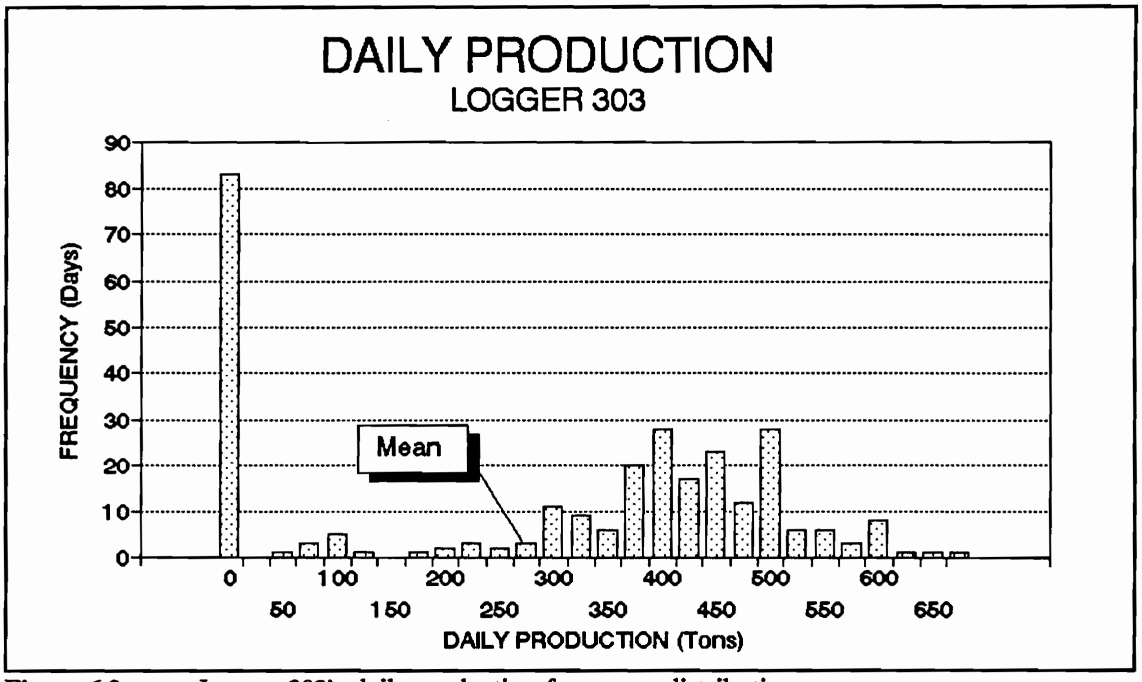

Figure 6.2. Logger 303's daily production frequency distribution.

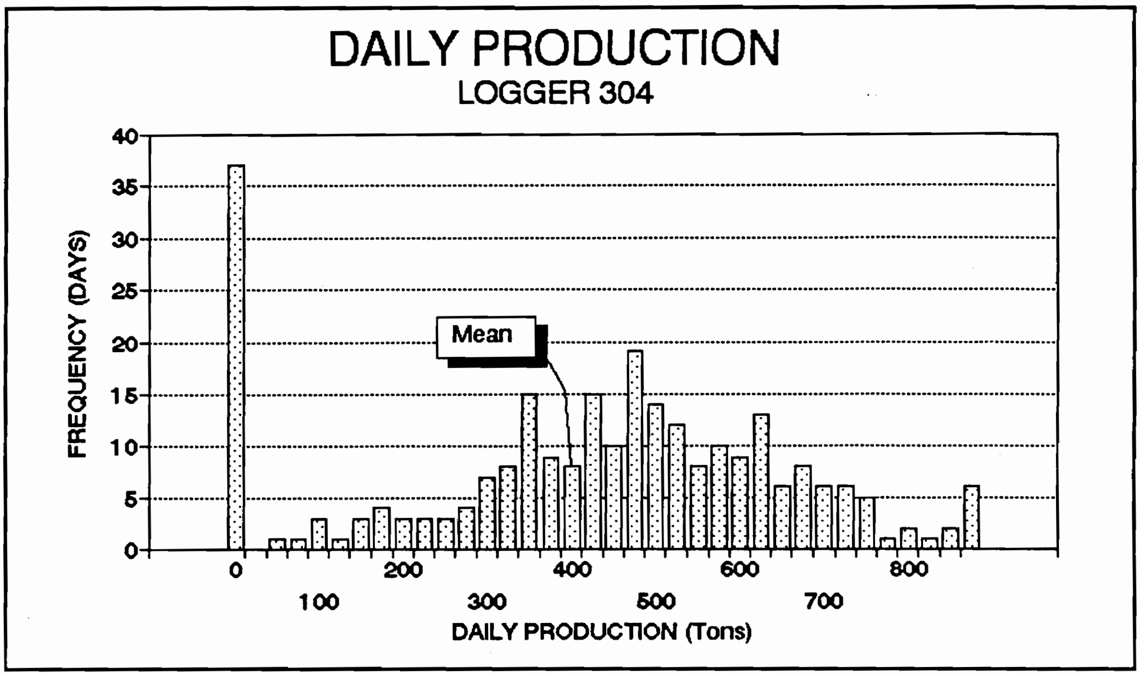

Figure 6.3. Logger 304's daily production frequency distribution.

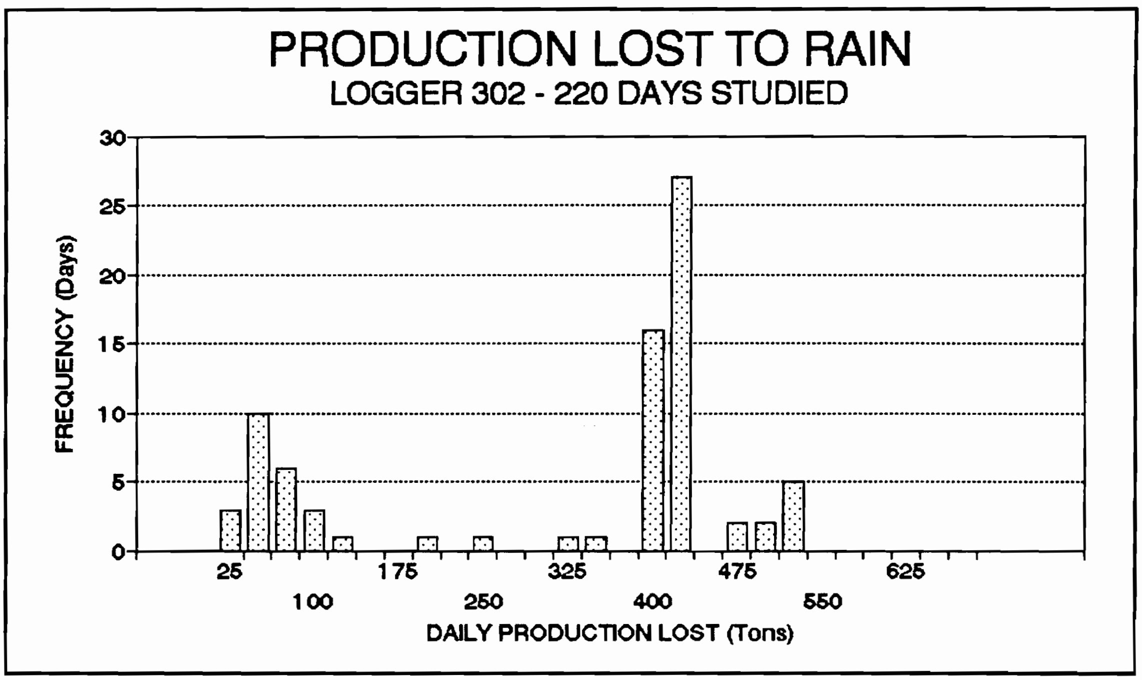

Figure 6.4. Logger 302's daily production lost to rain frequency distribution.

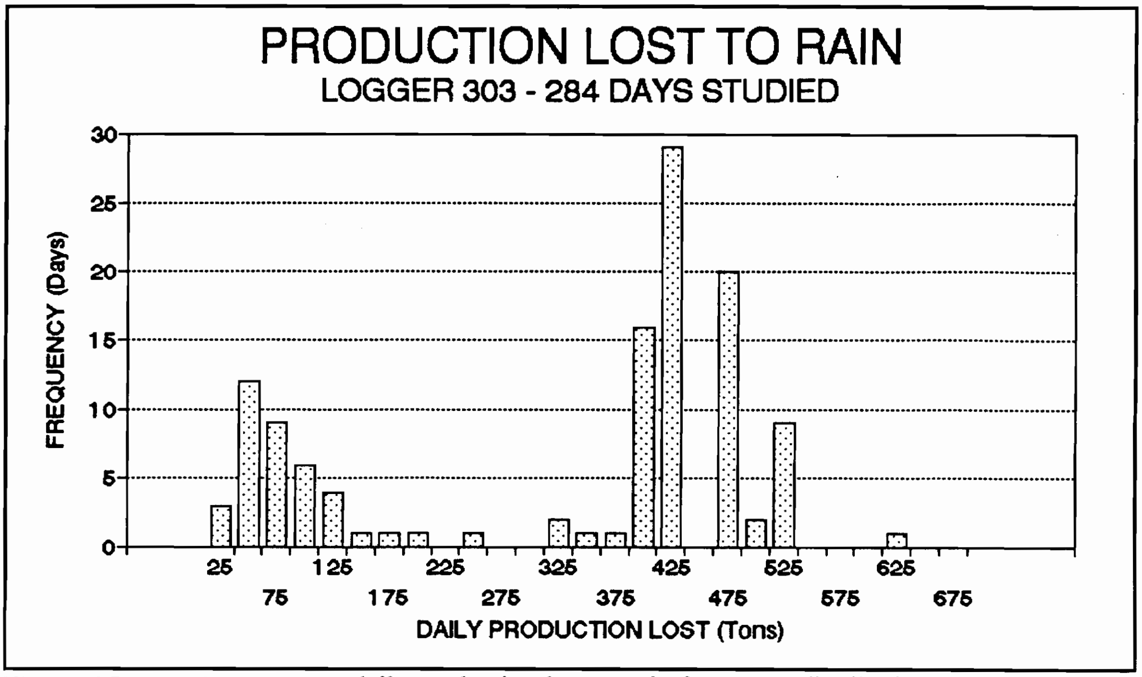

Figure 6.5. Logger 303's daily production lost to rain frequency distribution.

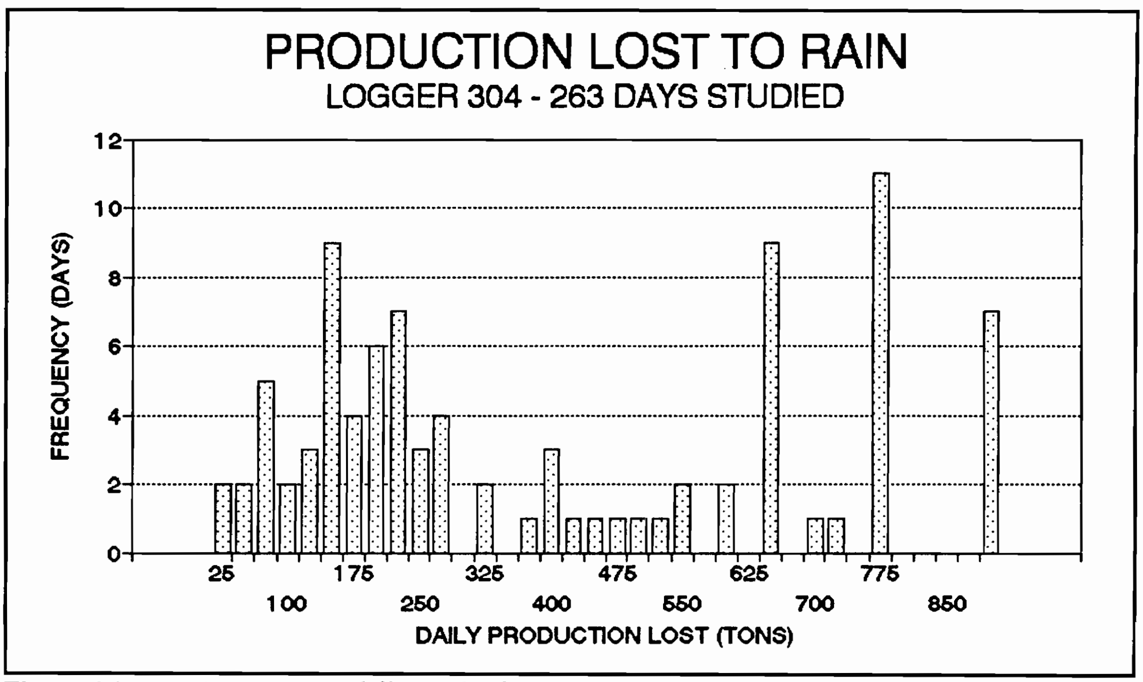

Figure 6.6. Logger 304's daily production lost to rain frequency distribution.

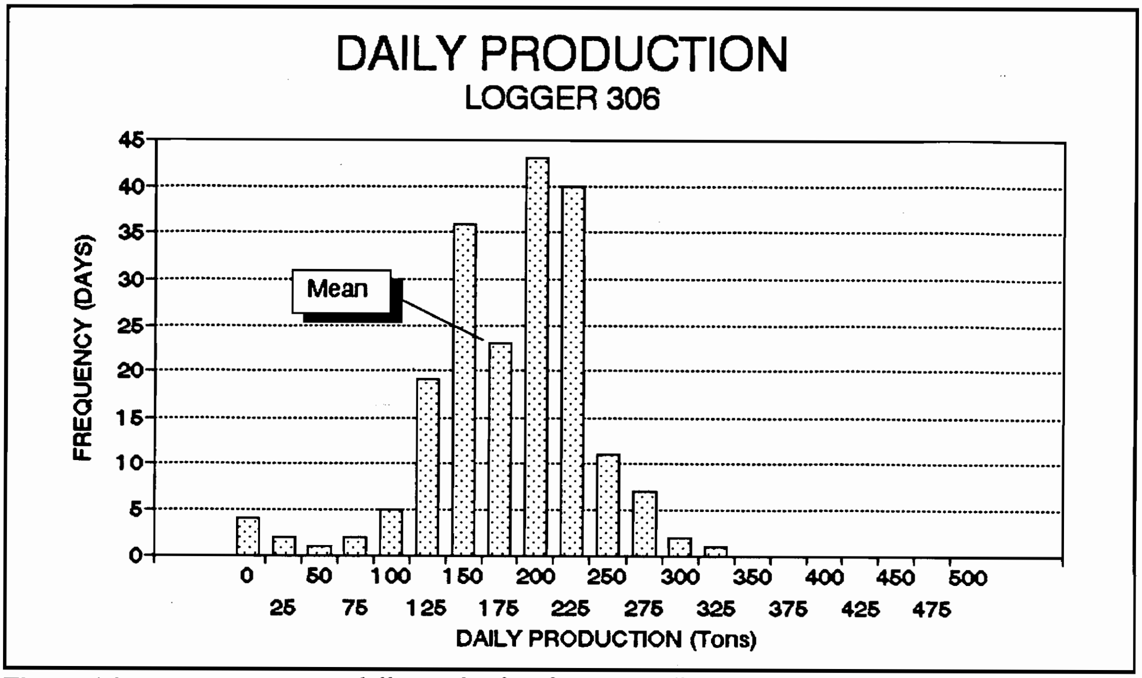

Figure 6.7. Logger 306's daily production frequency distribution.

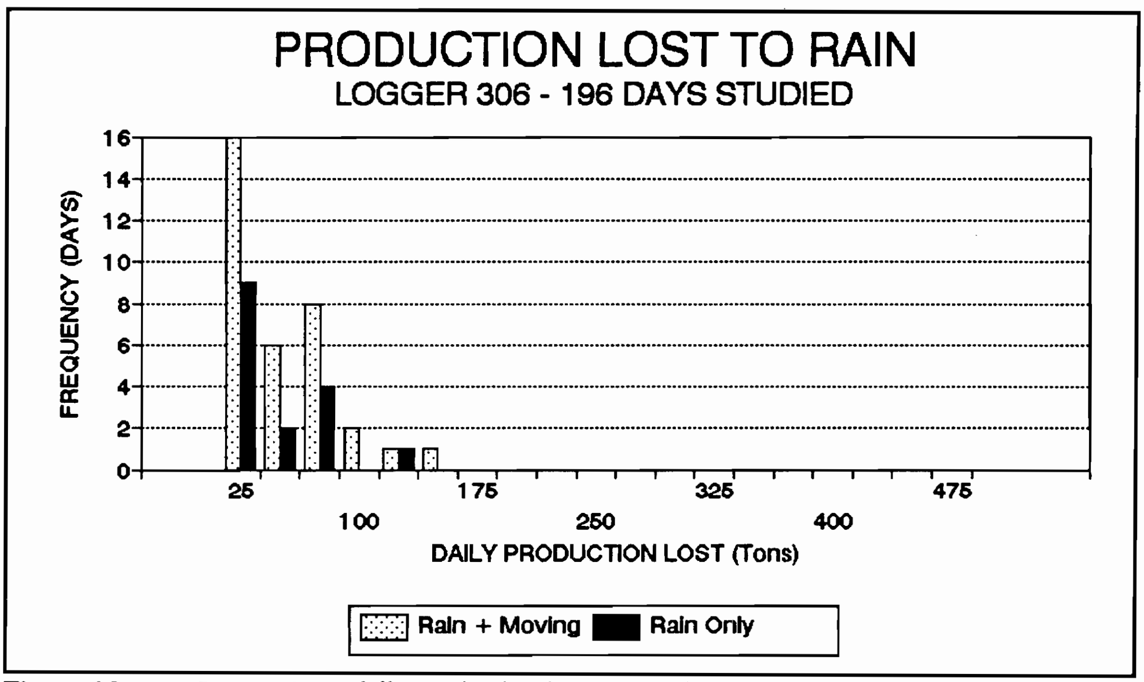

Figure 6.8. Logger 306's daily production lost to rain frequency distribution.

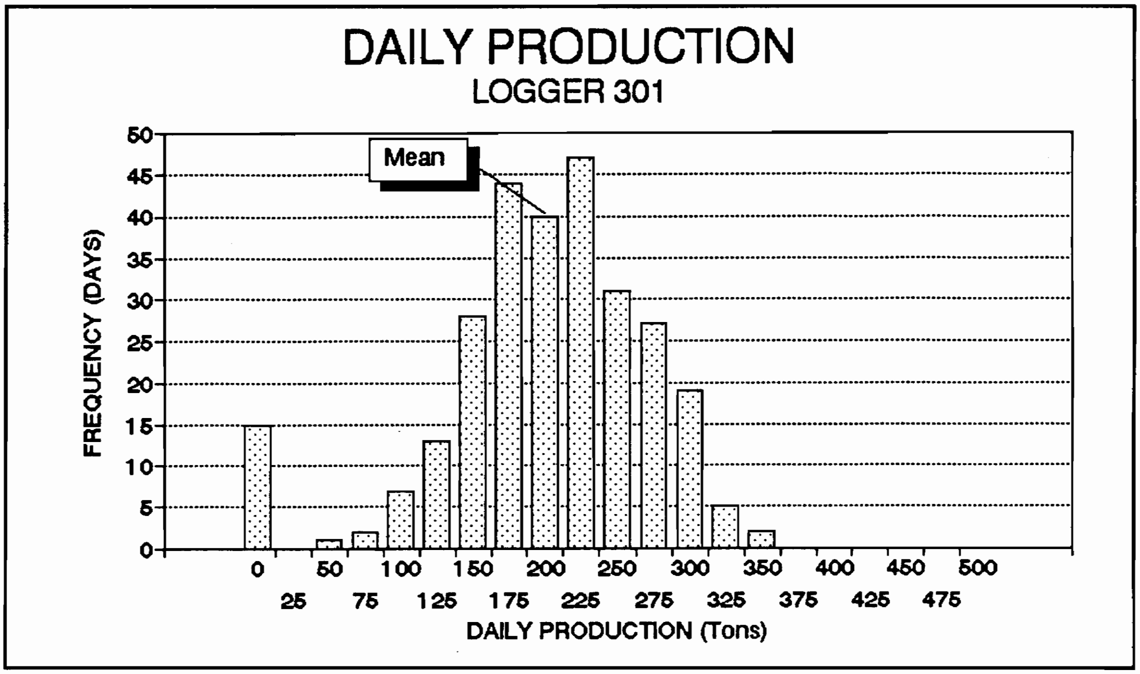

Figure 6.9. Logger 301's daily production frequency distribution.

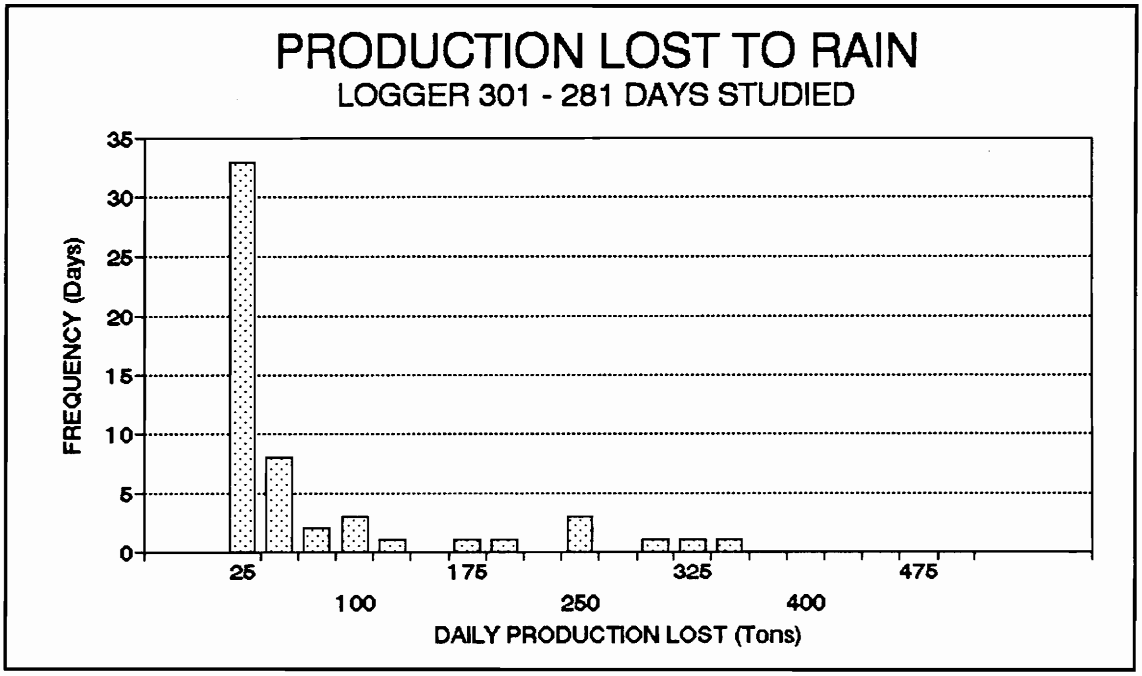

Figure 6.10. Logger 301's daily production lost to rain frequency distribution.

Weather Effects Compared with Other Production Inhibitors

Earlier, an hypothesis was put forth that a contractor would not operate on those days when rain would slow production. They would either operate at maximum speed or not start operations at all. This hypothesis was tested by comparing the cumulative probability function of what the logger did with the cumulative probability function of the hypothetical "no-rain effect" production. Only worked days were considered in the analysis. The no-go days, mostly caused by rain, were excluded because they represented a different population, a different stage for the business with costs different from those experienced during a normal operating day. What is left are all the other productive days where rain slowed production. The cumulative probability function for the actual production (what the logger did) was compared with the cumulative probability function of the hypothetical "no-rain effect" production. If the operations worked only those days when weather would have little impact, the distributions of actual daily production for worked days should not be significantly different from the distribution of production formed by adding the contractor's estimate of volume lost to rain to the volume actually produced on days when weather affected but did not rule out production.

A Kolmogorov-Smirnov test (Hollander 1973) was performed to test for a difference between these distributions. Contractors 301 (Figure 6.11) and 303 (figure 6.12), for example, displayed no significant difference between the two distributions at an alpha level of 5% ($\alpha = 0.05$), confirming the hypothesis that these contractors only operated on those days they could achieve full productivity. Significant differences were found for other loggers (Figures 6.13, 6.14). The difference came from their attempts to "fight" weather. In wet conditions they tended to keep producing as long as it is physically possible, losing partial days productivity. A summary of the results for all loggers tested on this hypothesis is provided (Table 6.4). The region of operation did not seem to impact on the test. Three Appalachian loggers with low wood orders had similar actual and hypothetical distributions (Fail to reject). These loggers can usually get their quota within three days, two extra days are therefore available to make up for lost production due to weather.

Table 6.4. Kolmogorov-Smirnov test for a difference between distribution of actual production (A) with the hypothetical no rain effect (B). H_0: A = B ($\alpha = 0.025$).

Loggers	Region	Maximum A-B	Test statistic	Decision
101	Appalachian	0.21	0.12	Reject
102	Appalachian	0.22	0.12	Reject
401	Appalachian	0.12	0.15	Fail to Reject
402	Appalachian	0.19	0.13	Reject
403	Appalachian	0.20	0.12	Reject
404	Appalachian	0.12	0.16	Fail to Reject
405	Appalachian	0.16	0.19	Fail to Reject
104	Piedmont	0.07	0.18	Fail to Reject
105	Piedmont	0.35	0.13	Reject
301	Piedmont	0.03	0.12	Fail to Reject
306	Piedmont	0.03	0.13	Fail to Reject
307	Piedmont	0.28	0.13	Reject
201	Coastal Plain	0.20	0.12	Reject
202	Coastal Plain	0.36	0.13	Reject
203	Coastal Plain	0.21	0.12	Reject
206	Coastal Plain	0.18	0.15	Reject
302	Coastal Plain	0.18	0.15	Reject
303	Coastal Plain	0.11	0.12	Fail to Reject
304	Coastal Plain	0.22	0.12	Reject
305	Coastal Plain	0.19	0.17	Reject

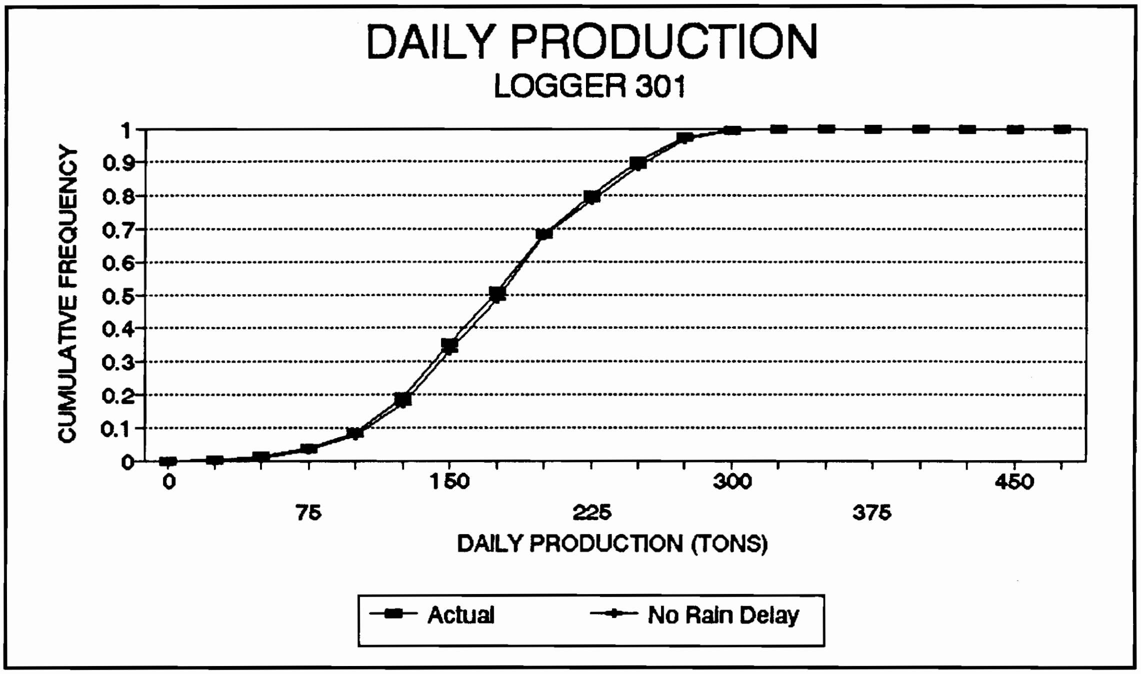

Figure 6.11. Logger 301's cumulative frequency distribution of actual production and hypothetical no rain effect.

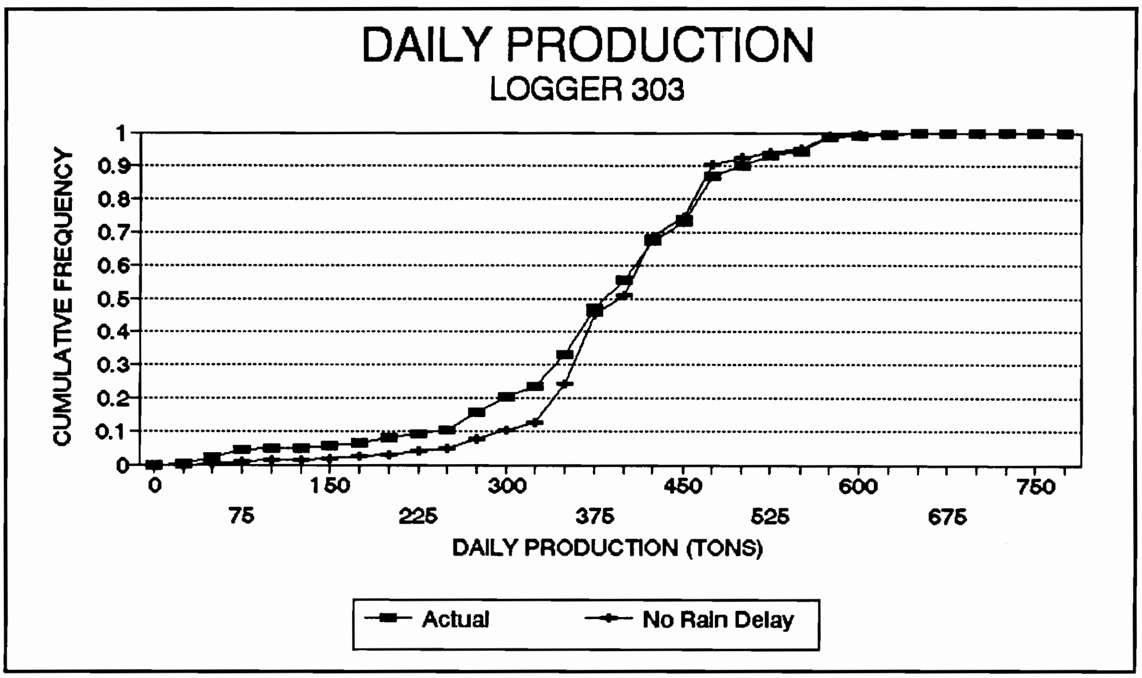

Figure 6.12. Logger 303's cumulative frequency distribution of actual production and hypothetical no rain effect.

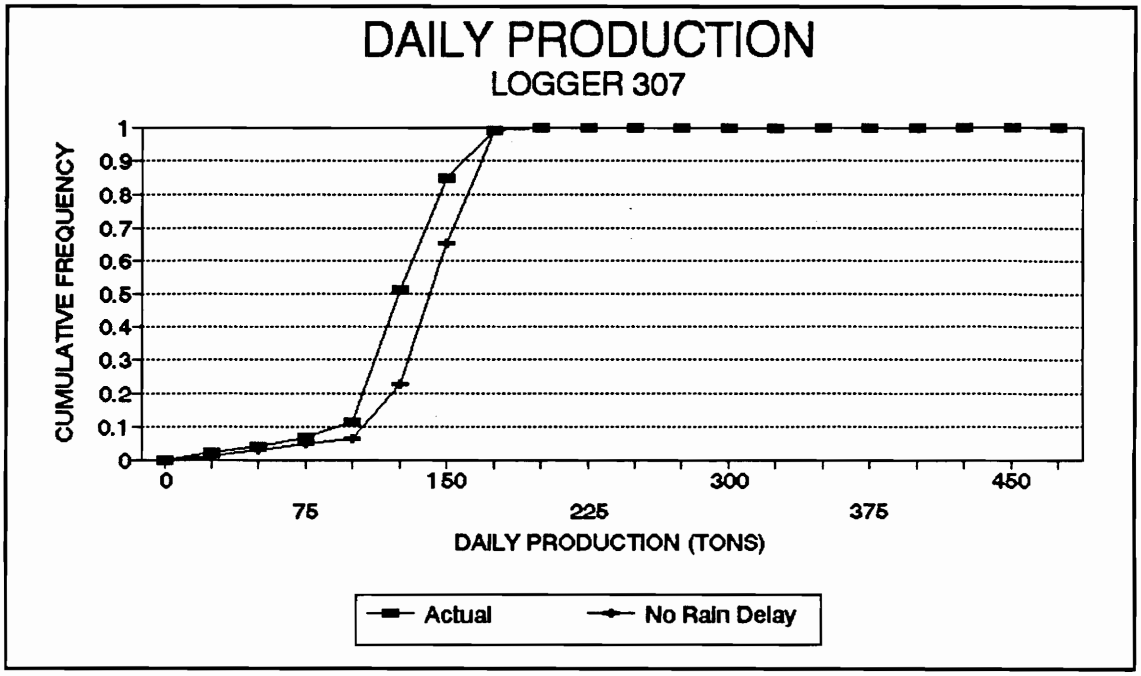

Figure 6.13. Logger 307's cumulative frequency distribution of actual production and hypothetical no rain effect.

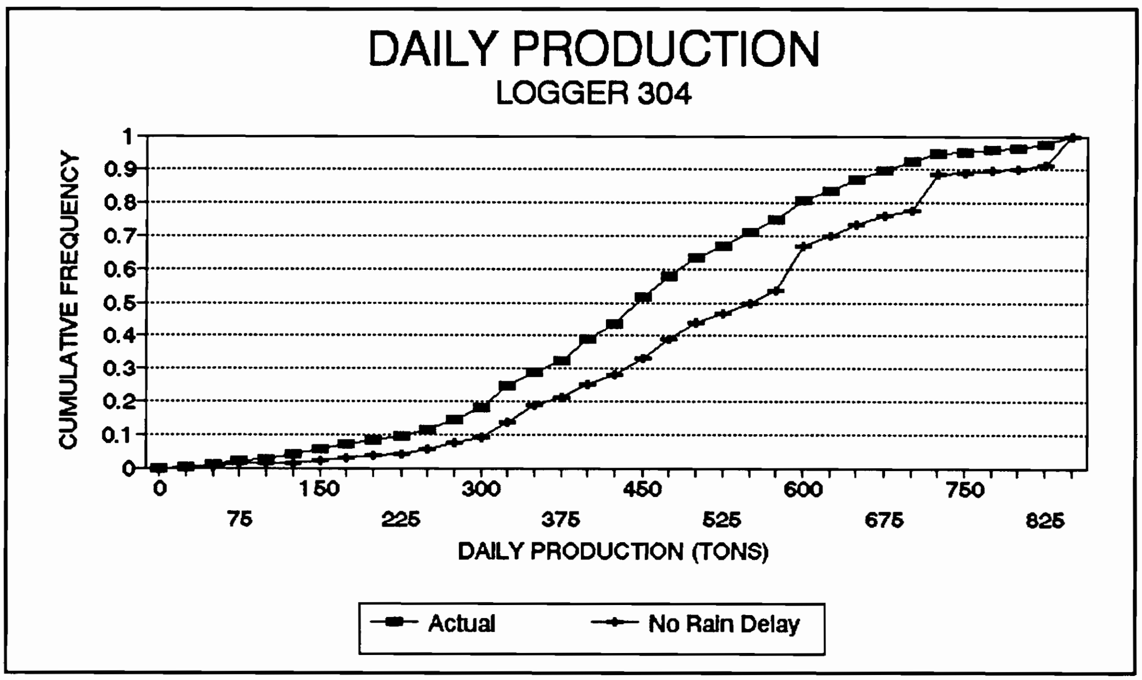

Figure 6.14. Logger 304's cumulative frequency distribution of actual production and hypothetical no rain effect.

Seasonal Variations

The wood supply system shows the greatest vulnerability to rainfall during the dormant season because of weather patterns and lower evapotranspiration. The effects of rainfall are highlighted in Figures 6.15, 6.16, 6.17, and 6.18. It was suspected that an inch of rain in the winter will have greater negative impact than the same amount when evapotranspiration is higher. In fact, what is expected to be a deterministic relation appears stochastic in some instances. Product demand, inventory level, and availability of winter tracts modify the wood supply system's response to environmental stimuli. Logger 307 (Figure 6.18) followed the expected relationship between rain and production. The trend was not as obvious for loggers 301 and 303 (Figures 6.15, and 6.16). Exogenous factors must have changed in January to modify the impact of precipitation on production. Availability of winter tracts was suspected to have contributed to avoiding major losses in the dormant period. The Christmas holidays mark the start of the traditional "wet season". Wet weather tracts reserved for this period are commonly made available. Mill inventory may have been low which led procurement to encourage loggers to continue to produce despite the risk of soil disturbance, the cost of soil remediation being less than that of a mill outage. The American Pulpwood Association statistics on consumption and inventory for the period tend to confirm the latter hypothesis (A.P.A. 1993). In December 1992 and January 1993 mill consumption reached its highest level in two years, at the same time inventories were diminishing. Forecasting favorable demand, the wood procurement department may have judged the situation critical enough to provide premium tracts to their contractors.

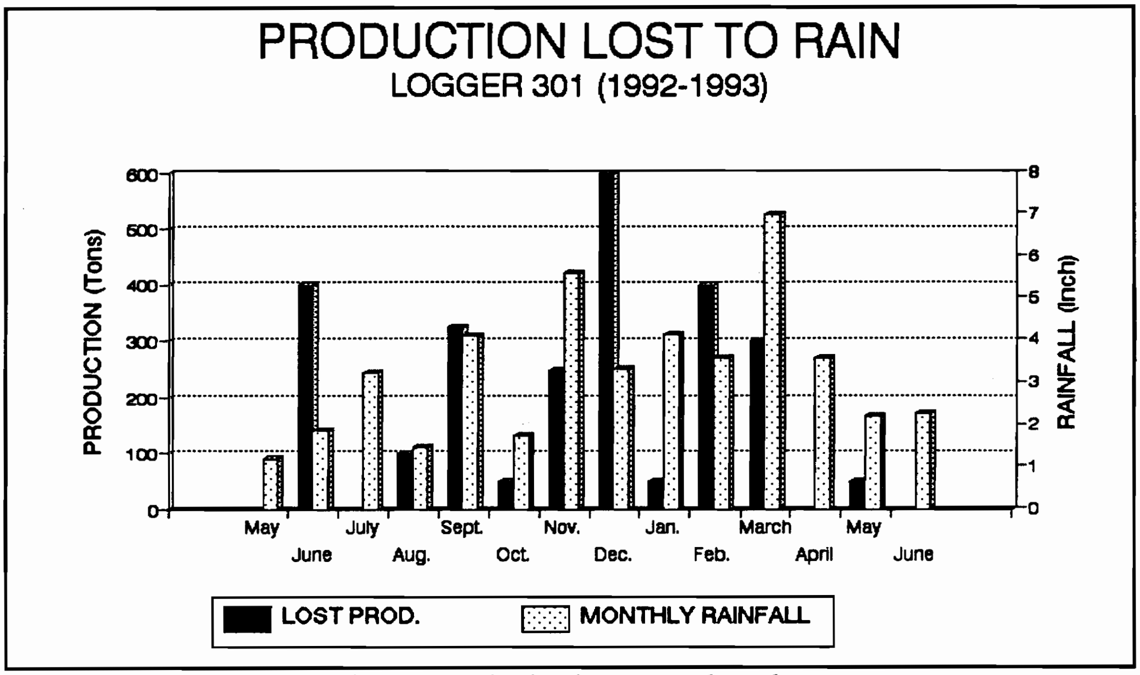

Figure 6.15. Monthly rainfall and production lost to weather - logger 301.

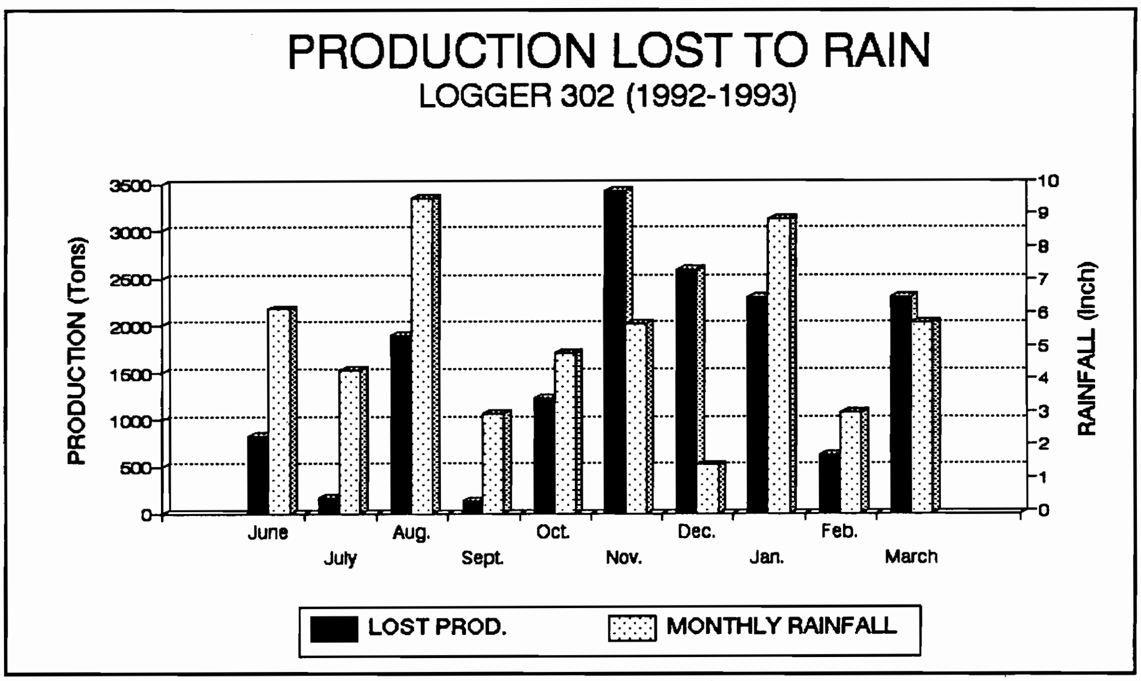

Figure 6.16. Monthly rainfall and production lost to weather - logger 302.

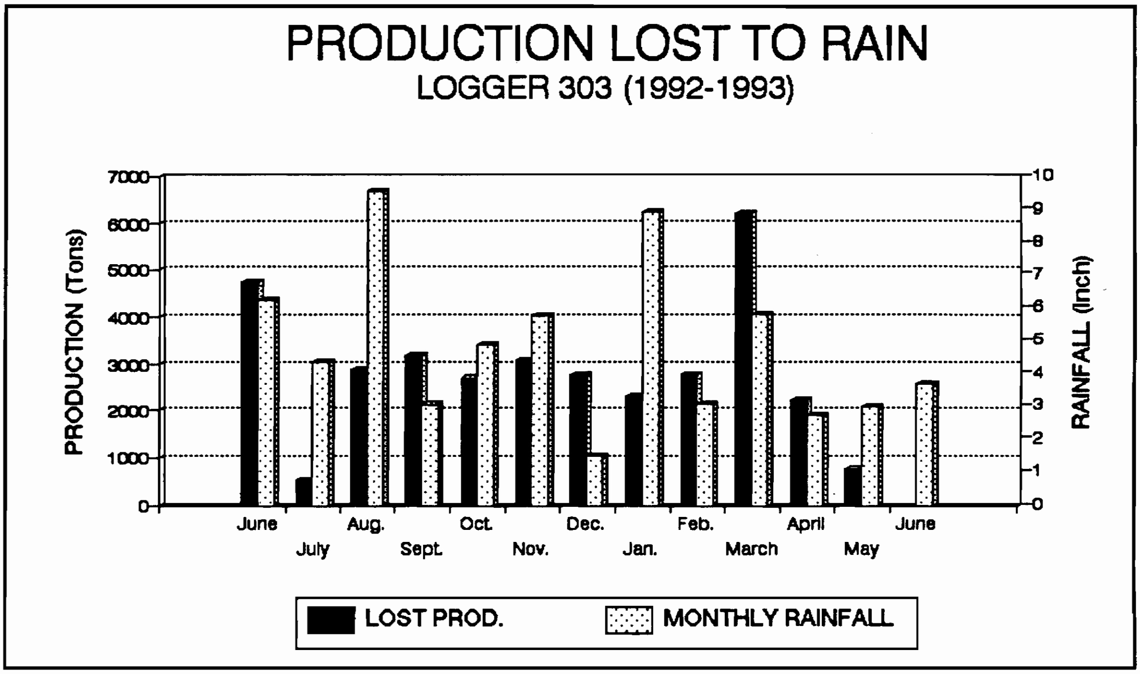

Figure 6.17. Monthly rainfall and production lost to weather - logger 303.

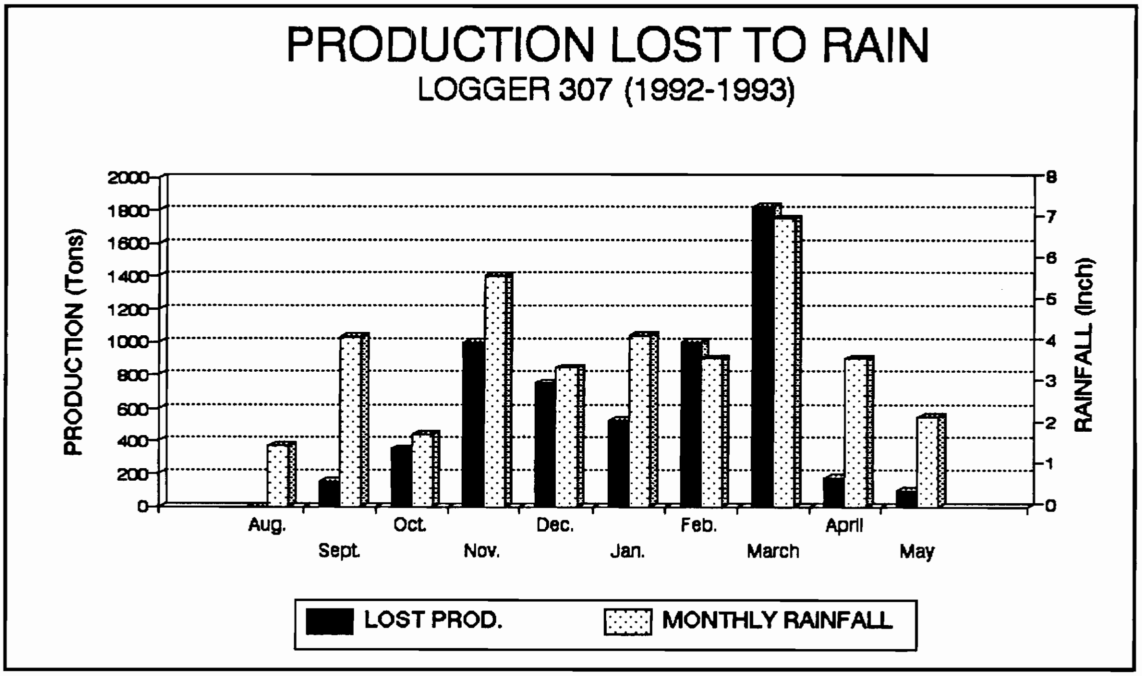

Figure 6.18. Monthly rainfall and production lost to weather - 307.

Many of the regions included in the study receive a large percentage of their annual precipitation during the dormant season. Water saturates the ground and the lingering effect on forest harvesting is most acute. Total rainfall in December, January and February 1993 were above average. The precipitation received during the dormant season is detailed in Table 6.5. The historical averages (NOAA 1988) were used to verify rainfall in December, January, and February. A proportional or uniform distribution would give 25% (3/12 months). Four stations, Lynchburg, Athens, Atlanta, and Columbia have an average close to this value. Three were below average, three above. That proportion was then calculated for the study period. All but one station had a proportion greater than 25%. Compared with the station average, only two stations received less rain during the past dormant season.

Table 6.5. Percentage of rain received during the dormant season (December, January, February).

METEOROLOGICAL STATION	Historical Averages		Observed (Study Period)		Δ %
	Inch	%	Inch	%	
Birmingham AL	14.44	28%	15.90	31%	3%
Huntsville AL	16.39	30%	13.30	24%	(6%)
Athens GA	13.1	27%	15.14	31%	4%
Atlanta GA	13.57	27%	14.70	29%	2%
Wilmington NC	10.58	20%	13.13	25%	5%
Charleston SC	9.81	19%	13.50	26%	7%
Columbia SC	11.87	24%	13.90	28%	4%
Chattanooga TN	15.03	29%	14.50	28%	(1%)
Lynchburg VA	9.15	23%	11.20	28%	5%

A look at the total annual precipitation for the past five years at some stations highlight the yearly variability (Table 6.6). As it is often the case, the average can be misleading. A "normal" year is a composite of past precipitation. Deviations from that value are to be expected. The only time Atlanta received annual precipitation close to its average was in 1991, for Charleston it was in 1992, and for Lynchburg it dates back to 1988.

Wood supply systems have been periodically plagued by wet years and will continue to be. The current harvesting technology, with adequate planning, is capable of coping with these wet periods. Overbuilding production capacity is not as imperative today as it once was.

Table 6.6. Total rainfall (in inch) for 1988, 1989, 1990, 1991, and 1992.

Station	1988	1989	1990	1991	1992	Mean[1]
Atlanta	32.4	59.09	49.71	37.61	59.96	40.74
Charleston	42.57	55.72	45.13	45.13	53.90	51.59
Lynchburg	45.85	63.31	57.56	37.61	40.41	48.79

[1] Historical mean as collected at the weather station.

Summary

Weather will continue to complicate harvesting. Stricter BMP regulations may affect harvesting even in drier seasons and could bring the wood procurement to a crisis level during wetter than normal year. Foresters are not totally at the mercy of weather. Suppliers equipped with proper machinery are usually able to produce in conditions where others would cause severe damage. Harvesting contractors are expected to continue to move toward equipment that minimizes soil disturbance. Changes may occur in drive-train design and machine suspensions (Stuart and LeBel 1993). Although suppliers using special machinery require a higher production level to pay for these new machines, the benefits of not running out of wood and avoiding emergency procurement actions should justify this approach. Elasticity to take advantage of those days when conditions are favorable and mobility to move quickly from tract to tract will be key elements in future system design.

It was frequently reported by loggers that they were forced to move off a tract solely because a short stretch of road was making it impossible to haul the wood. Upgrading roads, especially on company tracts might represent an alternative to the cost of managing several logging jobs. Better roads could allow a more constant flow of wood in wet periods. A more predictable wood flow would help in controlling wood yard inventory while still permitting loggers to smooth weekly production. Finally, being able to move among several tracts seemed to pay off for logger 306. Few loggers can enjoy similar situation. It was reported by several logging contractors that they, too frequently, have no idea where the next tract will be. A Coastal Plain wood dealer involved in the study wished the organization could afford to line up two or three tracts ahead of each loggers: *"I know it would make their (the loggers) life a lot easier, but unlike the large organization we just don't have the capital to do it, at least not a year ahead of time."* He added that during the winter months they will try to provide an alternative tract to their larger contractors.

It was mentioned earlier that very little work on the impact of adverse weather on the Southern wood supply system was available. It is difficult to isolate a single factor to obtain a deterministic relationship. It does appear however that an holistic approach to the problem yield important knowledge on the dynamic of this complex system.

CHAPTER 7. SUMMARY AND CONCLUSIONS

Summary

Daily production data was obtained from twenty three independent contractors. The quantitative information collected include the logger's estimate of maximum production based on the tract's characteristics (distance to markets, soil roughness, and timber quality). Contractors recorded their actual daily production and provided explanations when actual production was less than estimated production. Weather, quota, mechanical problems, and labor problems, were the most frequent production inhibitors. When possible, a procurement forester working with the logger was asked to provide an estimate of the contractor capacity. Daily rainfall information was obtained to document the impact of adverse weather on logging. Loggers' estimates proved to closely reflect the operating conditions and were used to estimate capacity utilization.

The loggers' median capacity utilization was 70% for the period studied. Significant differences in utilization were found between physiographic regions: Piedmont contractors enjoyed the highest utilization ratios. The median utilization value is 81%. Coastal plain harvesting contractors followed with a median capacity utilization of 70%. Lowest capacity utilization was obtained for loggers operating in the southern Appalachian region. The median utilization for that group is 63%. Loving's (1991) results yielded similar ranking for the three regions but median values were slightly lower. High demand for hardwood, wet weather tract harvesting, and high demand for lumber may have significantly reduced loggers' maximum capacity level, making it easier to achieve full capacity.

This study focused on developing techniques to define a range of capacity levels for the logging force. Ignorance of capacity level may lead to the use of "outside" suppliers and cause financial difficulties to the regular contractors.

Rain was found to have most impact on southern harvesting contractors during this period among all factors affecting production. Roads conditions rather that in-wood conditions were frequently reported as the main obstacle to higher productivity. All loggers were affected and losses to weather accounted for up to 30 percent of their maximum capacity. Computation of a deterministic relation between rain and lost production proved to be irrelevant due to the system complexity. Strategies adopted by loggers to minimize the impact of rain on harvesting operations were identified. A first group of contractors adopted a "Go/No Go" approach. Loggers opting for this strategy ceased production when conditions were such that only a marginal portion of their capacity could be used. Usually upwardly elastic, these loggers pushed their operation to a maximum production level when conditions permitted. Their distribution of daily production was bimodal, with a peak at zero (days with no production), and a second at their most frequent production level. Average based statistics did very poorly in estimating production capacity of loggers using this strategy.

In other circumstances, some contractors attempted to work every day it was possible to get a load of wood. Losses were taken as they came. This approach was usually characteristic of loggers facing important payments on their equipment. They could not afford long period of idleness without income. It is important to distinguish between these two types of loggers. Wood procurement organizations must be able to identify or help define these strategies to maintain a balanced and stable logging force.

Two loggers did exceptionally well with regard to weather losses. In both cases winter tracts availability seemed to be the key factor. For one of the two, several tracts were made available to move among. When operations became impossible on one site, the equipment was moved to a different tract and deliveries resumed. Excellent capacity utilization was obtained with this approach.

All region received above average precipitation during the study period. Less lost time to weather in a drier year does not necessarily guarantee higher capacity utilization. A trade off exists between bad weather and quotas. Given drier conditions, quotas might have replaced weather as the main inhibitor. Transition from reduced production due to rain to quota-limited production were observed to take place, sometimes in less than two weeks.

Stricter BMP regulations will surely amplify the effects of adverse weather, even in drier seasons. Suppliers equipped with proper equipment, if supported by reliable road networks should generate sufficient wood deliveries. Elasticity is another of the possible ways to circumvent the impact of adverse weather. Upwardly elastic loggers should be identified to take full advantage of their potential. It is believed that the impact of rainfall could be minimized at little cost to permit a more regular wood flow. Need for quotas could be significantly reduced.

Production quotas affected a number of loggers during the study, especially those in the southern Appalachian, causing capacity losses accounted for six to nineteen percent. Quotas are one of the few control mechanisms available for the procurement organization to control wood flow. Quotas permit a degree of influence over the logging force's business decisions that meets all the restrictions imposed by the American legal system. Several ways to distribute quota were identified. None is perfect but some are more adequate than others in specific situation. Because of their negative impact on contractors, uses of quota should be minimized and based on proper computation that reflect the company's long term interests and the loggers' profitability.

A model was developed to estimate the cumulative cost of extra capacity in relation to the risk of wood outage at the consuming mill. Such a model should be used to determine the economical range of extra capacity rather than the exact amount of idle capacity needed (Matthews, 1942). The model served as a starting point for a better understanding of stump to mill wood flow. It may also provide enough flexibility to integrate round wood production with other raw material sources into a wider procurement model.

The number of delivery points, or markets, had a slight effect on capacity utilization. Loggers with three or more weekly delivery points had higher capacity utilization than those enjoying fewer markets, although it is not clear if other factors contributed to the difference. For some loggers, it was evident that additional markets made the difference between a good and a very good week.

No difference was found in capacity utilization between loggers marketing their production through a wood dealership, compared with those dealing directly with a procurement organization. The dealer's sample size may have been to small to provide definite results.

Simple graphical techniques, run charts, control charts, and cusum charts were used to measure variability in the logging system. Run charts were the first step toward process analysis. Addition of control limits to run charts permitted easy detection of variation in production. Two approaches were used to establish control limits: the three standard deviation method, and the ogive method. The first proved to be inappropriate because of the great variability in daily production. With the ogive approach, specifically developed for this study, control limits are based on the distribution shape and operational characteristics. Control charts serve to identify exceptional observation. Causes for the observation can then be investigated. Increased knowledge of the system variability may serve the procurement organization in identifying emergency capacity levels as well as low demand production levels.

Long-term impact of variable production can be visualized with cusum chart. The necessity of balancing prolonged low production periods with equal periods of above average deliveries became evident. Cusum charts were also suggested as a tool to define capacity index.

Production records for the last five years were available for five independent contractors. The variation in production levels appears to be increasing with the imposition of increased regulations and change in markets. Loggers were forced to total or partial idleness more often, and had to compensate with higher production when conditions were favorable. Weeks of total idleness were so frequent in recent years that they were frequently not considered outliers to the distribution. Elasticity has become essential to maintain profitability by allowing contractors to net sufficient gains to go through long periods with little or no incomes.

Conclusions

As the southern wood supply system has evolved, the wood consuming mill's inventory and those responsible for specifying it's level have become isolated from the contractors. Production patterns and operating costs are often averaged due to missing information. External pressures such as the BMP's may force the wood consuming industries to have more interaction with their raw material suppliers.

Defining total production capacity of the logging force seems to be the first step toward increased control of variation.

The future will likely see an increased demand for well equipped, production oriented loggers. However, smaller contractors are not condemned to extinction. There will be niches available for them. Analogous to the airline business, a polarization trend to high production loggers with relatively small, well equipped, efficient crew (largest contractors may have a maximum daily capacity of 400 to 500 tons) and very small producers is likely to take place (Laestadius pers. comm. 1993). Loggers operating more than one large crew and a second, specialized one (like a thinning operation) will have difficulty in properly managing a business of that size in such a demanding industry. Procurement organizations will likely be dealing with fewer contractors that are allowed to utilize a larger share of their capacity year round. In return, loggers will be expected to guarantee quality of their operation. Quality may be defined to include labor safety considerations, trucking practices, compliance to BMP's, and wood owners satisfaction.

The eagerness to minimize wood cost over shadows the possibility of maximizing profit. Buying the cheapest wood is not always in the best interest of an organization. Deming (1986) quotes W.A. Shewart as saying that price without a measure of quality is of little use. He goes further by affirming that in absence of ways to measure quality, organizations will be tempted to purchase from the lowest bidder, which will ultimately results in higher costs. For the American wood industry total quality from stump to mill, not only within the mill, may be the greatest opportunity to secure world wide markets.

Suggestions for Further Research

1) Long term production records to study the wood supply system sustainability and adaptability should be maintained. The intensity of data collection needs not to be as demanding to the loggers. A calendar or monthly agenda collection form appear like a proper way to maintain loggers cooperation.

2) More attention should be placed on the refinement of the extra capacity cost model. It appears as starting point to study the components of the wood supply system. Paired with Laestadius (1990) isoquant curve, the interaction between round wood suppliers, sawmill residues, gate wood producers, and consuming mill inventories may be clarified.

3) A broader use of quality management tools should be considered in wood procurement. The forest industry is moving toward stiffer regulations. Internally recognized standards such as those of ISO 9000 type certification should be investigated to study their possible benefits in forest operations.

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APPENDIX A. LOGGER'S FORM

Front Side

Name: ________ __/__/93	Monday	Tuesday	wn'day	Thr'day	Friday	Sat'day
Worked	Y N	Y N	Y N	Y N	Y N	Y N
Changed Tract Today	No	No	No	No	No	No
	B D E	B D E	B D E	B D E	B D E	B D E
Ch.Equip.	Y N	Y N	Y N	Y N	Y N	Y N
Ch.Labor	Y N	Y N	Y N	Y N	Y N	Y N
Weather Dry Wet Rain	D W R	D W R	D W R	D W R	D W R	D W R
Hot Cold Mild	H M C	H M C	H M C	H M C	H M C	H M C
Sch. Hours						
Worked Hrs.						
Max. Prod.						
Actual Prod.						
If Not Max. Give Main Reason(s)	Quota Weather Labor Mech. Other	Quota Weather Labor Mech. Other	Quota Weather Labor Mech. Other	Quota Weather Labor Mech. Other	Quota Weather Labor Mech. Other	Quota Weather Labor Mech. Other
Destination and miles : 1)____ 2)____ 3)____ 4)____	**Loads**	**Loads**	**Loads**	**Loads**	**Loads**	**Loads**

Back Side

Tract's Name: Miles to shop

1) ____________________ ____________________

2) ____________________ ____________________

3) ____________________ ____________________

If you changed tract, give the reason

Weather ☐ **BMP's** ☐

Finished tract ☐ **Wood Order** ☐

Other ____________________ ☐

What production would you normally expect in this type of tract: _____ Loads/week.

Comments:

____

____

____

____

____

____

____

____

____

____

APPENDIX B. FORESTER'S FORM

WOOD BUYER WEEKLY REPORT

Forester's name:____________________ Week ending date:___/___/1992

Logger's name:______________________

Number of days worked:__________

Logger's weekly production

	Pulpwood	Logs	Total
Loads	______	______	______
Tons	______	______	______

Tract(s) worked	Date	Hauling distance to market			
1) ______________	___To___				
2) ______________	___To___				
3) ______________	___To___				

Reason(s)for move:

Weather ___ *Other (Explain)*___ *BMP's* ___

Finished tract ___ *Product mix* ___ *Wood order* ___

What was the operating rate for this producer this week (in %) :

30 40 50 60 70 80 90 100 110 120 130 140 150 160

Identify the reason(s) for variation, the direction, and the % due to each:

		Direction	% of capacity
__	*Weather*	+ -	________
__	*Haul distance/trucking capacity*	+ -	________
__	*Quota/Wood order*	+ -	________
__	*Crew attendance/Manpower*	+ -	________
__	*Equipment Breakdowns/Problems*	+ -	________
__	*"Cleanup" or "Re-entry" Tract**	+ -	________
__	*Other (____________________)*	+ -	________
__	*Other (____________________)*	+ -	________
__	*Other (____________________)*	+ -	________

Did the producer's wood order/quota change during the week? __________

General comments: ______________________________________

____

____

APPENDIX C. MONTHLY NEWSLETTER

LOGGERS' INFO

A newsletter for the cooperators in the "Production Capacity" study.

June 1993

By Luc LeBel, Virginia Tech

Dear Cooperators,

I hope you are fine. This is the last "regular" Newsletter I will be mailing you. The study will officially end July 1, and you will not have to fillout the cards after that. It would be important for me to receive all the cards you may have as soon as possible so I can complete the analysis. If you still have old cards at the office or on the dash board of your truck please mail them to me. We are interested in how the transition from very wet weather to very dry weather will be handled, especially how much of the time lost due to weather will be replaced by time lost due to quota. I am including cards for July for those of you who wish to continue to cooperate with us voluntarily. We (the Industrial Forestry Operations Research Coop) are not certain of the future direction of this project. The long term records (up to five years) provided by some contractors is an important basis for evaluating the effects of programs such as the BMP's.

Simply knowing the number of work days lost each month to weather, quota or other factors and the number of tons produced each week is extremely valuable. What we would like to do, with your cooperation is switch from the intensive data collection of the past year to a more relaxed type. Many of you keep a journal or record of the days worked and lost and tons produced as a part of your normal activities. We will be in contact with you to determine if you would be willing to share this information with us on a continuing basis.

My major challenge is to produce a thesis and report of all this data over the summer. Once the report is written, Dr. Stuart and I will make arrangement to present the results to all the cooperators. This should take place in late summer early fall.

You will find in this issue three production graphs for ALL the loggers that sent information during the study. The same business code as before was used but this time loggers are sorted by physiographic region. The first region is the Appalachian ridges and valleys, the second is the Piedmont, and the last one is the Coastal Plain.

LAST WORD

This study allowed me to discover beautiful regions in the Southeast. But most of all, I met extremely friendly people. I am continuing on at Virginia Tech in pursuit of a Ph.D., so we will probably meet many times in the future, if not, I will always remember your hospitality and kindness. A very significant part of what learned during my master at Virginia Tech, I learned it by listening to you.

Thank you! Luc

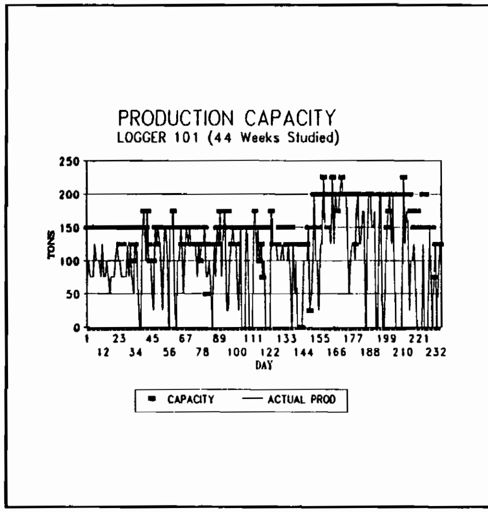
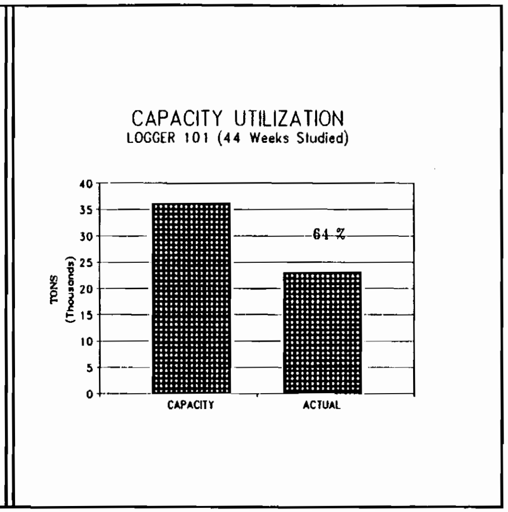


Figure 1



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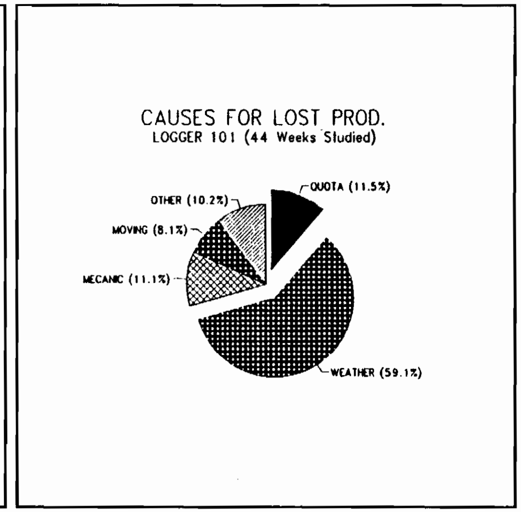

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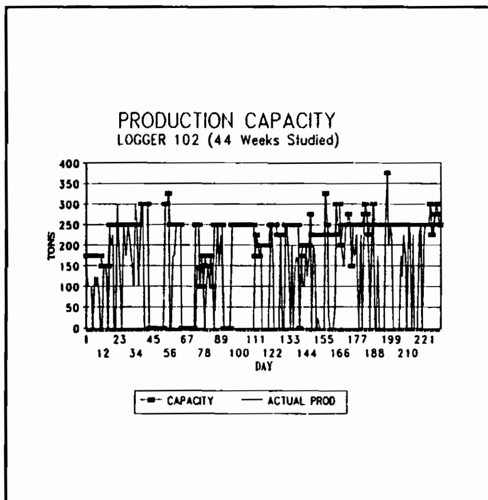

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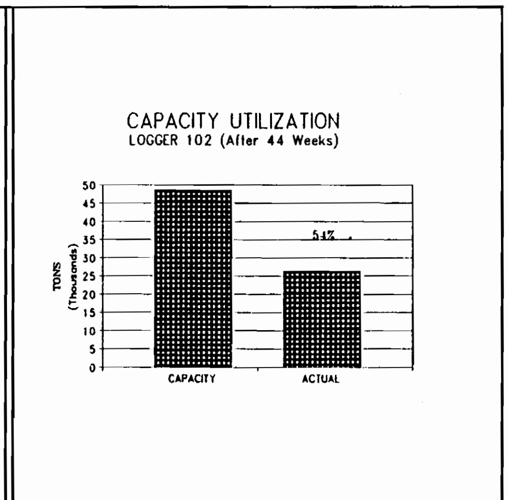

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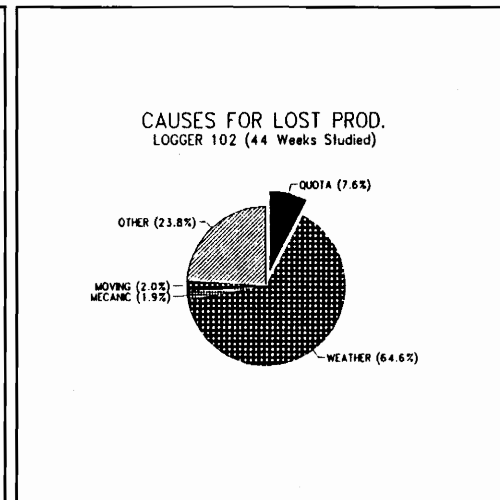

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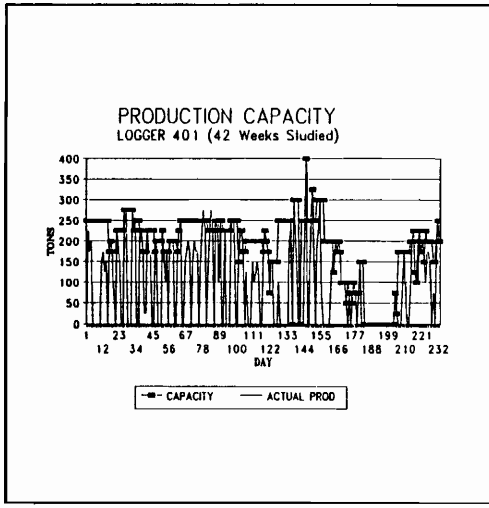

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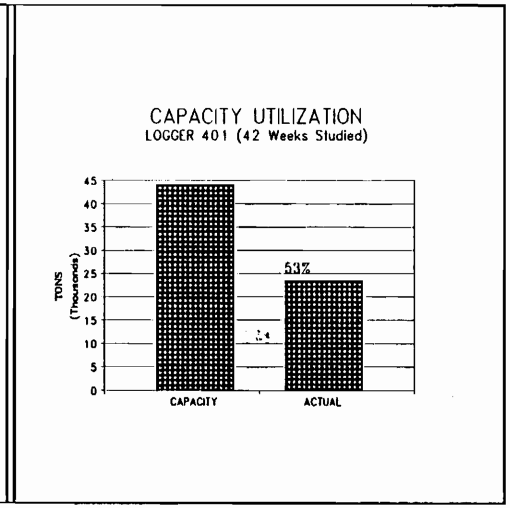

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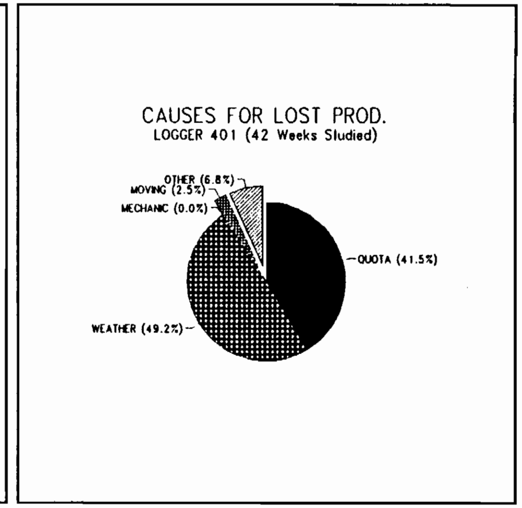

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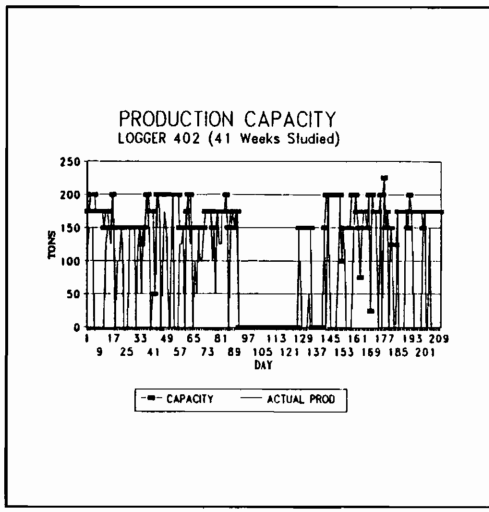

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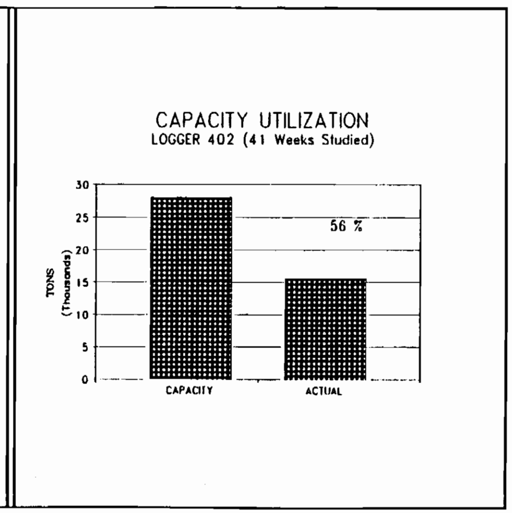

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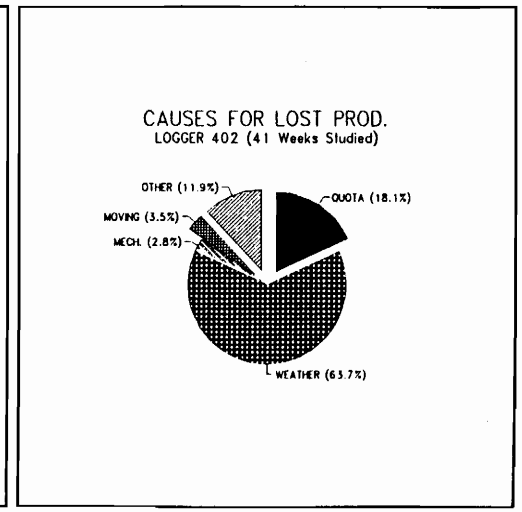

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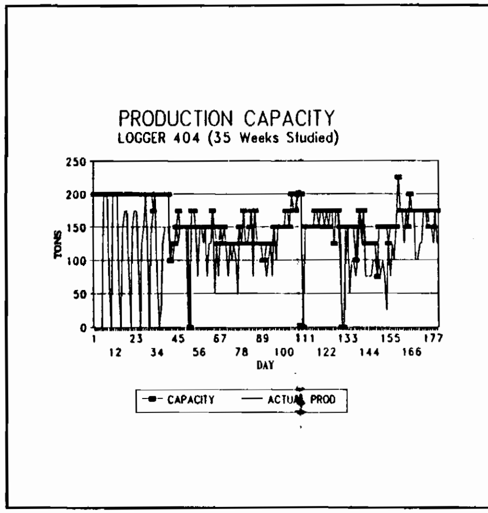

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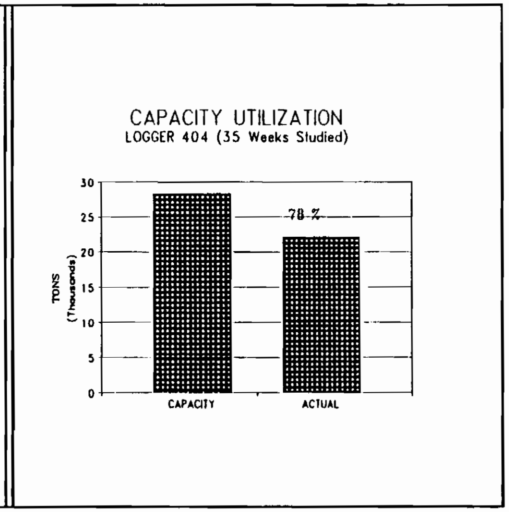


Figure 14

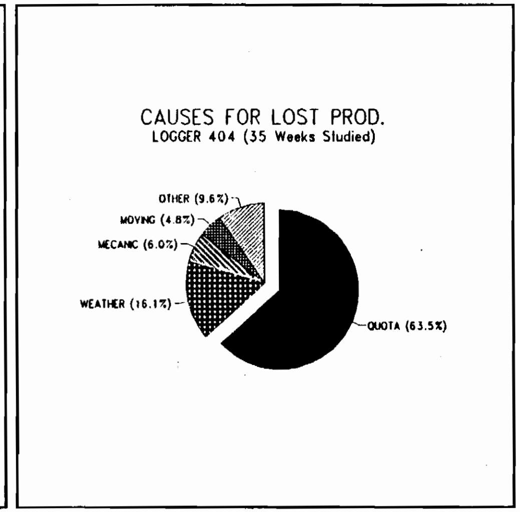


Figure 15

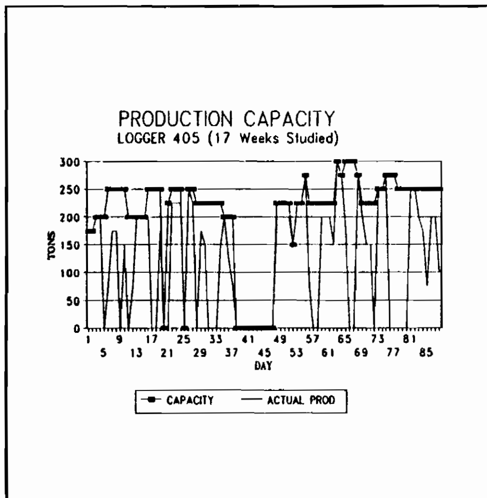


Figure 16

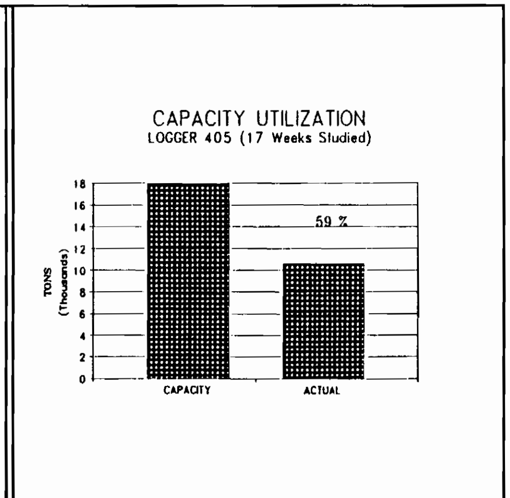


Figure 17

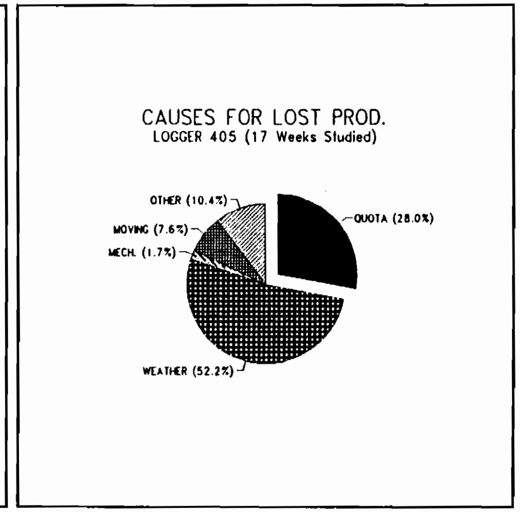
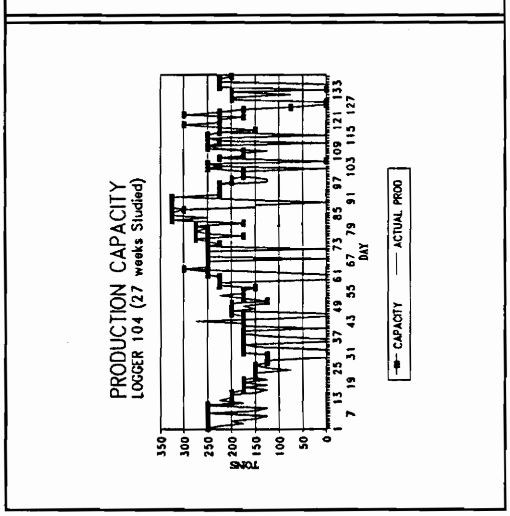


Figure 18

Piedmont



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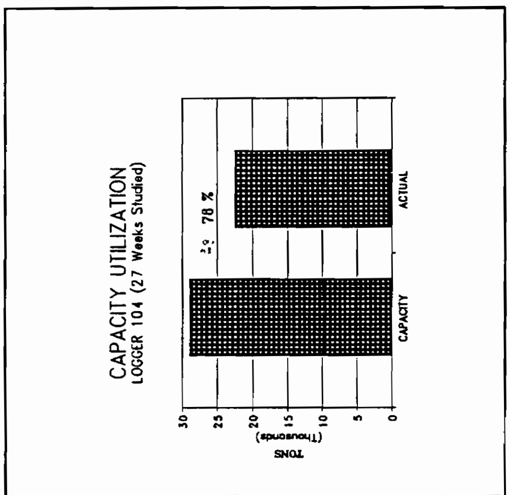

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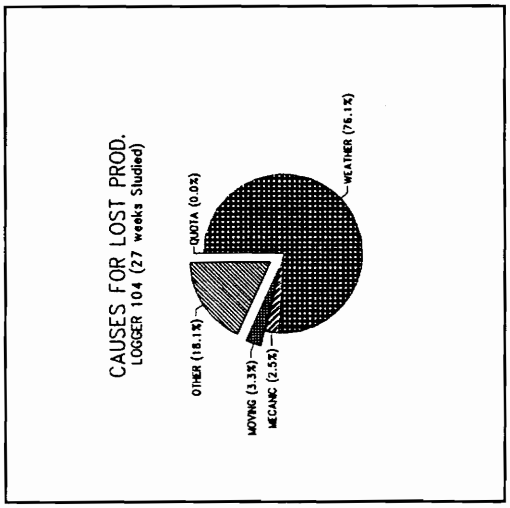
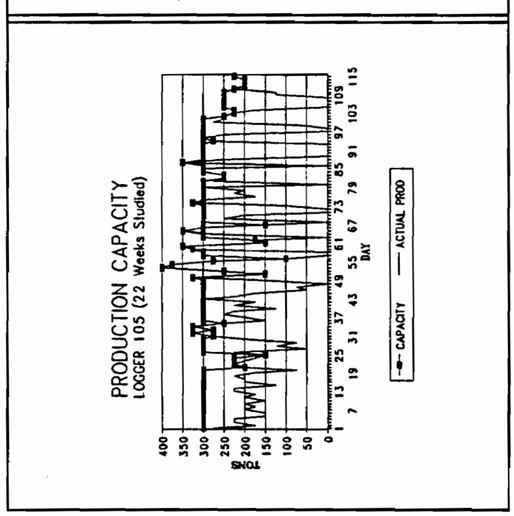


Figure 21



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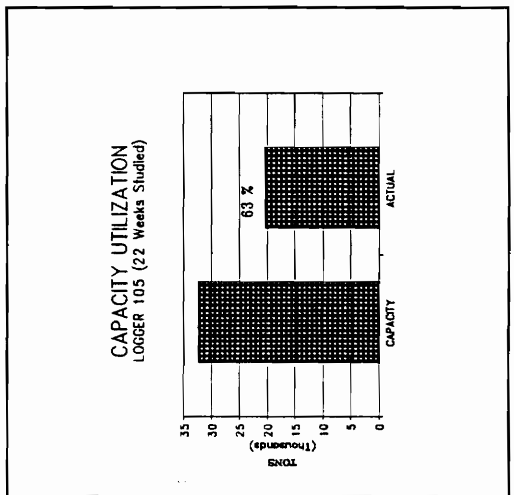

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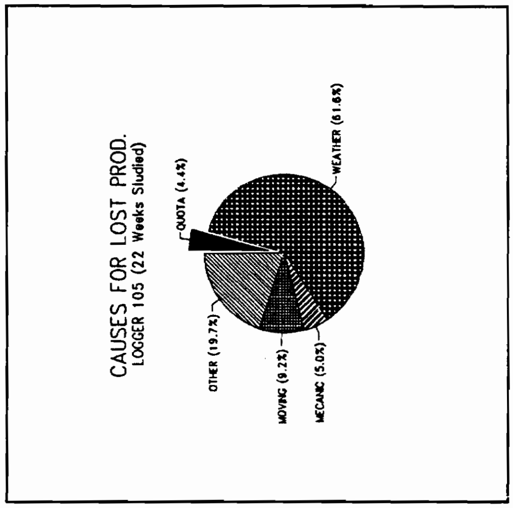
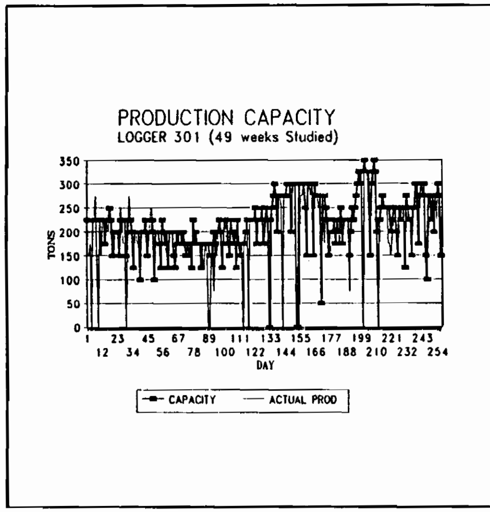


Figure 24

Piedmont (continued)



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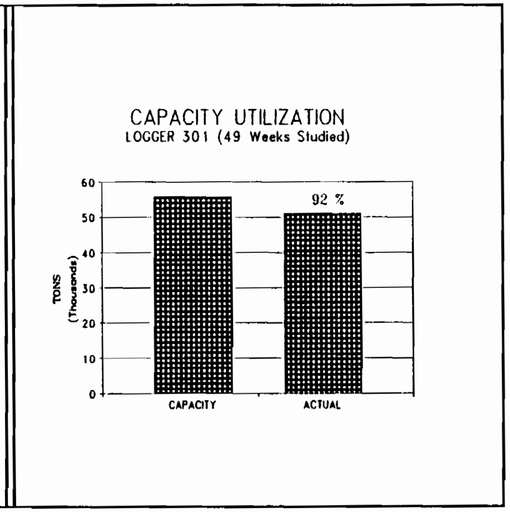

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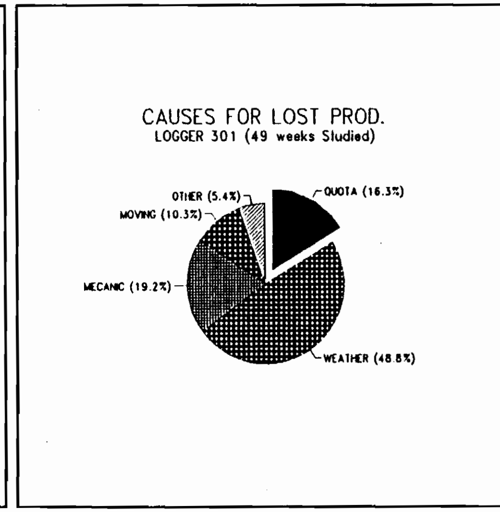

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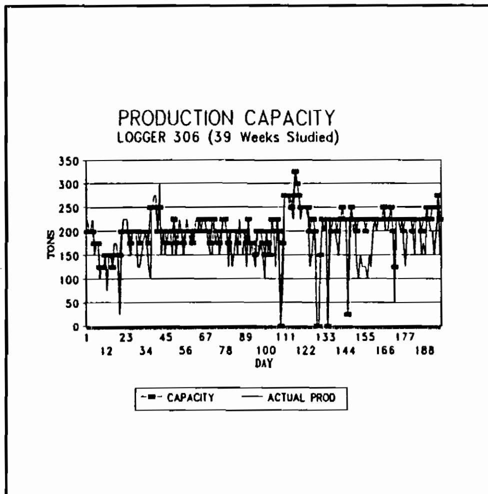

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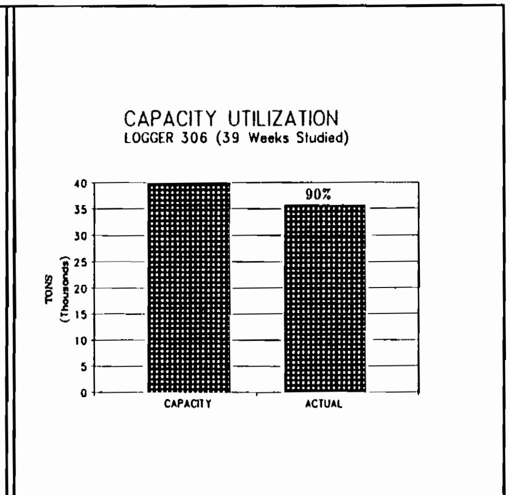

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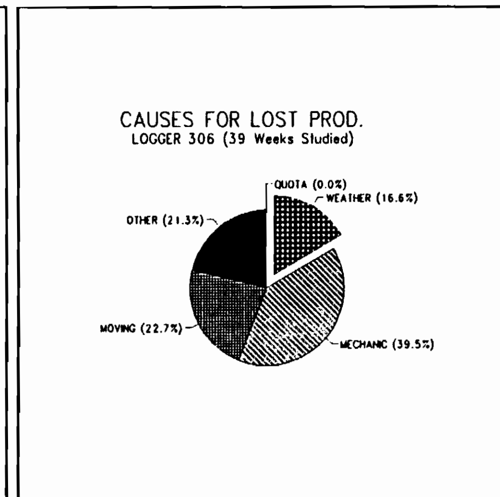
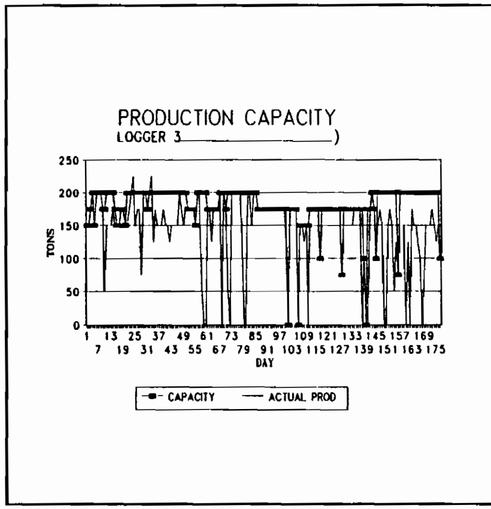


Figure 30

Piedmont (continued)



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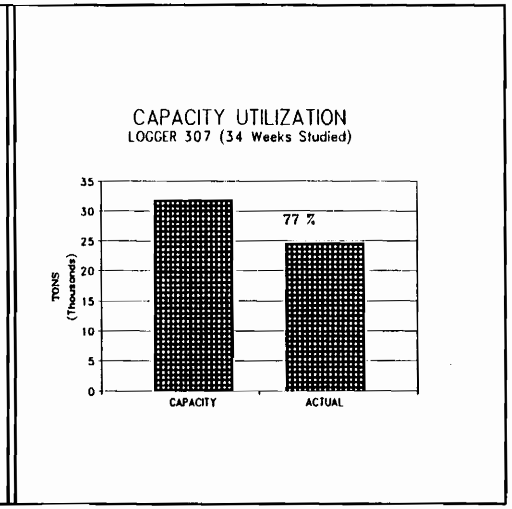


Figure 32

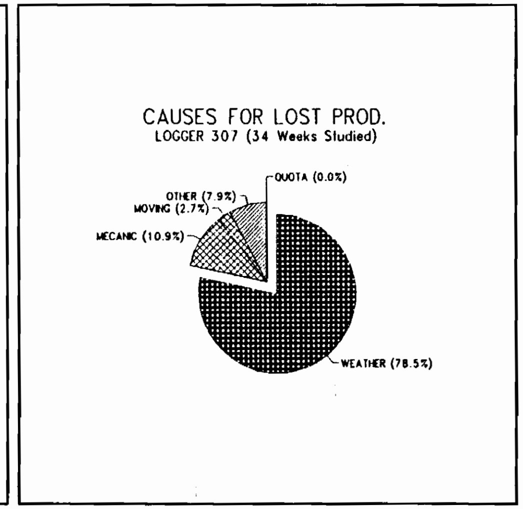


Figure 33

Coastal Plain

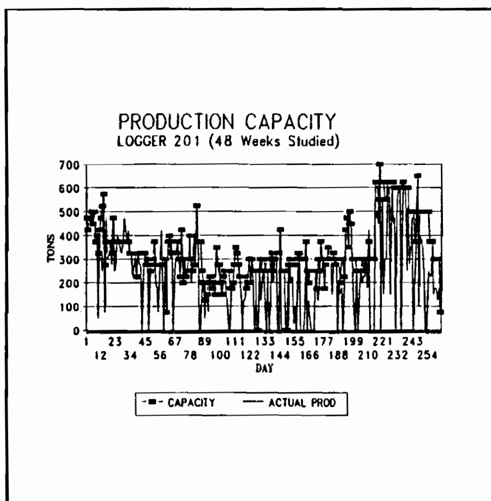


Figure 34

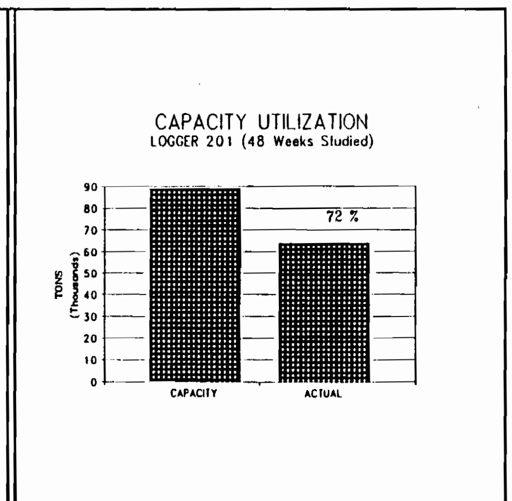


Figure 35

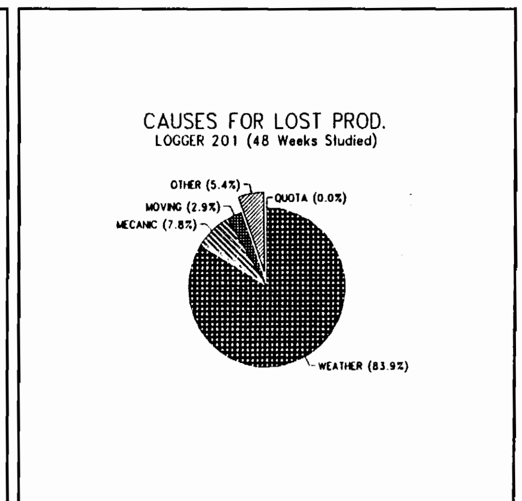
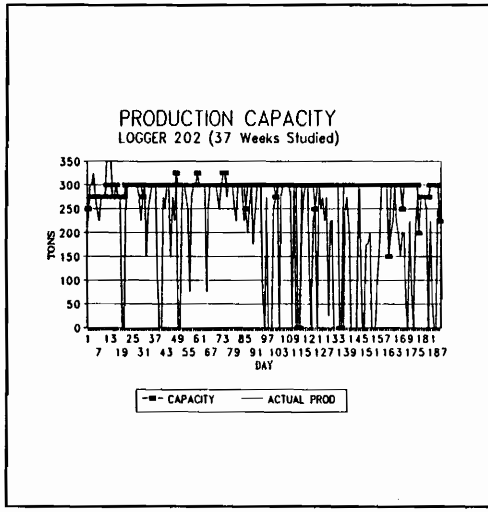


Figure 36

Coastal Plain (continued)



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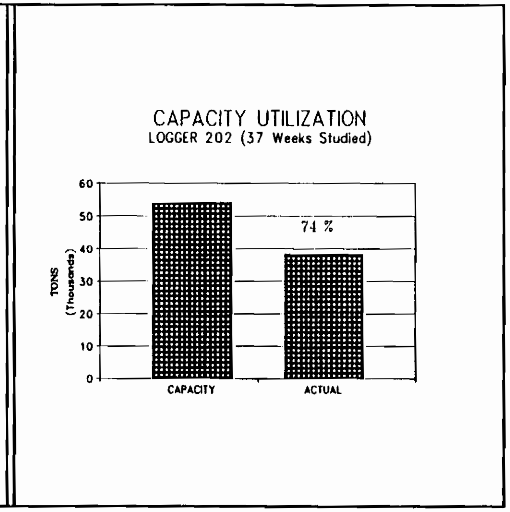


Figure 38

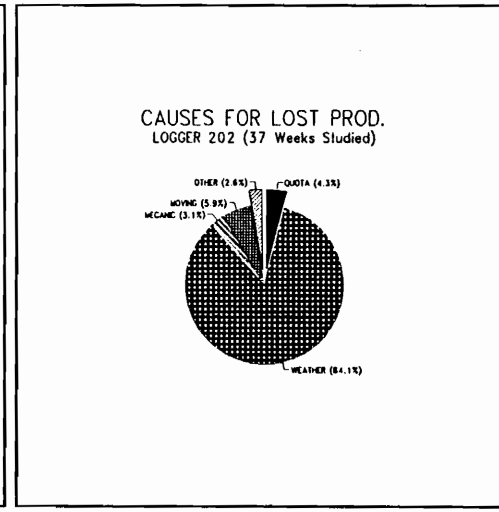
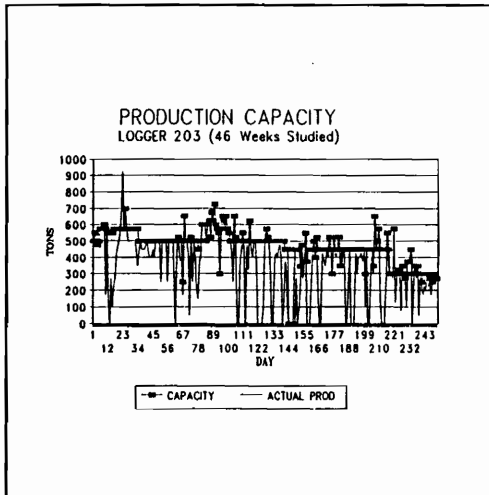


Figure 39



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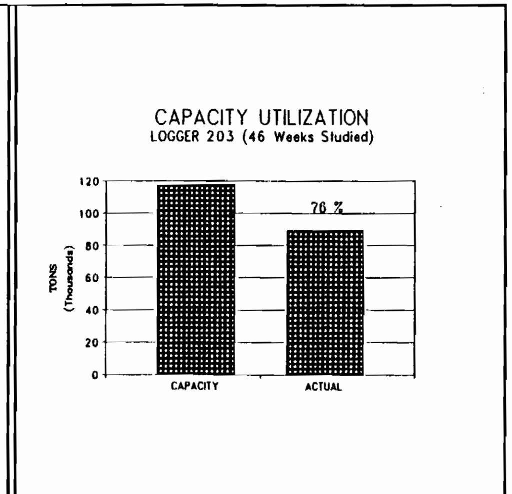

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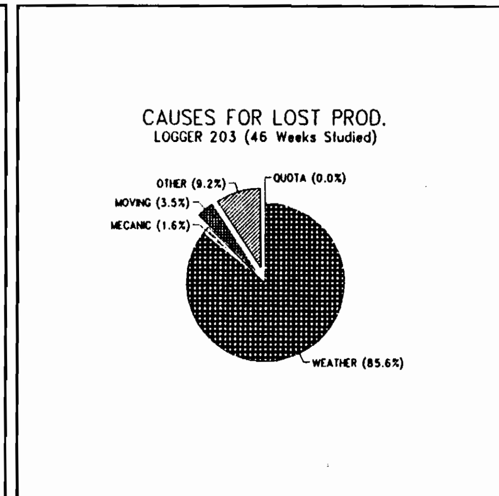

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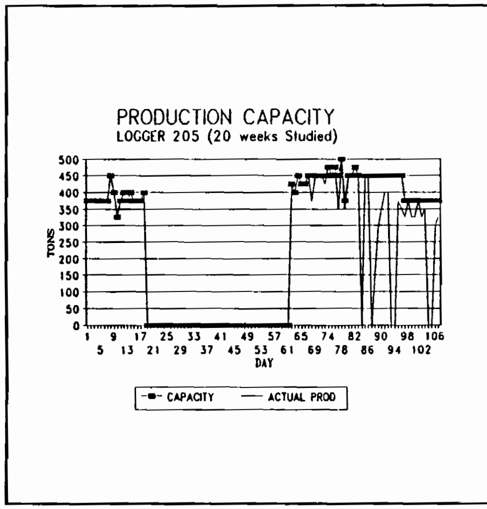

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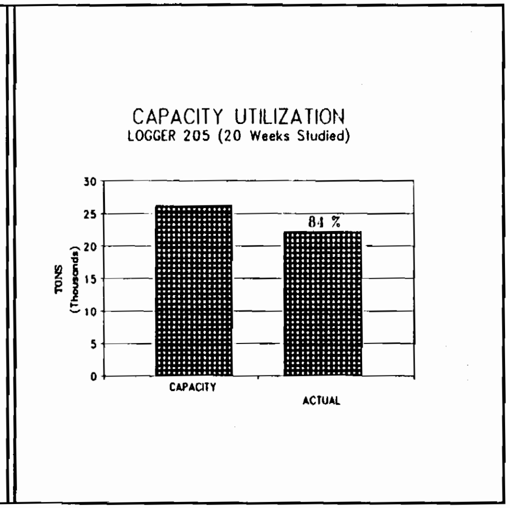

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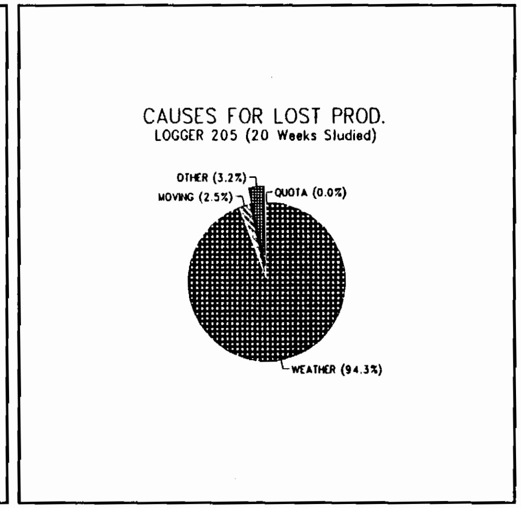

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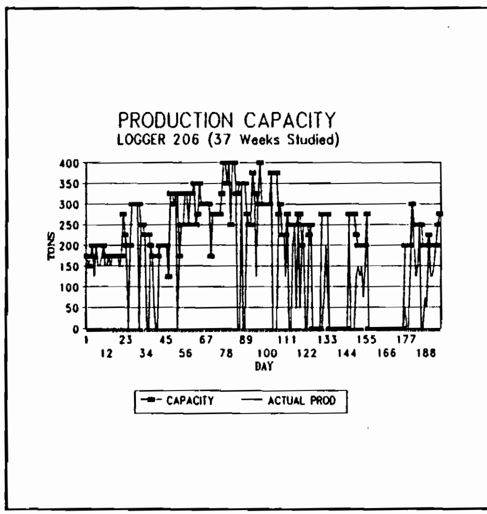

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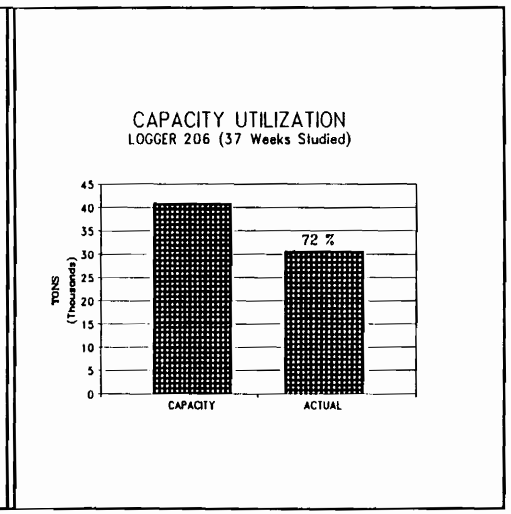
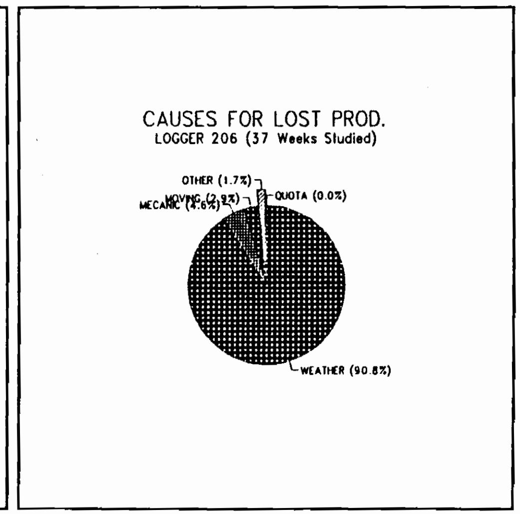


Figure 47



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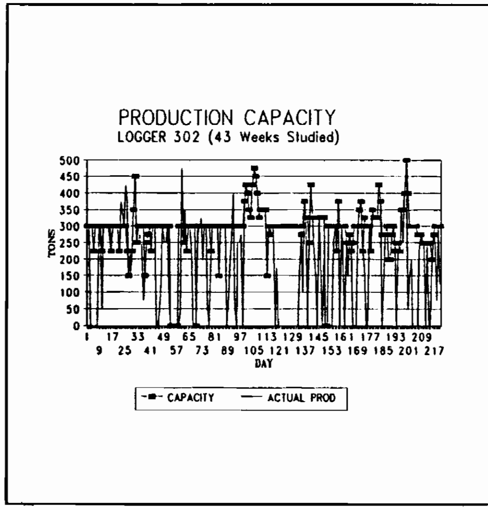
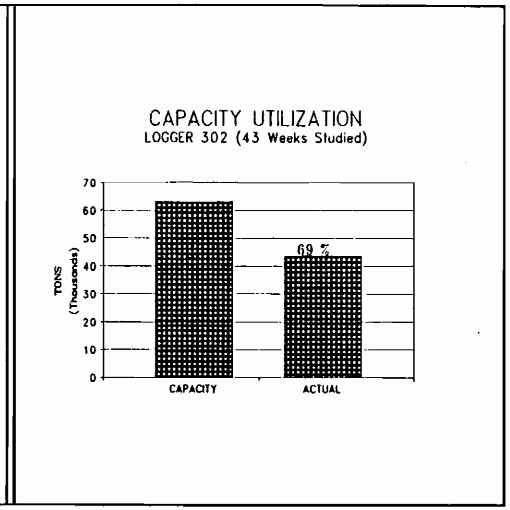


Figure 49



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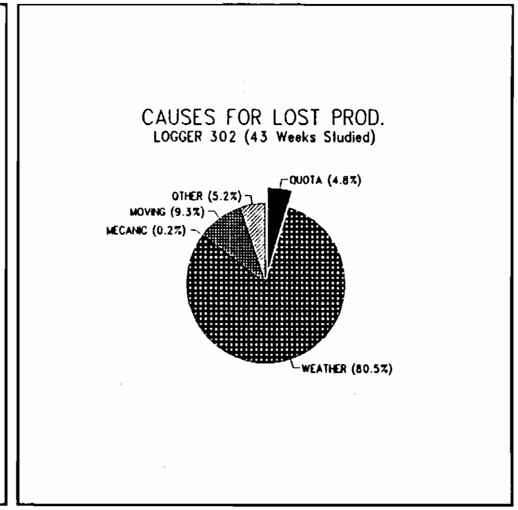

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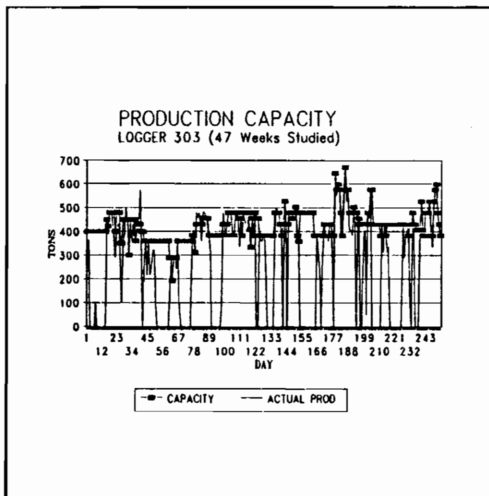

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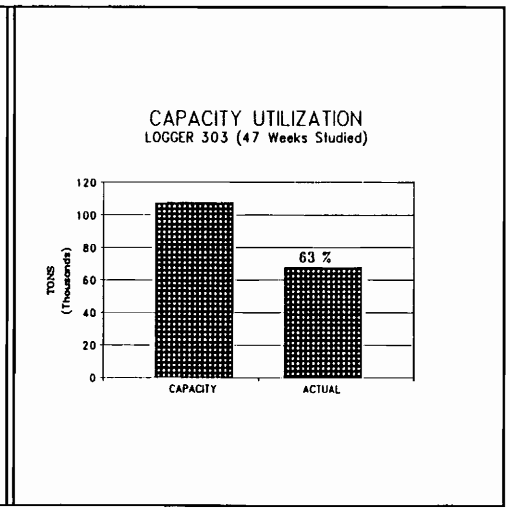


Figure 53

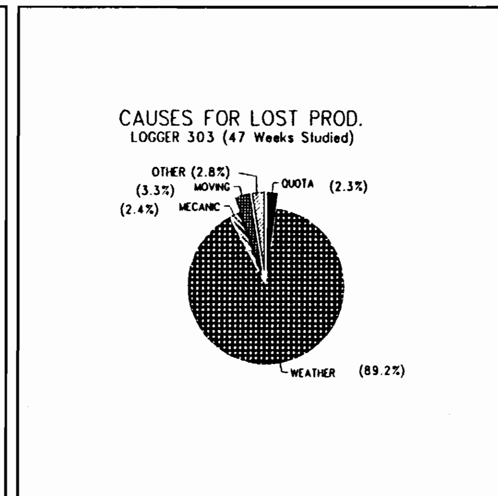
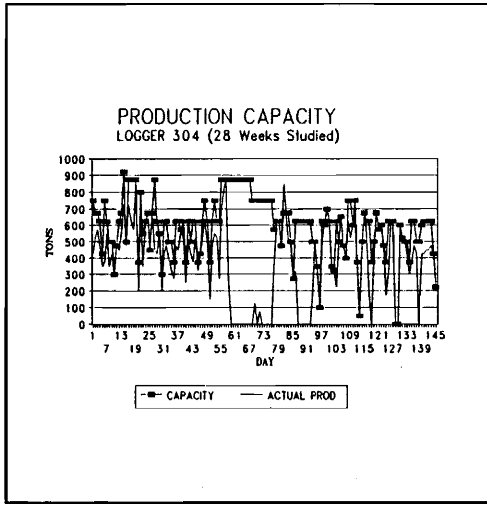


Figure 54

Coastal Plain (continued)



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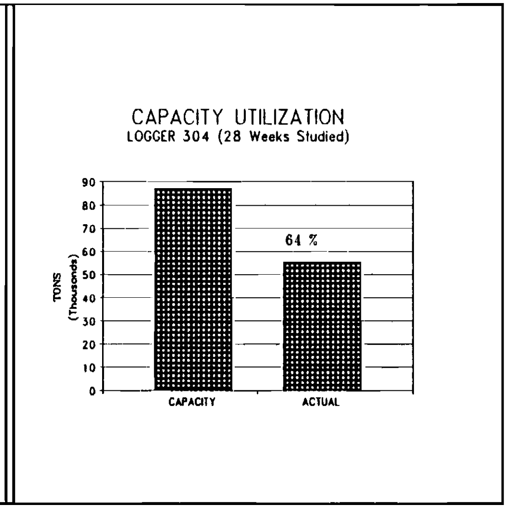

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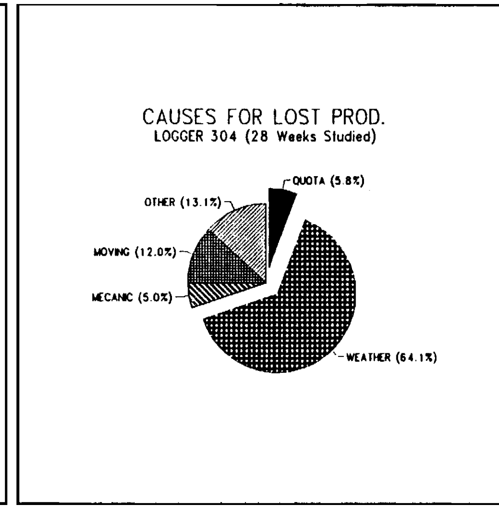

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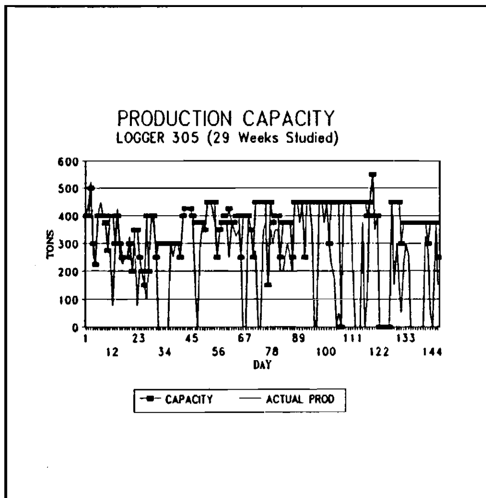

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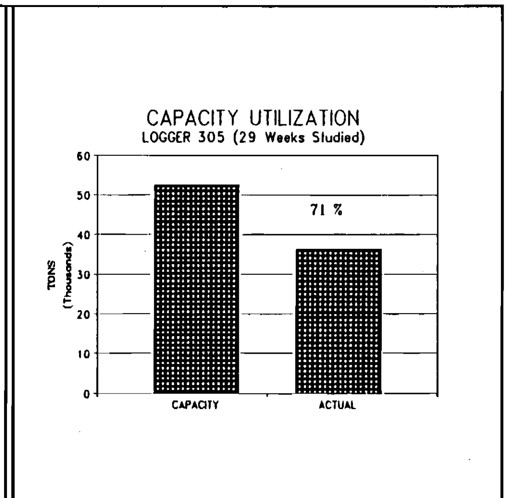

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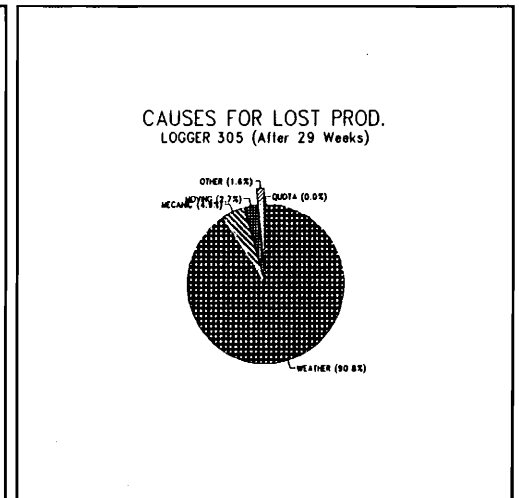

Figure 60

VITA

Born in Maniwaki, Québec, on November 1967, the author is the son of Réal LeBel and Lorraine Montminy. He completed primary school in Carleton, Gaspé peninsula, and high school at Polyvalente Félix Leclerc in La Tuque, where he received the "Student of the Year Award". Beginning college in 1985 at Collège de Sainte-Foy, he completed a pure and applied sciences diploma in 1987 before being accepted at Université Laval in the forest operations program. Prior to graduation in 1990 he worked for the New Brunswick International Paper Co., The Forest Engineering Research Institute of Canada, and the Ecole de Science Forestière in Edmundston. Grand son of a logger, and son of a forest engineer, the author will honor the family's green blood by pursuing a Ph.D in Industrial Forestry.

Luc LeBel

Luc LeBel