OUTLOOK AND NEEDS IN FUTURE WORK

Cost-Return Relationships of Tree Improvement Programs

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Widespread and sustained acceptance of tree improvement programs as a forest management activity by the public and the forest industries can only follow demonstrable evidence of economic worth. Your research to date gives convincing evidence of technical possibility and a suggestion of economic feasibility. This paper will briefly explore the principle questions involved in establishing economic worth.

To simplify, this discussion is confined to tree improvement programs for pulpwood and where all costs are embodied in the seed used for regeneration. In this situation, the forest manager is faced with the conventional investment question of whether the discounted additional sale value of harvested wood exceeds or at least equals the seed costs. Stated as a textbook valuation problem, we are concerned with the equation:

$$\frac{(P^*Q^* - PQ)}{(1+i)^t} - C \geq 0 \quad (A)$$

where P^* is the price per unit of improved wood in year t

Q^* is the quantity of 'improved' wood harvested per acre in year t

P is the price of 'conventional' wood in year t

Q is the quantity of 'conventional' wood harvested in year t

C is the investment cost in 'improved' seed per acre

t is the time required to produce a crop of 'conventional' wood

i is the discount rate appropriate to the decision maker.

The benefits of a tree improvement program are reflected in a combination of ways. Increased photosynthetic efficiency and disease or insect resistance would cause Q^* to be larger than Q. Qualitative improvements in wood fiber yields should cause P^* to be higher than P. Finally, we would expect the time required to grow a given amount of wood to be shorter for the improved stand.

The textbook valuation problem is always given to us with a nice set of values to plug in and obtain solutions, giving the illusory confidence that there really is not much to it. For this problem it just is not empirically possible at present to fill in the equation and find a solution, What I would like to do in this paper is define the equation elements and indicate the sort of information needed from research. To avoid accusation of being a pure theorizer, the cost aspect of tree improvement will be examined first and covers some work we have recently completed (1).

Seed Costs

The investment cost of improved seed is the difference in price between what the forest manager would have to pay for improved seed and what he would have to pay for ordinary seed. To establish this cost, our study started with this viewpoint and basic question: "what could a privately owned commercial orchard sell seed for, covering all production costs and making a normal profit?"' In a relatively competitive market this would, in the long run, approximate the expected market price for improved seed. A schedule of seed yields over time is the basic expression of orchard output(Figure 1).

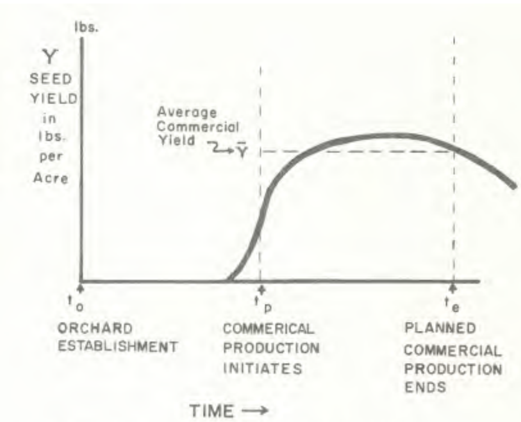

Figure I. Seed Orchard Yield Schedule

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Three major reference points are the time of establishment (to), the time commercial production effectively begins (tp), and the time the orchard is administratively abandoned for commercial production purposes (t_e). Weather and other problems would cause actual seed yields to be variable from year to year but for planning purposes, an average annual seed yield during commercial production, (Y), is assumed. Associated with this yield and the reference points is a schedule of costs involved in obtaining orchard production. Broken down by major capital outlays, annual operating costs, harvesting costs, and progeny testing costs, the cost schedule is shown in figure 2.

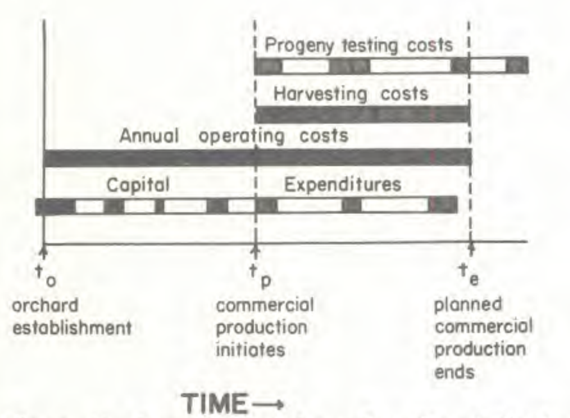

Figure 2. Cost Schedules of a Seed Orchard

To compute a selling cost, the orchard owner is visualized as being at point tp when commercial production has just started. All establishment costs incurred between (t_o) and (tp) would be carried forward with interest. The size of a sinking fund required to cover future outlays for progeny testing and capital items can be computed by discounting these anticipated expenses to the present (tp). The sum of these compounded and discounted costs represents the total value of past and future capital obligations for the orchard at time (tp) which must be covered by revenue from seed sales. Using a standard amortization formula, the amount that must be recovered each year of commercial production to cover this cost can be calculated. Additionally, the orchard must return enough to cover current operating expenses, harvesting and seed processing costs plus returning the owner a normal profit. A summary equation for these calculations is:

$$SC \text{ (seed cost per pound) } \frac{(k+a)+i\,(a)}{Y}$$

where k is the annual requirement to amortize the capital investment

a is the annual operating and harvesting cost

i is the owners normal rate of return

y is• the average annual seed yield expected during commercial production

The right hand expression, i(a), charges a normal profit of i% against current operating costs. This same profit rate is already built into the amortization formula for determining (k). This seed cost, as computed, applies only during the amortization period from tp to te. It is quite probable that the orchard will continue to produce for several years following amortization. However, new research findings and improvements in parent stocks from second generation breeding will likely render any given orchard technologically inefficient and subject to abandonment after a certain period.

Loblolly Pine Clonal Seed Orchard Costs

Data were collected by field visits in 1965 from two loblolly pine seed orchards, a 100 acre orchard in the southeast and a 40 acre orchard in the mid-south. Both orchards were initiated in 1959 and are now nearly complete. The plan of management is well developed for both orchards and future management requirements and cost schedules could be estimated with reasonable certainty. The orchards should be fairly representative of many loblolly orchards since both belong to the Industry-North Carolina State Cooperative Tree Improvement Program whose 19 members all follow approximately the same general plan of orchard management. A listing of management activities found in each orchard is given in table 1. The average per unit management activity costs which are somewhat unique to seed orchards are shown in table 2.

TABLE 1. Planned and observed management activities found on Loblolly pine seed orchards studied

Item	Orchard A	Orchard B
	(amount or frequency)	
1. Plant rootstock	: 395/acre	195/acre
2. Graft and release rootstock	: 350/acre	194/acre
3. Mulch rootstock	: once	once
4. Fertilize	: 450 lb. 8-8-8./acre/year	1000 lb./acre/year
5. Spraying	: 3 times/year	6 times/year
6. Disking	: 3 times	once
7. Mowing	: 3 tim es/year	5 times/year
8. Site preparation	: subsoiling	drainage ditches
9. General supervision	: approximately 1/3 of a supervisor and a full time foreman foreach orchard	
10. Technical assistance	: $25/acre/year	$10/acre/year
11. Clones per orchard	: 24	45
12. Progeny testing	: 5-tester system	4-tester system
13. Capital expenditures	: integrated with nursery for buildings, equipment and roads	2 buildings, tractor and roads
14. Acres in orchard	: 40	100
15. Mature orchard density	: 50 trees/acre	50 trees/acres

TABLE 2. Selected per unit costs for management activities on seed orchards studied.

Item	Cost
1. Planting rootstock	: $25 per acre
2. Grafting and graft release	: $.75 to $1.50 per graft
3. Progeny testing	
a. one bagged cross	:: $.13 per cross
b. one acre of progeny outplanted (extra cost)	: $20 per acre
c. measurement of outplanted progeny	: $100 to $175 per outplanted acre for each measurement occasion
d. present value of total progeny testing costs at the time progeny testing is initiated. (assuming a 5-tester system, a 5% interest rate, and measurements taken at 1, 3, 5, 10, 15, and 30 years.)	: $550 per clone tested
e. acres outplanted to test one clone	: 2 acres per clone (5-tester system)
4. Seed orchard harvesting and extraction costs.	: $2.35 per pound of seed
5. Location and selection of parent clones	: $150 per clone
6. Estimated total average annual orchard operating expense per acre during commercial production	: $217 per acre

Using the previously developed procedure for calculating costs, gross seed costs per pound of seed were calculated for both orchards under a range of assumed interest rates (i), annual seed yields (v), depreciation periods (j), and the period before commercial seed production commences (a). Costs were averaged for the two orchards and are shown in table 3.

Based on current information from orchards in the Industry-N.C. State Program and field discussions with several seed orchard managers and research workers, interest rates on the order of 5% and 7%, seed yields on the order of 50 to 75 pounds per acre of orchard, an economic amortization period of from 20 to 30 years and an establishment period of from 10 to 15 years seem to be reasonable estimates in the context of current experience and the viewpoint of seed orchard owners. The circled seed costs in table 3 reflect these estimates and indicate gross seed costs in the range of $7 to $20 per pound. If a single estimate had to be made at this time from the limited empirical base of this study, perhaps $15 per pound would be a reasonable yardstick for seed orchards 'in general'. Such a generalization would be inappropriate and probably misleading if applied to any individual orchard.

Several cost relationships were found which should be of interest to seed orchard investors. First, while cost of seed per pound is fairly low,

Table 3. Average total cost per pound of seed from Loblolly seed orchards studied.

	Average seed yield 1/ per acre in pounds (Y):	30 pounds			50 pounds			75 pounds		
	Depreciation period 2/ in years:	15	20	30	15	20	30	15	20	30
Years before seed production	interest rate (i)	-----------------------(Dollars)-----------------								
10 years	.04	16.85	15.43	12.88	12.21	10.24	8.71	8.21	7.69	6.61
	.05	18.20	16.15	14.16	11.90			8.76		
	.07	21.55	19.40	17.47	13.93			10.13		
	.10	27.37	25.14	23.32	17.45	16.11	15.02	12.49	11.60	10.87
15 years	.04	25.26	23.06	18.50	16.14	14.82	12.44	11.57	10.69	9.11
	.05	26.41	24.64	21.49	18.76			12.66		
	.07	34.65	31.02	27.72	21.79			15.37		
	.10	48.81	44.52	41.06	30.31	27.74	25.66	21.07	19.35	12.97
20 years	.04	30.84	27.73	22.06	19.49	16.44	14.22	13.80	12.56	10.29
	.05	37.73	30.79	26.13	22.42	19.46	16.68	15.77	12.79	11.93
	.07	48.59	42.72	37.52	30.15	26.63	23.51	20.95	18.60	16.52
	.10	77.29	69.79	63.59	47.40	42.90	38.04	36.54	29.46	27.02

1/ Average annual seed yield in pounds per acre of seed orchard during the productive life of the orchard.

2/ Period over which establishment and other costs incurred prior to commercial seed production are depreciated against seed production. Defines the economic or investment life of the seed orchard as a productive asset.

3/ Period between initial establishment of a seed orchard and the initiation of commercial seed production from the orchard.

the capital cost of a seed orchard at the age of initial commercial production is high. For example, assuming a 5% rate of interest, the per acre capital value of the 40 acre orchard at age 15 was $7636 and for the 100 acre orchard it was $4728. Fixed costs of supervision, capital equipment, progeny testing and other overhead expenditures were about the same for each orchard, on the order of $10,000 per orchard per year and amounting to 60+% of total annual costs. Direct variable costs for cultural work ranged from $80 to $120 per acre per year for both orchards. Spreading overhead and fixed costs against a larger acreage resulted in significantly lower annual total cost per acre and cost per pound of seed for the 100 acre orchard. 'Since observed overhead costs were as low as could reasonably be expected if the orchard were to be properly cared for, establishing the largest orchard consistent with the given supervisory capacity and seed requirements can be recommended as economically efficient and desirable.

As a final observation, the relative cost of parent stock selection is extremely small, on the order of 1/2 of one percent of seed cost. All of the genetic benefit from clonal seed orchards stems directly from the parent stock selected. From the cost standpoint, relatively lavish expenditures could be made in searching for and testing parent stock without appreciably raising the cost of seed from the orchard.

We haven't considered seedling orchards yet but I assume they would be developed and managed in the same manner as clonal orchards, except for the source of parent stock. If this is the case, then costs per pound should be about the same as from clonal orchards.

Forest Investment Costs of Improved Seed

Reported seed costs (2, 3, 4) for ordinary seed range from $3 to $7 per pound in ready-to-plant form. An average figure might be in the neighborhood of $5 per pound. Subtracted from the gross cost estimate of $15 per pound of seed, a net investment cost of $10 per pound of improved loblolly pine seed is obtained.

A pound of loblolly orchard seed contains an average of 15,000 seeds (5). Ordinary seed is smaller and averages 18,400 per pound (U.S.D.A. 1948). Experience has shown that approximately one plantable seedling per two seeds or approximately 7,500 seedlings can be obtained per pound of improved seed.[1/] Using a range of improved seed costs, investment costs per planted acre are shown in table 4.

For normal plantation spacings, from .05 lbs. to .15 lbs. of seed are required per acre. Direct

TABLE 4. Net investment east per acre of commercial loblolly pine plantation using improved seed from seed orchards.[1]

Spacing'	Number of trees per acre	Net seed cost per pound $6	$10	$16
6 x 6	1210	$.97	$1.61	$2.58
8 x 8	680	$.54	$.91	$1.45
10 x'10	436	$.35	$ .58	$ .93

seeding, which uses somewhat more seed, would require a correspondingly higher investment per acre.

Returns to Improved Seed Investments

Manipulation of tree genotypes through either the seedling or clonal orchard route is directed to increasing the 'quantity or quality of wood yields from commercial forests under a given environment and management regime. I am not sure whether quantity or quality has received the most emphasis in your improvement programs . . . . probably a combination of both. Quantitative improvements are certainly the easiest to evaluate. In equation (A) we simply set the prices equal and determine the increase in rotation value yield due to more wood being present. Not yet knowing the magnitude of yield increases, we can make some management assumptions and, using our estimated seed costs, calculate what the quantity gains must be to justify the seed investment.

Assuming an interest rate of 5%, a constant stumpage price of $5 per cord, and a rotation age of 30 years, the extra yield in cords of wood at rotation age required to justify the net investment costs given in table 4 are shown in table 5.

Again running the risk of generalization, an 8 x 8 spacing and a net investment cost of $10 per pound of seed appears reasonable for current conditions in the South. This would indicate a yield gain of slightly less than one cord at rotation age is required to justify the investment in improved seed. Yields of managed loblolly pine plantations run from 25 to 40 cords per acre at age 30. The 'needed gain would therefore be on the order of a 2A% to 4% increase over current yields. Published expectations of growth and yield increases summarized by Barber (6) run from 5 to 10% and more based on initial measurements of progeny from clonal orchard parents.

Recognizing the many assumptions used in reaching the cost and required yield increases given above, it is still fairly clear that the investmerit costs in seed from commercial loblolly pine seed orchards is sufficiently low that realizing only a minimum expectation of increased yield will

[1] These costs were calculated assuming a pound of either improved or ordinary seed yield 7500 plantable seedlings. While the improved seed have fewer seed per pound, they also are larger and have higher percent viability. If both seed sources had the same ratio of seedlings/seed, the tabled costs should be approximately 9 percent higher.

TABLE 5. Increase in yield cords per acre from 30 year loblolly pine pulpwood plantations required to justify investment in improved seed.

Spacing	Number of Trees per acre	Net seed cost per pound $6	$10	$16
6 x 6	1210	.84 [1]	1.39	2.23
8 x 8	680	.47	.78	1.25
10 x 10	436	.25	.50	.80

1/ Assuming: stumpage price = $5/cord, r = 5%

justify them. In short, from the stumpage grower's point of view it certainly appears that current investments in loblolly seed orchards are well within the "ballpark" with respect to financial justification. If the upper expectations of quantitative gains materialize, they should prove to be excellent investments.

Wood Quality Improvements

The last and most intriguing topic covered here is the question of returns due to wood quality improvements. Returning once more to equation (A), we need to know the price or value differential between ordinary wood and improved wood. To my knowledge price differentials do not currently exist and to estimate what they might be, we must travel from the woods and take on the viewpoint of the mill manager.

Wood is an industrial raw material and therefore, quality of this material must be defined with respect to the products and processes in which it is used; in this case, paper making. Given the nature of pulp and paper manufacture, the pulpwood woodpile standing ready to be run into the debarker could be appropriately described as a pile of unseparated cellulose fibers. The relevant attributes de scribing the raw material might be fiber length (X_1), fiber diameter (X_2), strength (X3), fiber/lignin ratio (X_4) and so forth. If we could take the woodpile apart and plot the distribution of all fibers by these parameters, we would surely get a well defined distribution (figure 3). In the manufacturing process, the amount of raw material required per unit of product, and the time and cost required to convert the wood into paper, is technically related to these parameters of the woodpile. Pulpwood quality, therefore, could logically be defined as the mean Xi and variance 6^2_{x1} of these parameter distributions.

Using this definition of wood quality, changes in quality could occur by increasing or decreasing the mean or variance of these parameters. The value of these changes could be either positive or negative depending on the type of paper or fiber product for which the woodpile is used.

Two empirical questions arise in order to appraise the feasibility of changing any of these parameter distributions in the mill woodpile.

1. How can the distributions be changed and what is the cost of the changes?
2. What is the value of different kinds of changes in the context of a specific mill and product situation?

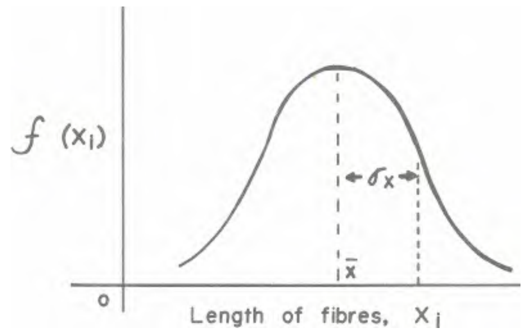

Figure 3. Fibre Length Distribution of Pulpwood in a Mill Inventory

Changes in wood quality

Several possibilities exist for controlling wood quality of which genetic or biological control is but one. Figure 4 illustrates the raw material supply system from woods to millyard. At each stage of the system the general types of quality control activities which might be undertaken are indicated. Procurement and millyard sorting could have at least as great an effect on the parameter distribution or quality of the final woodpile as genetic control in the forest. At the moment I have no idea as to the potential magnitude or costs of quality control made throughout this system. The data presented earlier on seed orchard costs gives some indication of genetic control cost but as yet it hasn't been closely related to the amount of change it can produce in the woodpile.

Research could probably go a long way towards providing some answers to this question. An operations research approach using existing data to simulate parameter distributions and the changes that would likely occur under a variety of control activities could probably be accomplished. Costs of most control activities could be estimated.

Value of Wood quality changes

Even assuming we could get some idea about how to change wood quality and what it costs, we are still faced with the difficult question of determining what these changes are worth. The value of any industrial raw material is derived from the value of the product for which it is used and the

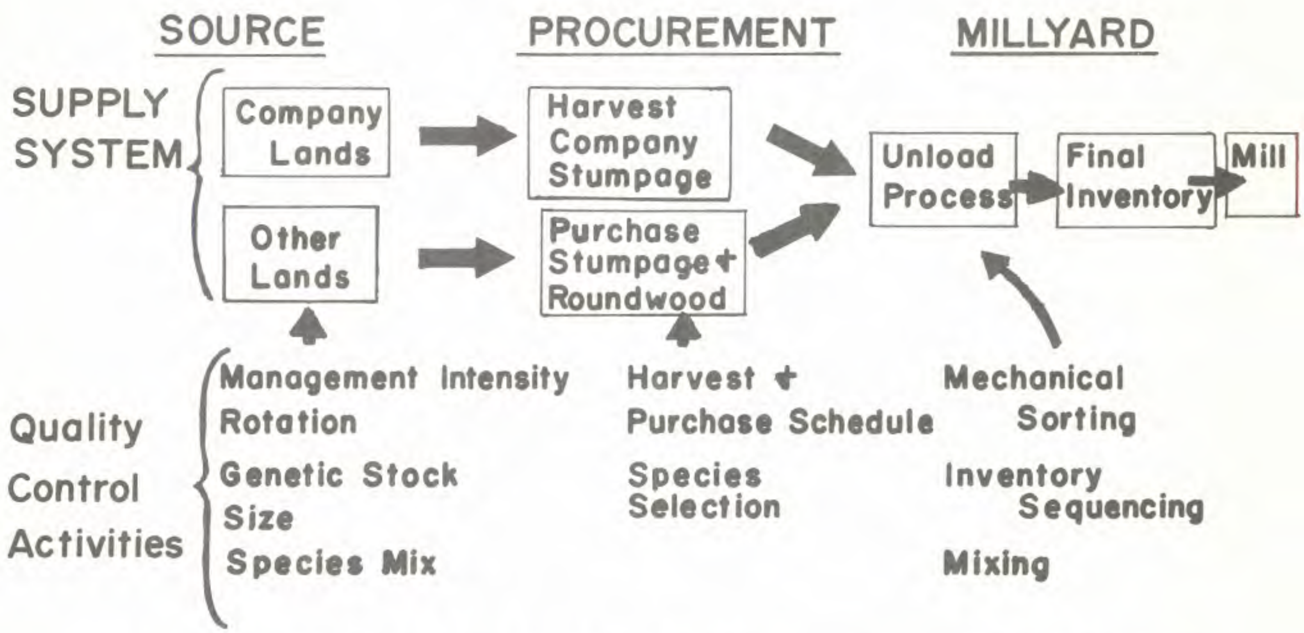

Figure 4. Location of Possible Quality Control in a Raw Material Supply System for a Pulpmill

cost of converting it into the product. To determine the value of controlling quality of the wood raw material, we must accordingly look at the paper making process. Paper making is represented in figure 5. Three main activities are involved; the wood input, pulping, and the paper machine. Each activity has several sub-processes which control the conversion of the wood to the final product. The total cost of a ton of standard paper is the cost of wood (C1) the cost of pulping (C2) and the cost of paper maker (C3). Allowing for some profit, the price of this ton of paper is approximately equal to the sum of these costs.

Within this wood-to-paper conversion process, increases in value and thus price for the wood input would arise if changes in the quality of wood reduce the total cost of producing paper. Control of wood quality could conceivably reduce conversion costs in the following ways:

1. Pulping and paper machine costs (C2 and C3) could be reduced. The hypothesis here is that C2, C3 = F(X1) i.e., cooking time and beating requirements might be reduced if the wood were more homogeneous.
2. Reduced wood variability within a given pulping and paper making setup might reduce the amount of finished paper rejected for not reaching product standards. This, at a minimum, would reduce the average pulping and paper making costs by reducing the amount of material that is run through twice.
3. By reducing the dry weight of fiber material needed to produce a given amount of standard paper. To illustrate: suppose if the fiber mix were perfectly controlled, a quantity of fiber W' would be required to construct a square yard of paper meeting certain performance standards of strength, etc. In practice, quality variations are experienced in the manufacturing process and to avoid excess rejections, a larger amount of fiber is used (W") and the paper is made, on the average, to exceed the specifications. The difference (W" - W') represents the amount of overbuilding in terms of the wood fiber used. Wood quality control should be able to reduce the difference and result in a cost reduction by requiring less input per unit of output and by reducing average processing costs per unit of output.

My reason for believing control of the wood input could achieve some significant cost reduction is an awareness of the tremendous variation and lack of control found in current mill pulpwood inventories. Pulpsticks vary by age, species, genotype, growth pattern, position of the tree, etc. It is difficult to imagine that reduction in this variability would not have an effect on the conversion process. Given current prices of wood pulp and paper, only a small reduction in average processing casts could result in million-dollar level savings when one considers the volume of raw material passing through a paper mill per year. To determine these potential cost reductions is a difficult research task.

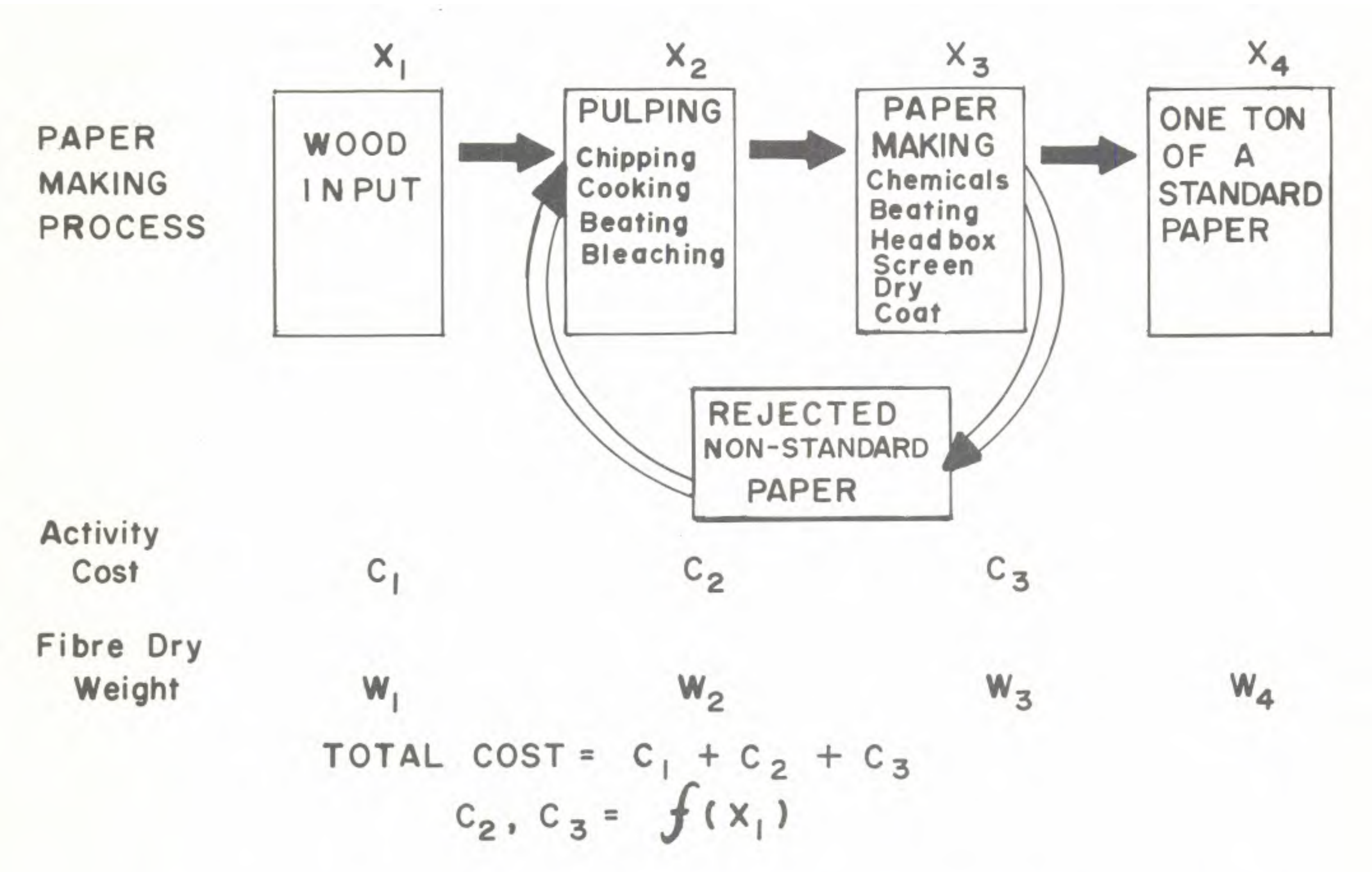

Fig. 5 Quality Control and Costs in the Paper Making Process

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