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Tree-Planting Machine — How Much Can You Afford to Pay for One?

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Tree-Planting Machine — How Much Can You Afford to Pay for One?

by

Dan W. McKenzie—*Mechanical Engineer*
David C. Hatfield—*Mechanical Engineer*
Kenneth K. Dykeman—*Staff Forester—Resources*

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The Forest Service, U.S. Department of Agriculture assigned a project to its San Dimas Equipment Development Center for the development of a mechanized intermittent tree planter. Center engineers established performance criteria for a tree-planting machine–one that would meet minimum requirements for quality, dependability, safety, reliability, etc. Also, such a device would have to be "affordable;" that is, compete economically with the hand planting of tree seedlings. In other words, the price one should be willing to pay for a mechanical tree planter is that at which a mechanized planter can perform at equal-or-less cost per tree than when only hand labor is used.

Hand planting cost data were readily available. To compare these to machine planting costs, we had to determine parametric costs for mechanized planting by considering operating expenses, depreciation, and the interest on capital. Parametric costs are estimated by developing cost relationships using such machine characteristics as the weight of the tree planter and its average production rate and crew size, plus the cost of the equipment. This was accomplished for the intermittent planting of containerized or bare-root tree seedlings by either a towed or self-propelled machine. To initiate the economic analysis, assumptions had to be made.

The set of assumptions (see the table) may have to be modified to fit each particular situation that might be under consideration. Also, remember that (1) assumptions can become invalid as circumstances change and (2) only economic values have been addressed in the analysis presented here. Decision makers usually have to consider social, political, site condition, specie, and seedling stock–as well as economic–factors. Also, recognize that you might be willing to pay a premium for some intrinsic features of mechanized reforestation–machines provide uniform, quality tree planting and avoid the multitude of problems associated with finding/importing, hiring, supervising, and caring for labor crews.

Note that the cost-determination method presented in this paper is a mathematical approximation. No field experience is available for an intermittent tree planter on which to base planting rates or machine reliability. Since the formulae presented are based on assumptions, the results should be considered approximations. The relations presented in the charts are mathematical and extend well beyond practical limits. The cost per unit area figures on the vertical axes of the charts are based on 680 trees per 0.40 ha (acre). The method is based on a spacing of 1.8 m (6 ft) between plants within the row and this plant spacing can be adjusted by changing the machine production rate (MPR) at a given speed (keeping the speed constant). Regardless of these restraints, the method presented in this paper can provide information on an "affordable" price for a mechanized tree planter.

Table. Economic Analysis Assumptions and Their Rationale.

ASSUMPTION	RATIONALE
1. The southeastern United States is the prime area of concern and the analysis can be based on its climate, terrain, and labor/equipment rates.	The southeastern United States is the most favorable area in the Nation for tree farms, has a long planting season and large areas to be planted, has been seeking mechanized

	planters, and recent (1980) data from this area, applicable to both hand and machine planting, are readily available.
2. While the affordable mechanized tree planter can be either an intermittent or continuous-row machine, the intermittent planter is the one under consideration.	While more costly, since more complicated than a continuous-row machine, the intermittent planter has lower energy requirements, may need less site preparation than a planter that plows a continuous row, causes less ground disturbance, and should result in a site with a more natural look.
3. Site preparation costs are the same for a mechanized intermittent planter and hand planting.	Site preparation costs for an intermittent tree planter are assumed to be less than that required for a continuous-row tree planter; when site preparation costs for an intermittent tree planter are assumed equal to site preparation costs for hand planting, the cost of site preparation need not be considered.
4. In any row, the tree seedlings are to be planted 1.8-m (6-ft) apart.	To maximize the planting rate, trees in the same row should be as close to each other as possible, while still having room to grow to the height desired prior to the first thinning.
5. Tree-planting machine equipment, having a performance criterion of 85% availability, has productive equipment time equal to 85% of labor time and, for a towed planter, the prime mover has an availability of 90%.	Due to the nonproductive time inherent in all heavy-equipment operations, 15% of the labor cost is lost time (e.g., delays due to equipment downtime, equipment maneuvering in the field at the end of planting rows, etc.). For a towed unit, 23% of the labor is lost time (0.85 x 0.90 ≐ 0.77; 100 – 0.77).
6. Equipment life is 6,000 hr of operating time over a 10-yr period.	Appelroth (1979) suggests the 6,000 hr. Taking into account the 85% availability and considering that the tree-planting season in the Southeast usually extends from mid-December to mid-May (approx. 20 wk), then a mechanized planter could operate approx. 600 hr/yr (0.85 x 20 wk x 5 day/wk x 8 hr/day = 680 hr), or for 10 yr (600 hr/yr until 6,000 hr is reached).
7. Overhead plus profit on labor are equal to direct labor cost.	This, in most instances, is standard practice for determining labor cost.
8. Maintenance cost is equal to straight line machine depreciation cost, without the cost of capital.	Repair and maintenance costs are highly variable and unpredictable as to time of occurrence. "Maintenance cost is equal to machine depreciation cost, without the cost of capital" is a standard rule of thumb for parametric cost estimating. This correlates closely with ASAE D230.3 when using a lifetime of 6,000 hr. [For forestry equipment, usually this results in an optimistic estimate–maintenance for the mechanized planter could be higher than given by this assumption.]
9. Machine depreciation cost is calculated by employing the capital recovery factor in conjunction with cost of capital and equipment life.	The capital recovery factor converts present investment into a uniform annual figure, and includes the cost of capital. It is preferred in economic studies as it is mathematically accurate and easily understood (Grant et al 1976). Also the method is suggested by ASAE EP 391.

10. Overhead and profit on equipment are equal to the straight-line depreciation cost, without the cost of capital, plus the maintenance cost; *or* twice the direct straight-line equipment depreciation cost; *or* twice the maintenance cost.	This is standard practice and a reasonable approach to recouping costs associated with overhead expenses and realizing a profit.
11. The cost of capital is 15%.	This is approximately the current rate; the analysis is not sensitive to minor changes in the interest rate. [Presently, for Federal purposes, the Office of Management and Budget suggests using 10%, (Fed. Reg. 1979), while some businesses are being charged more than 15% by commercial lenders.]
12. The crawler tractor that tows a tree planter ranges in size from 4500 to 6300 kg (10,000 to 15,000 lb) and can travel at a speed of approximately 2 km/h (1.24 mi/hr) on cutover areas.	Actual field experience in the assumed area.
13. The pass-through equipment cost (renter's overhead and profit) equals 0.25 times the equipment cost.	The operating cost of the prime mover (i.e., a tractor for a towed tree planter) is 25% more than the rental rate, which includes fuel, repair, depreciation, interest, insurance, and profit–but not the renter's general administration, overhead, storage/transportation costs, nor profit.
14. The salvage value of the equipment after 10 yr of use is zero.	To estimate, on the day the equipment is acquired, that after 10 yr it will have any value remaining is highly optimistic. In fact, charges might be incurred to have the 10-yr old, potentially wornout machine carted off to the dump. [If fortuitously after 10 yr there is some salvage value, the cash received would be a windfall and has very little present-day value.]
15. Tree survival rates for intermittent machine planting are equal to hand planting.	This is not a particularly good assumption, since machine survival rates are generally better than hand-planting survival rates. This can be partly overcome by raising hand-planting costs or using hand-planting costs where inspection was good (better planting) and survival rates were good.
16. Government experiences the same direct and overhead costs as private enterprise.	Salaries and wages, interest and depreciation rates, etc. that are established by regulation are influenced by, or tied to, private sector rates.

Mechanized tree planters presently available have production rates ranging from 300 to 2,000 trees/hr and can be purchased for prices ranging from $10,000 to over $100,000. When potential tree-planting machine users were questioned by us on the maximum price they would be willing to pay for an intermittent tree planter, a range of prices from $5,000 to $15,000 was quoted.

MECHANIZED PLANTING PARAMETRIC COSTS

A towed tree planter essentially consists of two pieces of equipment (a prime mover and a tree planter), while a self-propelled machine is a combination of both elements in one piece of equipment. In either case, based on experience and observation in the Southeast (1980), the labor costs associated with mechanized planting would be as follows:

- Heavy-equipment operator @ $7.79/hr to drive the machine
- Planter operator @ $5.39/hr to operate the planter
- Helper @ $3.35/hr to spell the planter operator, help load the seedlings into the machine, and occasionally place seedlings by hand in locations inaccessible to the machine.

Thus, the direct hourly labor cost is $7.79 + 5.39 + 3.35 = $16.53.

By assumption 7, this is the same amount as the overhead and profit on labor, giving a total hourly labor cost of $16.53 x 2 = $33.06. (Even when a planter with an automatic feed system is used, three workers are still required: The heavy-equipment operator, a helper to load tree seedling belts or holders, and a helper to relieve the other two plus hand-place seedlings on an as-required basis.)

Towed Tree Planter Prime Mover

The approximate crawler tractor rental costs (see assumption 12) in the Southeast (1980), from Forest Service published rates, are $10.48/hr. Adding on the "pass-through" rate of 25% (assumption 13), this becomes $13.10.

Tree Planter (Towed or Self-Propelled)

Tree planter costs, for any particular device, are given by taking into consideration the purchase price, cost of capital, depreciation, and maintenance, where:

- Machine depreciation/hr, with 15% return on capital and capital recovery = [Machine purchase price ÷ 6,000 hr machine life (assumption 6)] x 1.9925* (capital recovery factor–assumption 9)
- Maintenance/hr = Machine depreciation/hr, without the cost of capital = Machine purchase price ÷ 6,000 hr machine life (assumption 8)
- Overhead and profit on equipment/hr = Machine depreciation/hr, without the cost of capital + Maintenance/hr (assumption 10).

For instance, take a towed tree planter whose purchase price is $10,000. Then:

- Machine depreciation/hr, with 15% return on capital and capital recovery = ($10,000 ÷ 6,000 hr) x 1.9925 = $3.32/hr
- Maintenance/hr = $10,000 ÷ 6,000 hr = $1.67/hr
- Overhead and profit/hr = Maintenance/hr x 2 = $1.67/hr x 2 = $3.33/hr.

Thus, the total hourly tree planter cost is $3.32 + 1.67 + 3.33 = $8.32.

Availability Factor

Equipment costs now have to be modified to account for the 85% availability criterion (assumption 5) and 77% when towed. This places them on the same basis as the calculated labor costs per crew hour. Thus, for the assumed tractor: $13.10 x 0.77 = $10.09. And, for the selected tree planter: $8.32 x 0.77 = $6.41.

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*Capital-recovery factor for 15% interest rate for 10-yr life (assumption 6)–see Grant et al (1976), table D-20, p. 594.

ECONOMIC ANALYSIS

Mechanized Tree Planter Purchase Price vs. Cost/Tree

Using labor and equipment costs calculated as just indicated, graphs have been plotted (Figs. 1 and 2) that show the relationship between the price of a tree-planting machine and the cost/tree for various tree-planting production rates. Points on the graphs were generated as follows: For a towed tree planter that can be purchased for $10,000, total hourly cost for mechanized planting (usually the results from the sample calculations in the previous section) would be: Labor = $33.06; tractor = $10.09; and tree planter = $6.41—for a total of $49.56. Now, if this machine had a production rate of 1,000 trees/hr, the cost/tree would be $49.56/hr ÷ (1,000 trees/hr x 0.77) = $0.064/tree.

Tree Planter Production Rates vs. Cost/Tree

The planting rate of a tree-planting machine is primarily limited by the 2 km/h (1.24 mi/hr) maximum speed (on cutover areas) that the prime mover can traverse the area to be planted. This translates, at 1.8-m (6-ft) spacing (assumption 4), to an approximately 1,100 trees/hr MPR for a single-row planter.

An additional limit to the MPR is the maximum speed at which the planter operator can load seedlings into the machine. This worker can probably singulate the trees at a rate of approximately 1,500 trees/hr, which (at a machine's maximum travel rate) is faster than a single-row planter can place seedlings into the ground. Thus, a two-row machine would appear to be the one to consider for purchase in some situations. Ideally, if the two-row machine had planting heads that were 1.58-m (62-3/8-in) apart, all tree seedlings would be planted in the two rows being planted 1.8-m (6-ft) apart (assumption 4) and the next two rows could be moved over to obtain the average desired stocking.

The Affordable Tree-Planting Machine

Now, the families of straight lines in Figs. 1 and 2 can be expressed as a linear equation that provides the answer to the question, "How much can you afford to pay for a tree planter?":

$$X = C_1 + C_2 \text{ (HPC) (MPR)},$$

where: **X** is the maximum affordable tree planter purchase price (in $); C_1 is a negative constant (in $) determined by extending the straight lines to their point of convergence as they intercept the X-axis—by inspection of Fig. 1, for towed tree planters, C_1 = −$67,500; of Fig. 2, for self-propelled tree planters, C_1 = −$46,700; C_2 is a constant (in hr) that, when multiplied by HPC, gives the additional amount, in $, that can be paid for a mechanized tree planter with an increase of one tree/hr in the production rate; **HPC** ("hand planting cost," in $/tree) is the hand-planting cost known to exist in the planting location being considered; **MPR** is the "machine production rate" (in trees/hr) for the unit under consideration.

C_2 has been determined by "plugging in" various sets of values for X, HPC, and MPR in the straight-line relationships in both Figs. 1 and 2. These solutions for C_2 have resulted in 1,203 for towed planter and 1,202 for a self-propelled planter. As an example of determining the maximum economical purchase price: Say that hand planting in your area costs $0.12/tree and a towed tree-planting machine, being considered for purchase, can plant 1,100 trees/hr. Then the maximum economical purchase price for that planter is $X = C_1 + C_2$ (HPC) (MPR) = −$67,500 + 1,203 hr ($0.12/tree) (1,100 trees/hr) = $91,300. Alternatively, you could use Fig. 1. The answer can be increased by a factor of 1.11 (except if being purchased by a government agency), as this is the investment credit allowed private industry by the Internal Revenue Service (USDR IRS 1979).

DECISIONMAKING PROCESS

Recent (1980) contracts in the southeastern United States indicate that the HPC range from $0.09 to $0.12/tree (Figs. 1 and 2). At $0.12/tree, the maximum that you should be willing to pay for an intermittent tree planter with an MPR of 1,100 trees/hr is $91,300 for a towed planter and $112,000 for a self-propelled unit. If one were to assume a two-row machine with an MPR of 1,500 trees/hr, the maximum affordable price for an HPC of $0.12/tree is

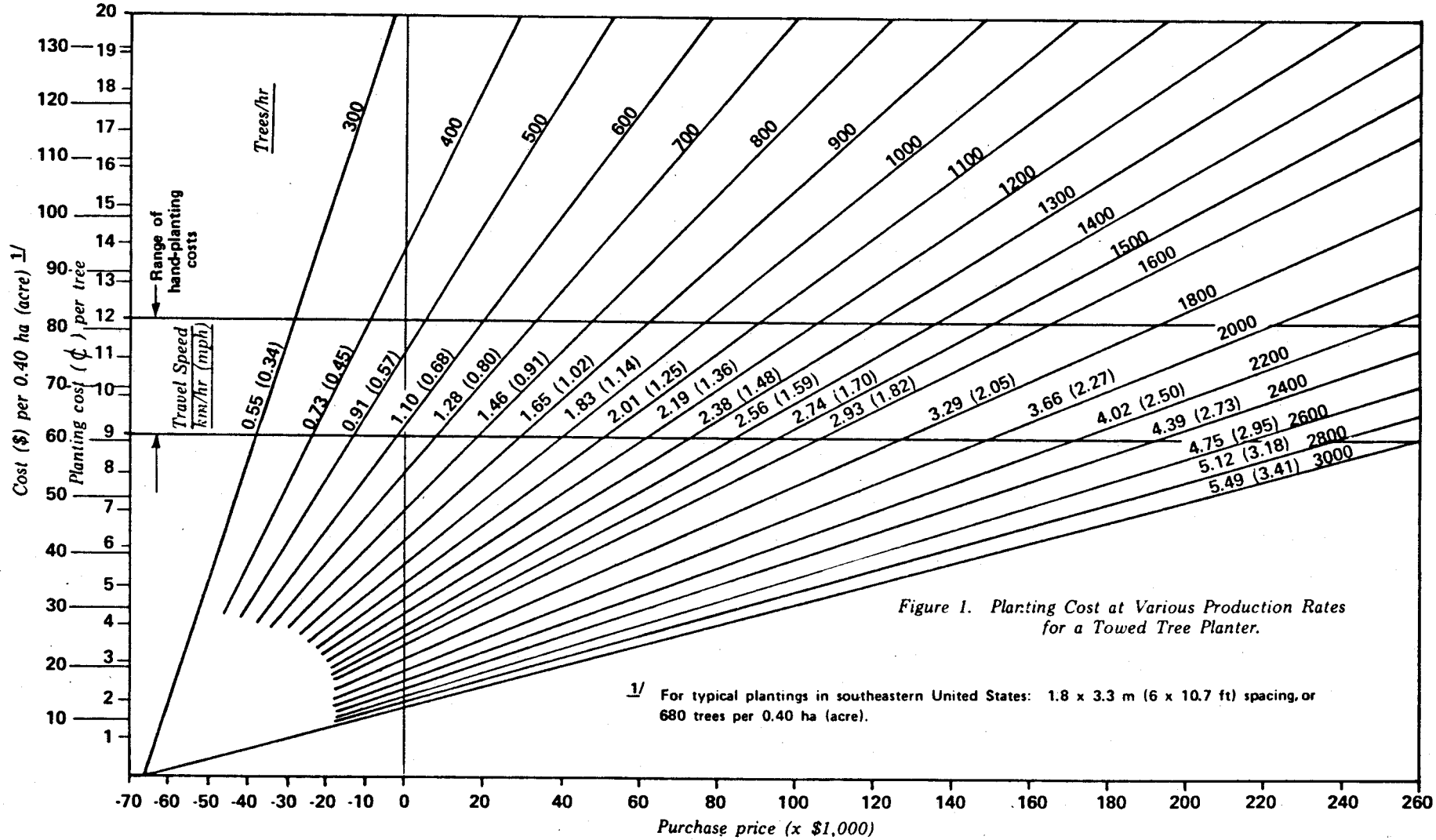

Figure 1. Planting Cost at Various Production Rates for a Towed Tree Planter.

1/ For typical plantings in southeastern United States: 1.8 x 3.3 m (6 x 10.7 ft) spacing, or 680 trees per 0.40 ha (acre).

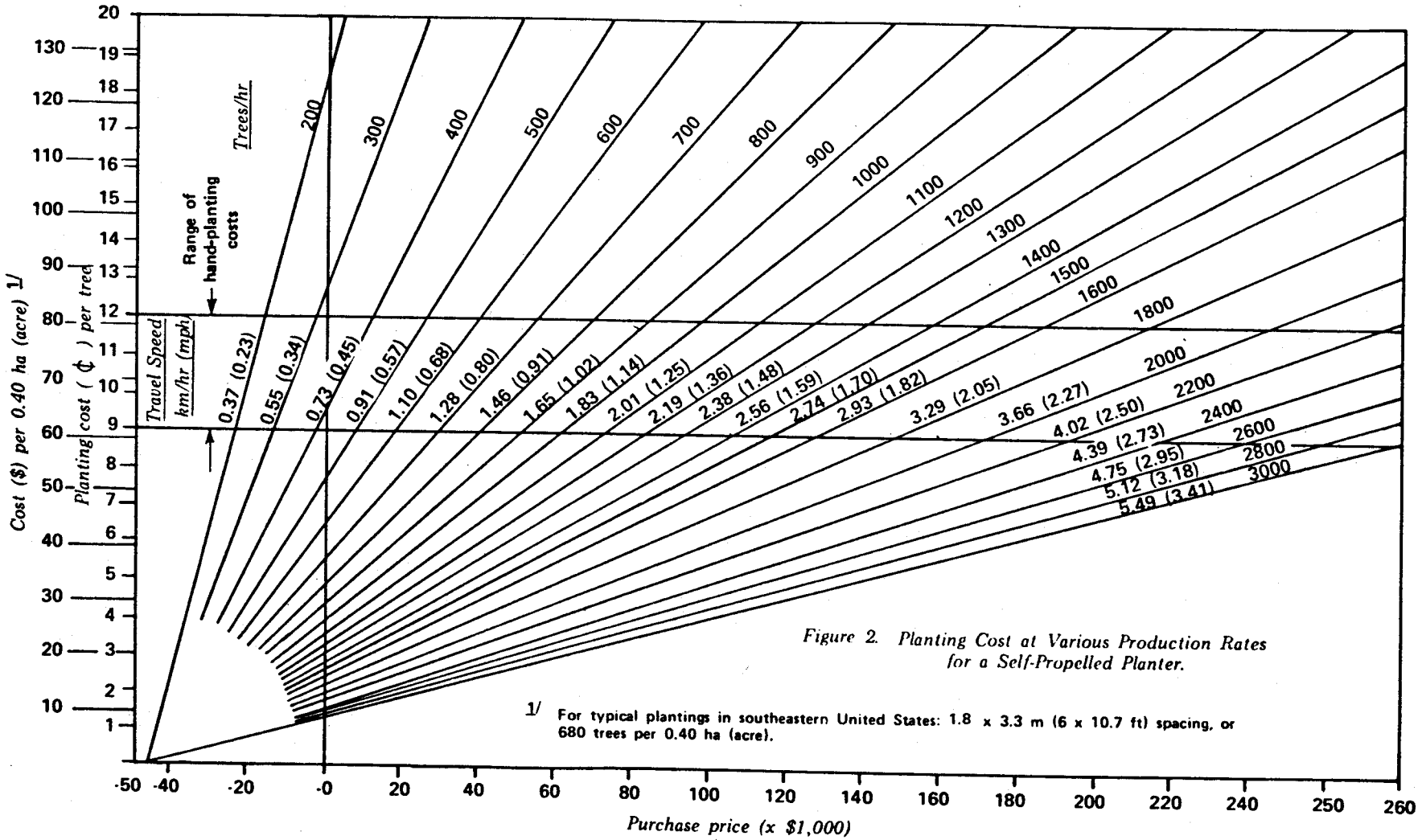

Figure 2. Planting Cost at Various Production Rates for a Self-Propelled Planter.

1/ For typical plantings in southeastern United States: 1.8 x 3.3 m (6 x 10.7 ft) spacing, or 680 trees per 0.40 ha (acre).

$149,000 for a towed machine and $169,700 for a self-propelled one. Also from Figs. 1 and 2, a machine must have a planting rate of at least 540 trees/hr (if one assumes a minimum machine cost of $10,000 for a towed unit and $27,000 for a self-propelled unit) to be affordable. At a planting rate of 540 trees/hr, this will only allow 6.7 sec to plant each tree. At this rate, planting can not be a stop-and-go operation and specific spot selection for seedling insertion can not be made. At higher, more desirable (and possibly necessary) planting rates, the problems of stop-and-go operation and specific spot selection becomes more acute.

CONCLUSIONS

1. For a tree-planting machine to be affordable it must have a high production rate (at least 600 trees/hr).

2. The price you can afford to pay for an intermittent tree-planting machine can be estimated by the following linear equations: (a) Towed Tree Planter, $X = -\$67,500 + 1,203$ (HPC) (MPR); (b) Self-Propelled Tree Planter, $X = -\$46,700 + 1,202$ (HPC) (MPR); where X is the maximum economical purchase price (in $), HPC is the local hand-planting cost (in $/tree), and MPR is the machine production rate (in trees/hr) for the unit under consideration. *NOTE:* X can be increased by a factor of 1.11 by private enterprise to take advantage of the investment credit offered by the Federal tax system.

3. The most important factor that a designer of a tree planter has control over is the production rate of the machine. A production rate of at least 600 trees/hr must be achieved, or an intermittent tree planter will not be economical. Much higher planting rates than 600 trees/hr are desirable and may be necessary for the machine to be affordable, depending on the cost of the machine and other circumstances.

4. Since the minimum MPR for a tree-planting machine to be affordable is at least 600 trees/hr, a stop-and-go operation would not be feasible, nor would the selection of exact planting spots be possible.

5. A much higher price can be paid for a tree planter than usually realized by potential users.

6. Due to travel speed limitations in planting areas, a two-row machine should be considered (based on assumed economics and theory) to obtain its inherently higher production rate.

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