STAGNENT LODGEPOLE PINE

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P R O G R E S S   R E P O R T

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THE PROBLEM

A vast area of accessible forest land is occupied by lodgepole pine (Figure 1) much of which is "stagnant". It is abundant in all of our study areas. These stagnant stands will not achieve merchantable dimensions by today's standards within a reasonable period of time. You can walk into a stand and wrap your hand around a 70-year-old tree. Yet the soil and climate are favorable and capable of producing a crop of sawtimber every 70 to 90 years. There is an urgent need to bring this land into production particularily in areas where timber shortages are foreseeable.

The problem is real and of a serious magnitude. We can ignore the situation and hope that technology will come to our rescue, or we can consult a fortune teller and gaze into her crystal ball, or we can initiate a research program designed to uncover the biological causes of stagnation. Our first goal is to bring the problem into focus.

The Webster Universal Dictionary defines stagnation as "the state of being motionless; inactivity, lifeless" with such synonyms as "still and sluggish". This label, which was probably based on superficial examination of the phenomenon, may have persisted because the prospects for stagnant stands appear to be too dismal to warrant further investigation (unless you're interested in supporting populations of rabbits). Our initial field work was designed to evaluate some of our cherished beliefs.

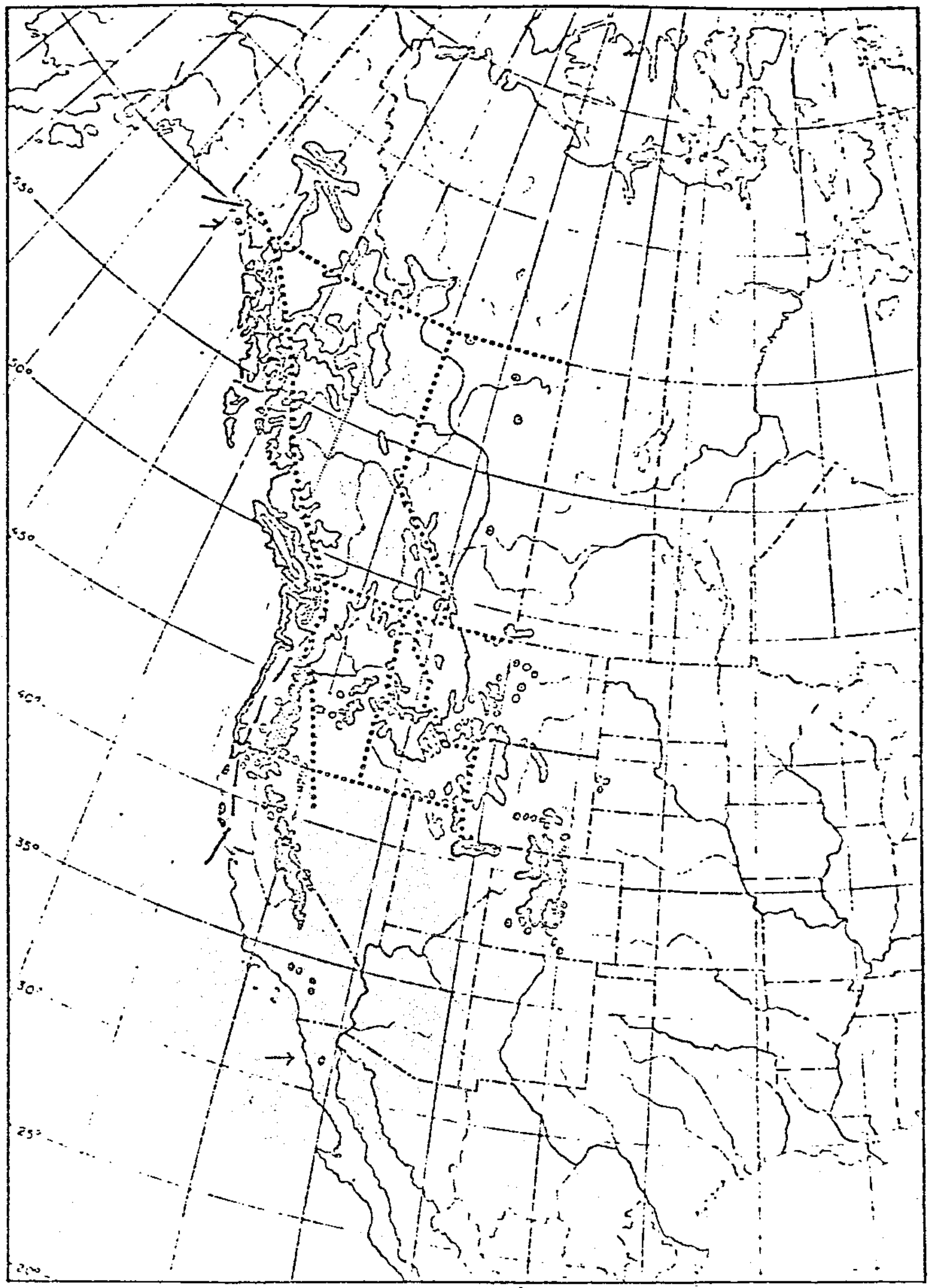

Figure 1. Geographic distribution of lodgepole pine.

Stagnant Stands and Negligible Height Growth.

One stand we examined had 800,000 stems/ha and only grew to a height of 1 meter in 18 years. However, detailed stem analysis revealed that the most "stagnant" stands we could find are adding appreciable height growth (Figure 2).

Stagnant Stands Will Never be Merchantable.

Analysis of some trees which are approaching merchantable dimensions shows that their growth has been repressed for a century or more. Stagnation may double or triple the length of the rotation but it does not stop the trees from becoming merchantable (Figure 3).

Stagnant Stands are Excessively Dense.

Stagnant stands of all ages carry the same number of stems per hectare as normal stands of the same height (Figure 4). Lodgepole pine, coastal Douglas-fir and most intolerant species have the same carrying capacity. Stagnant stands are no exception. However, lodgepole is somewhat unique in that young stands commonly have 50,000 to 500,000 stems established per hectare whereas most species are likely to have 5,000 or fewer trees. Stands of lodgepole are not excessively dense even though a horrendous number of trees may be established.

Stagnation is a Profound and Obvious Phenomenon.

A normal stand may be growing close to a stagnant stand which appears to be equally as healthy. The difference in height might mistakenly be attributed to a difference in the age or site quality. However, our analysis shows that stands may achieve from 25 to 100 percent of their

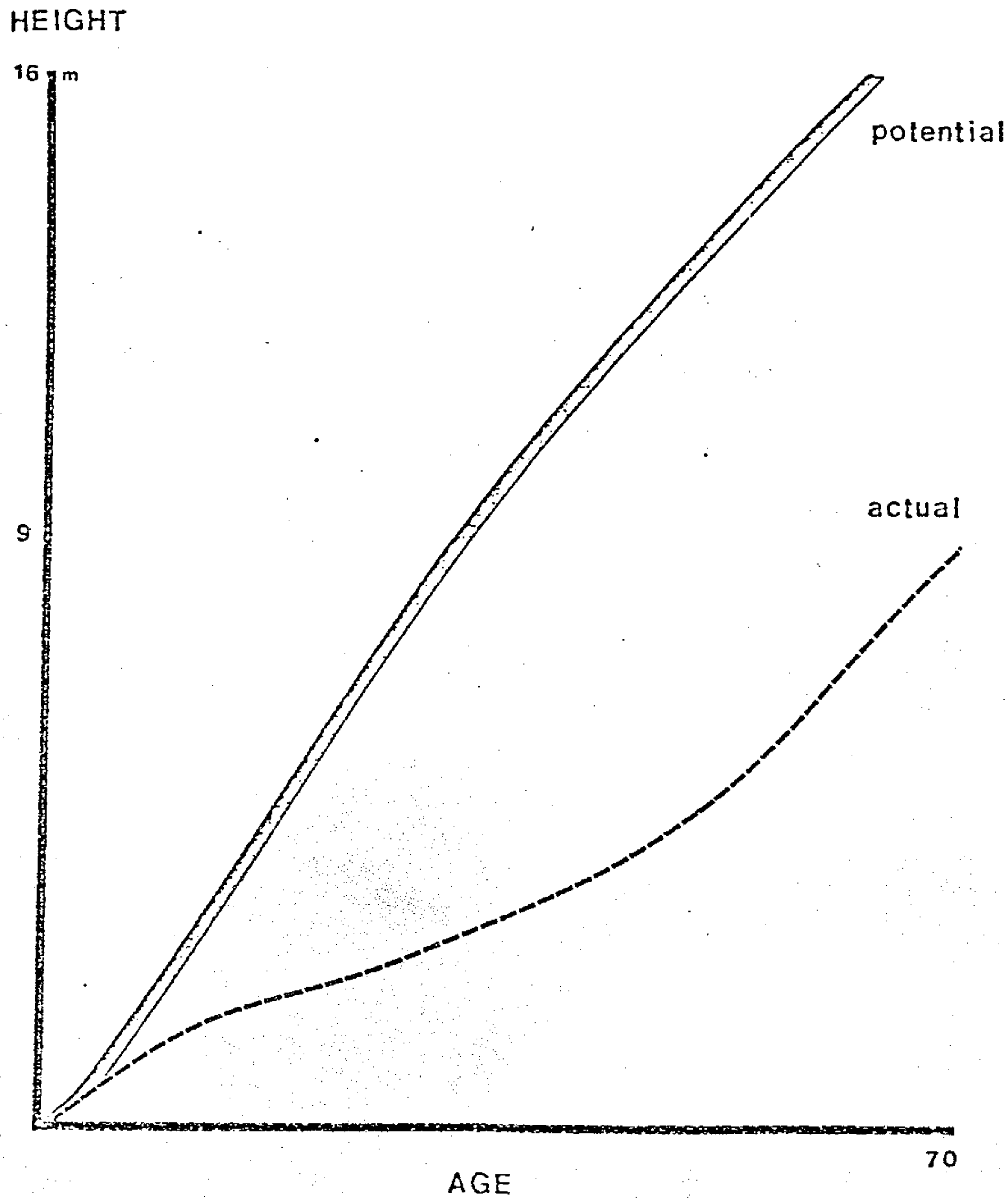

Figure 2. Height-age development of a 70-year-old stagnant tree in relation to it's potential.

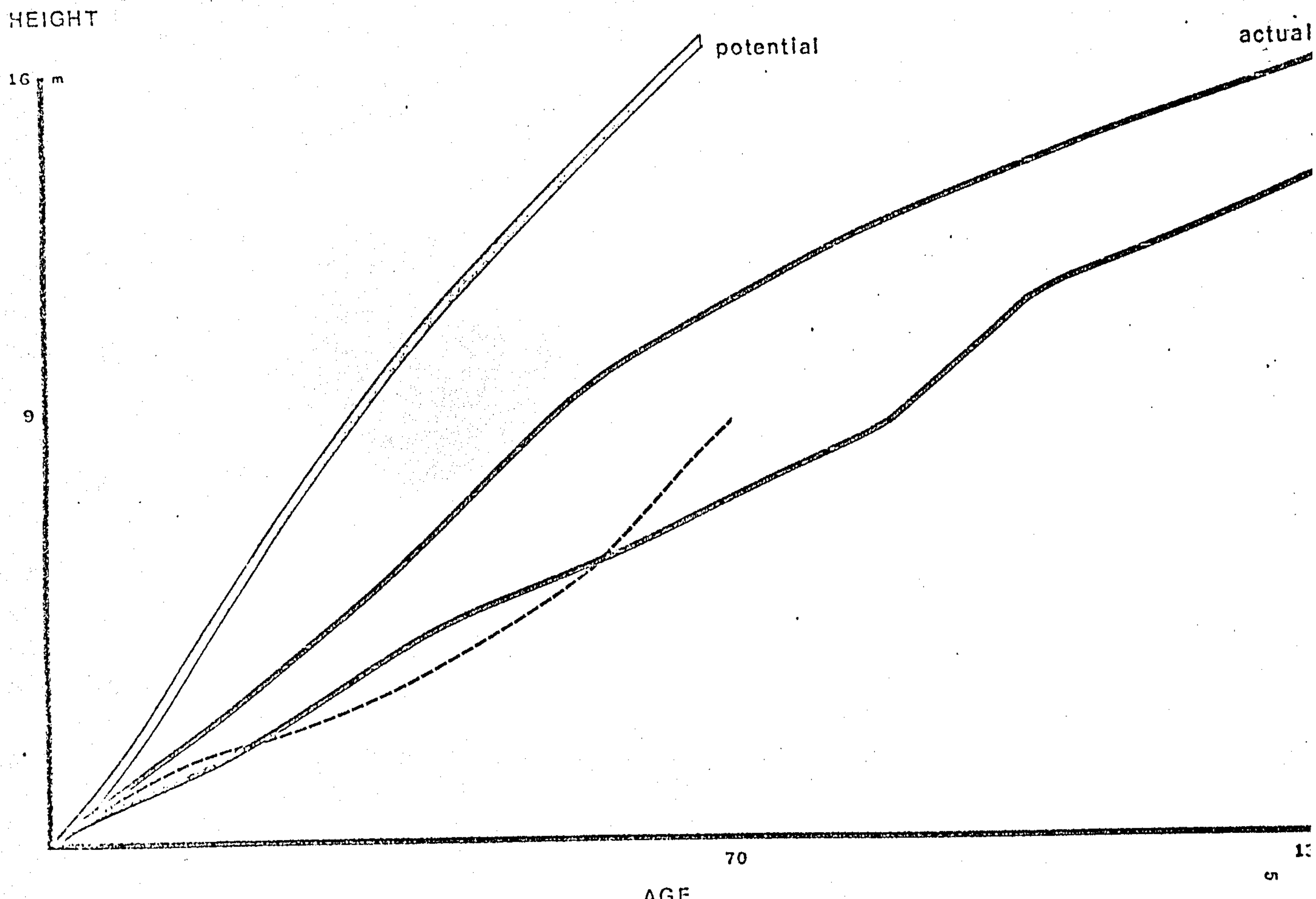

Figure 3. Height-age development of 130-year-old stagnant trees in relation to their potential.

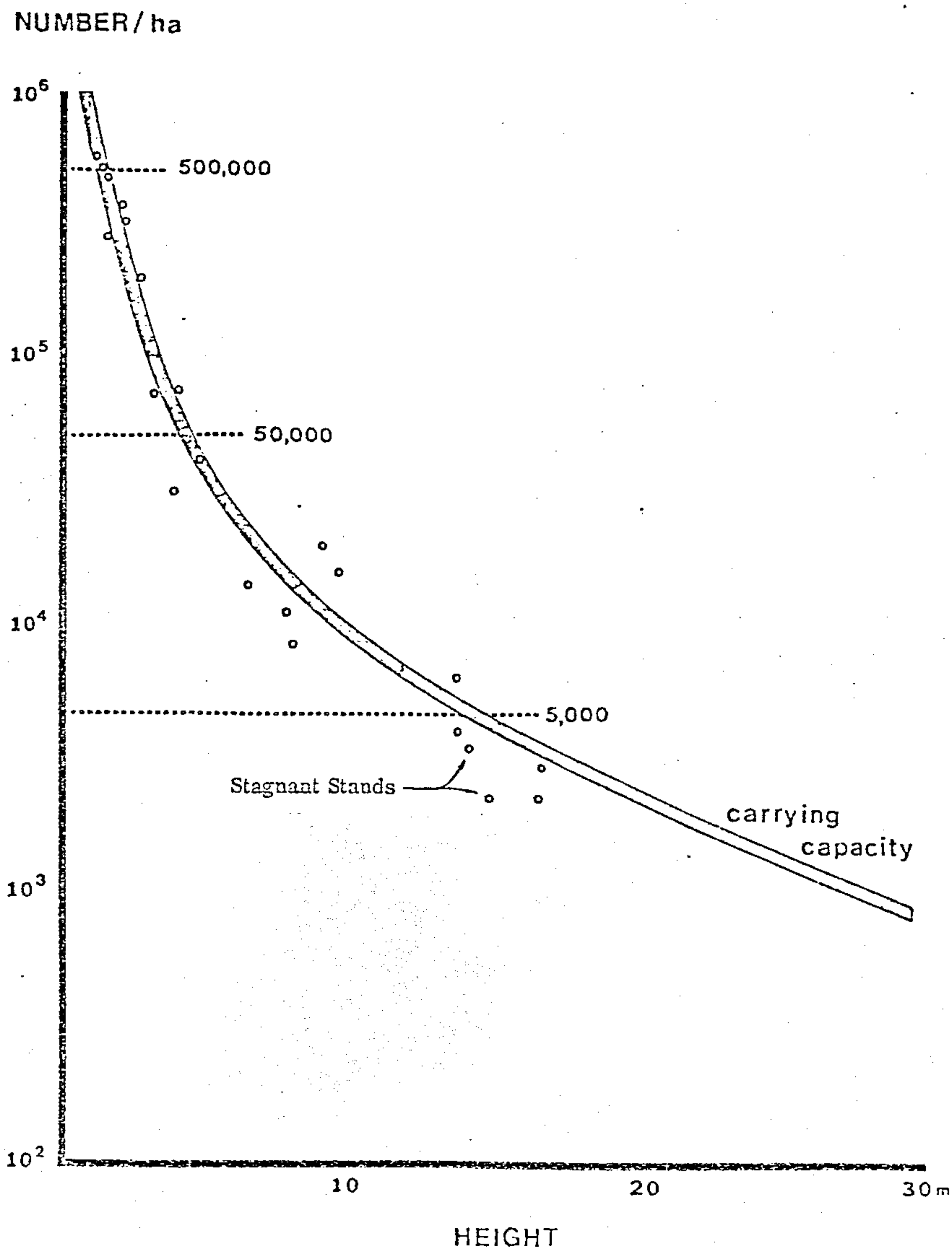

Figure 4. Relationship between the number of stagnant stems/ha (circles) and the height of site trees.

potential height growth on a particular site depending on the degree of repression (Figure 5). Stagnation is anything but obvious.

Stagnation Can Occur at any Age in Dense Stands.

The repression of height growth usually begins in the early years before trees reach a height of 2 or 3 meters and not at later ages (Figure 5).

Trees in Stagnant Stands do not Express Dominance.

Crown differentiation and mortality in repressed stands is similar to normal stands even though the height growth of all trees is repressed (Figure 6). Even super-dominants are found in stagnant stands.

Stagnation is Likely with 5,000 - 10,000 Trees/Ha.

Stands with 7,000 stems/ha have well-developed crowns and are growing vigorously. Some stands now 4 to 5 meters tall are not repressed even though they were initially established with 10,000 to 50,000 stems per hectare. However, stagnation is highly likely if more than 50,000 trees are established per hectare (Figure 7). On the other hand stands with only 5,000 - 50,000 stems should be quite productive.

* Note: THIS SHOWS YOU that we MUST continue to start our thinning programs before they stops growing

~~Stagnant Stands will not Respond to Release.~~

Repressed trees do respond when the competition is reduced drastically by fire, and then grow normally to rotation age. They are capable of achieving their potential rate of height growth if released at a young age (Figure 8).

We concluded from our initial study of stagnation that we should be using the term "repression" which describes a state of "restrained" growth.

Repression can be characterized as curtailed height growth which begins before the dominant trees attain a height of 2 or 3 meters if 50,000 or

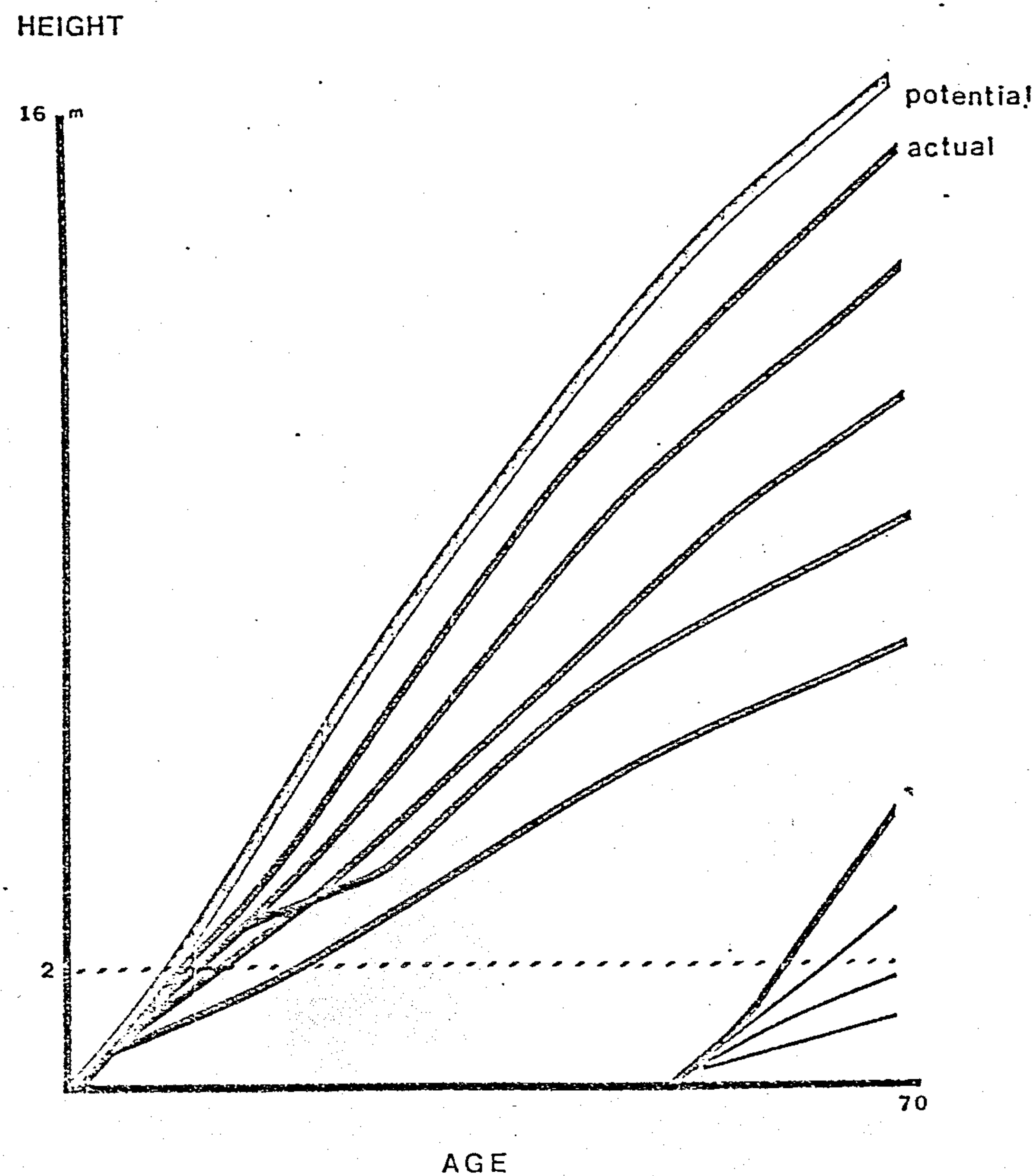

Figure 5. Height-age relationship of stands with different degrees of stagnation.

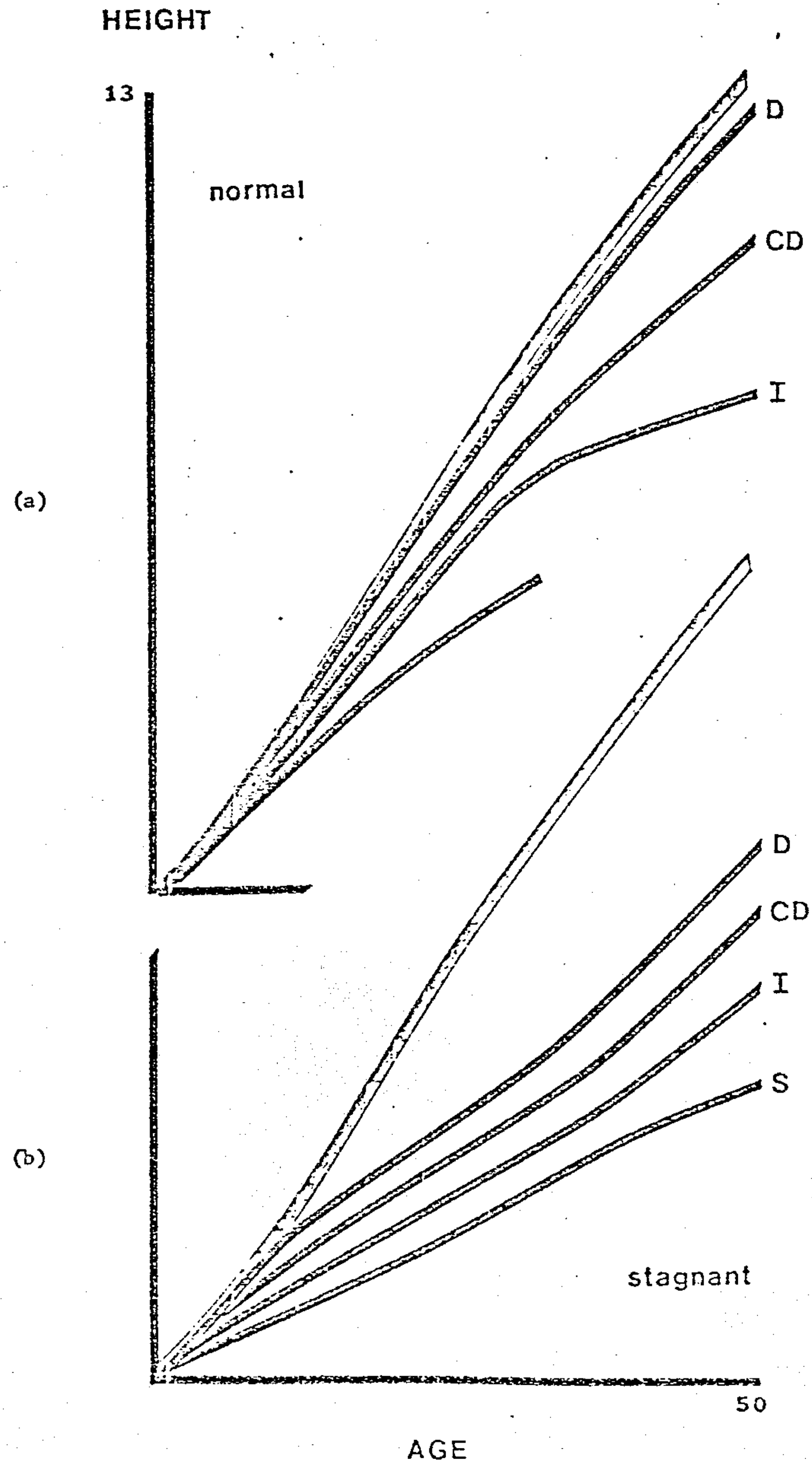

Figure 6. Height-age relationship of trees of various crown classes in a (a) normal and (b) stagnant stand.

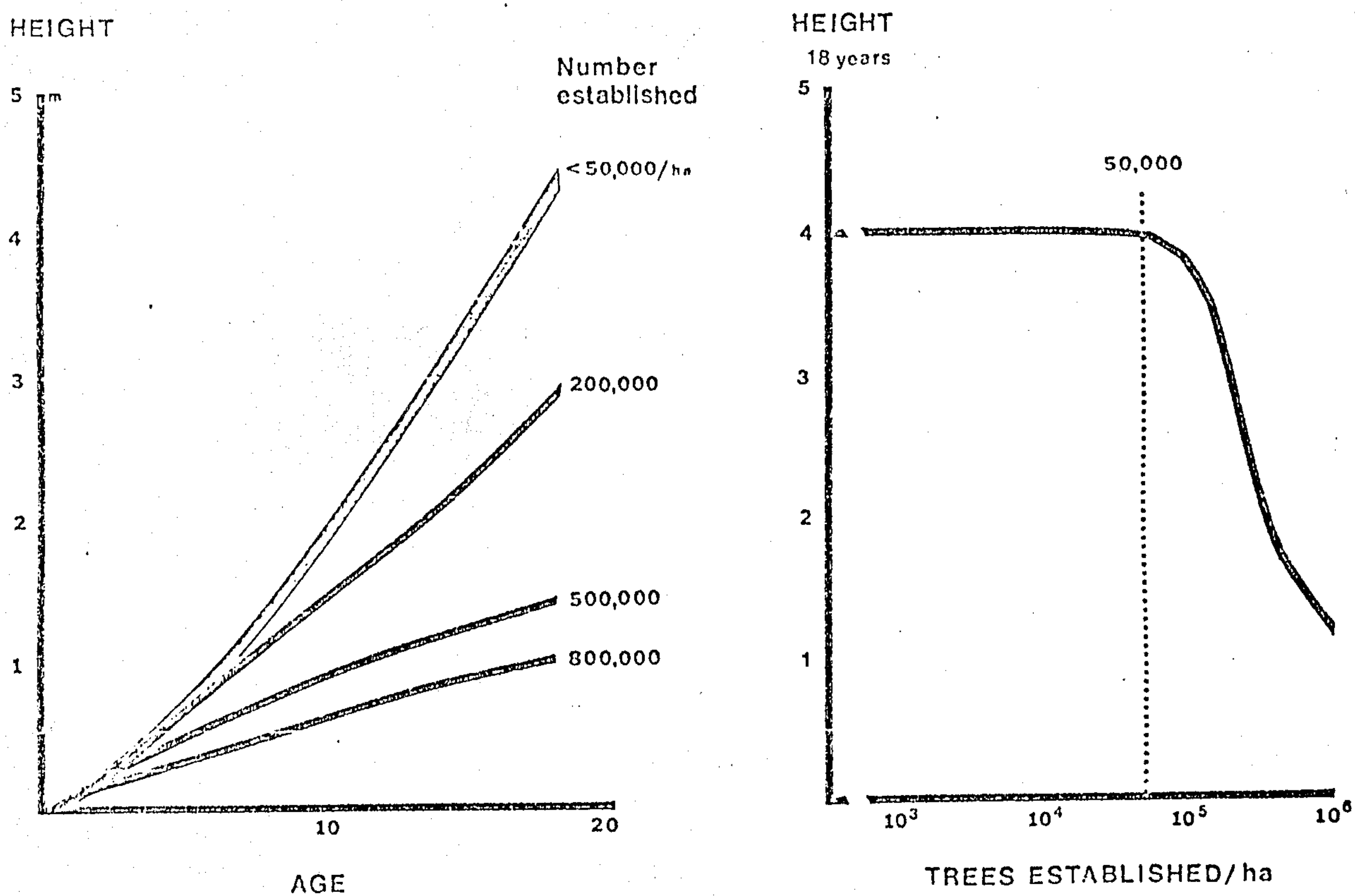

Figure 7. Height development of stands established with 50,000 to 800,000 trees/ha.

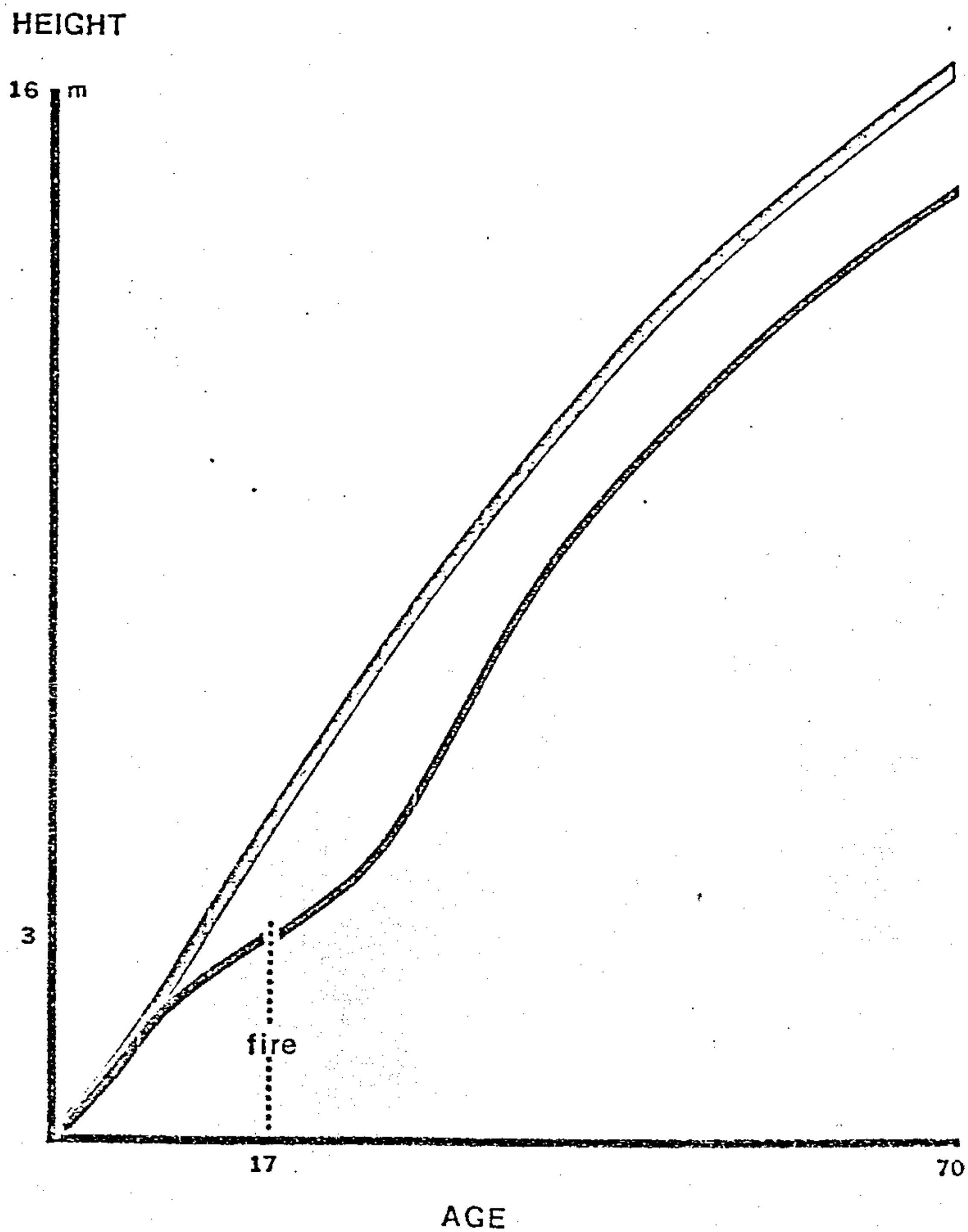

Figure 8. Height-age relationship of a 70-year-old tree released by fire at age 17.

more seedlings are established per hectare. The severity of repression is related to the level of initial stocking.

After characterizing the phenomenon of repression we next began to search for a biological explanation.

SEARCH FOR AN EXPLANATION

We examined a vigorous 18-year-old stand and measured each component of sample trees. The procedure was repeated in repressed stands of the same age including adjacent plots in which 200,000, 500,000 and 800,000 stems were established per hectare. The height of dominant trees decreased from 4.5 to 1.0 meters across this range of plots. We wanted to investigate potential causes of repression.

Root Competition

Hydraulic excavation of root systems revealed that root extension, unlike crown expansion is not physically impeded by competing trees. Root systems intermingle freely in plots established with 50,000 (Figure 9), 200,000 (Figure 10) and 500,000 (Figure 11) stems per hectare. Repression is not due to the physical competition of root systems.

Root Grafting

None was uncovered in the excavated stands. Consequently, root grafting does not interfere with the mechanics of intertree competition. We did, however, find a white spruce that captured a root from a distant neighbour (Figure 12).

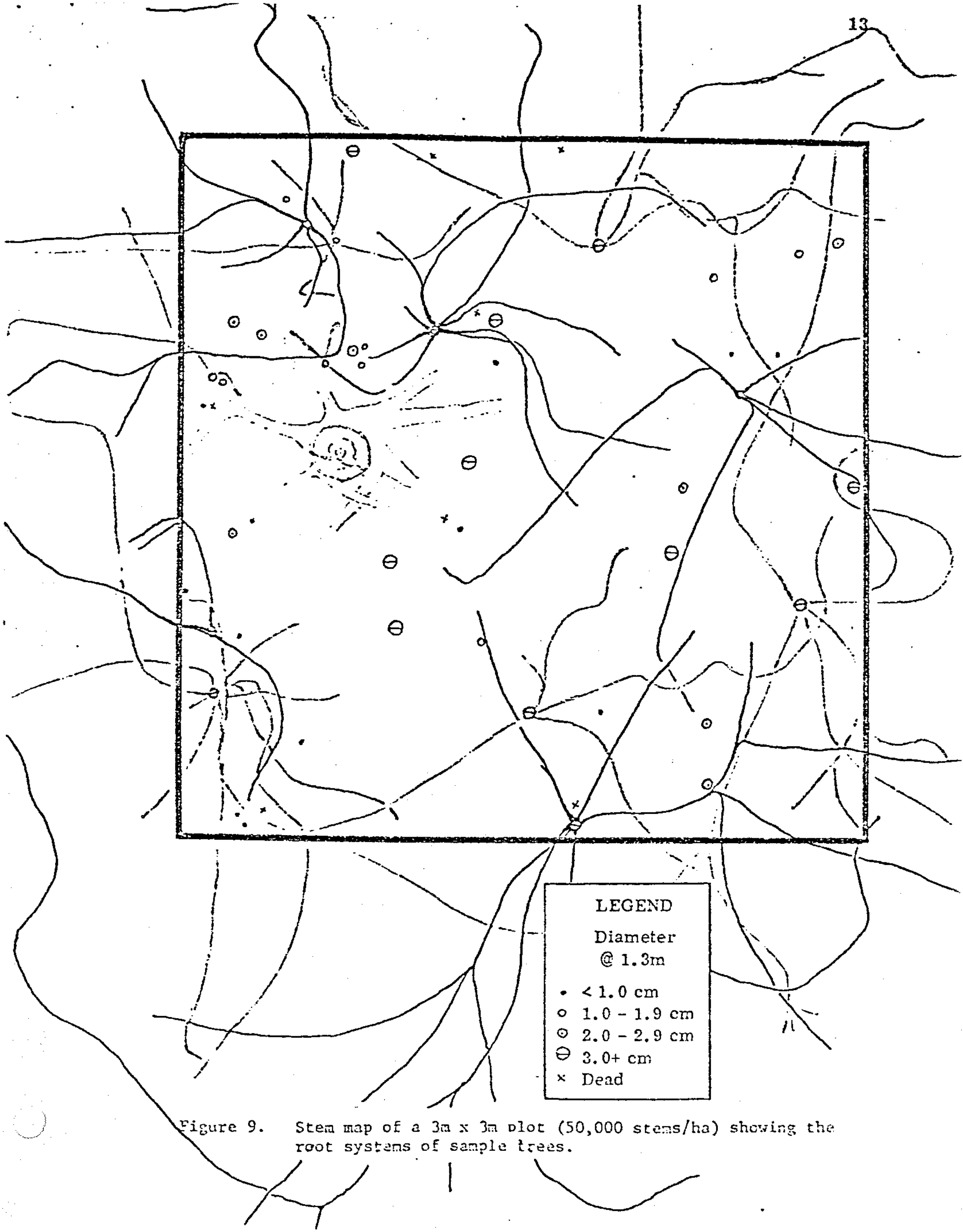

Figure 9. Stem map of a 3m x 3m plot (50,000 stems/ha) showing the root systems of sample trees.

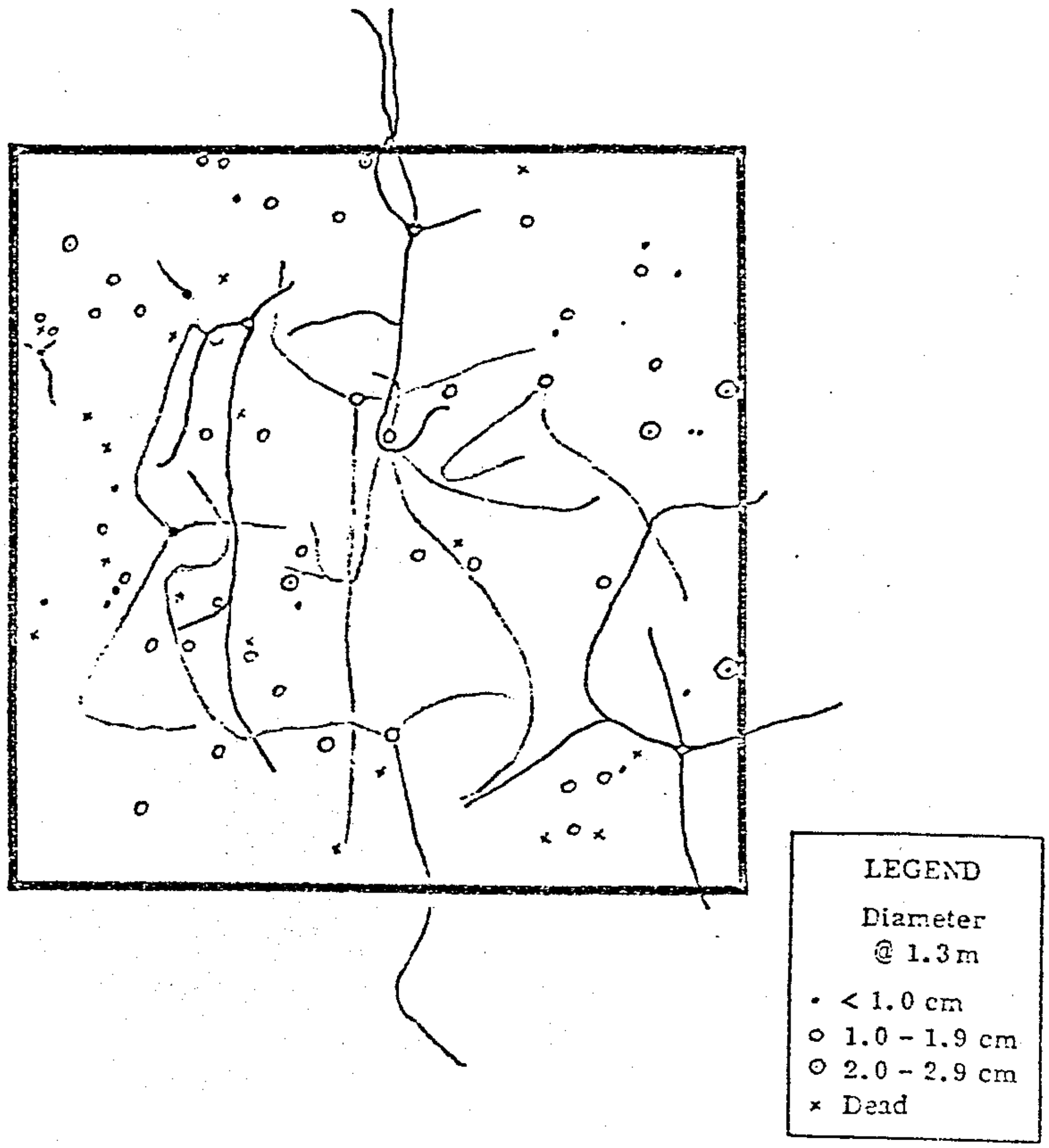

Figure 10. Stem map of a 2m x 2m plot (200,000 stems/ha) showing the root systems of sample trees.

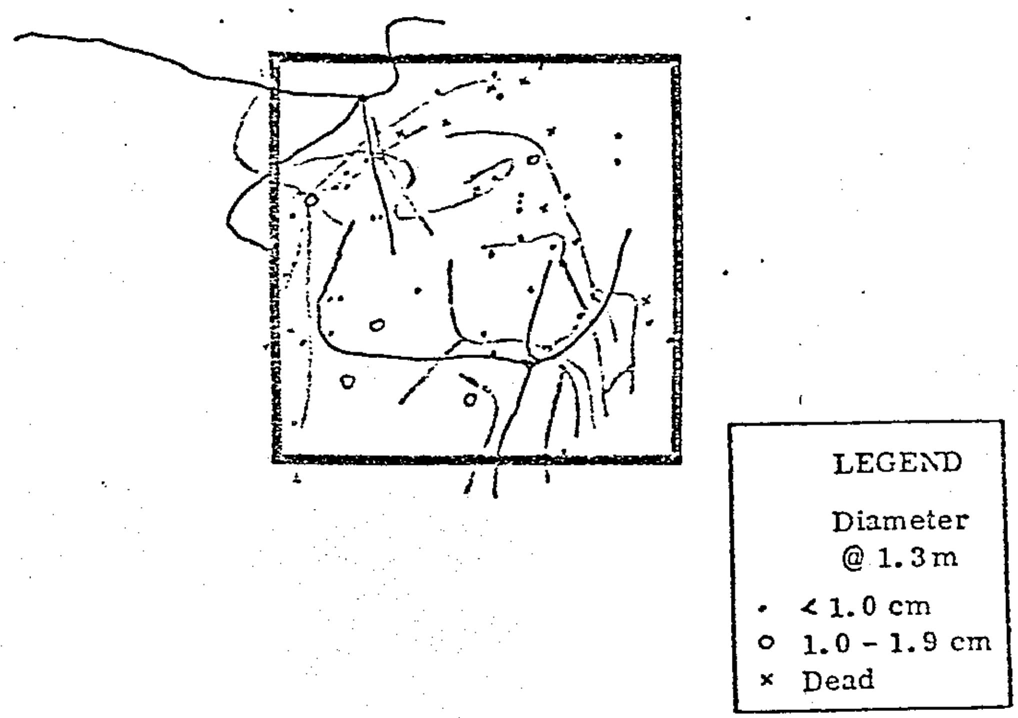

Figure 11. Stem map of a 1m x 1m plot (500,000 stems/ha) showing the root system of sample trees.

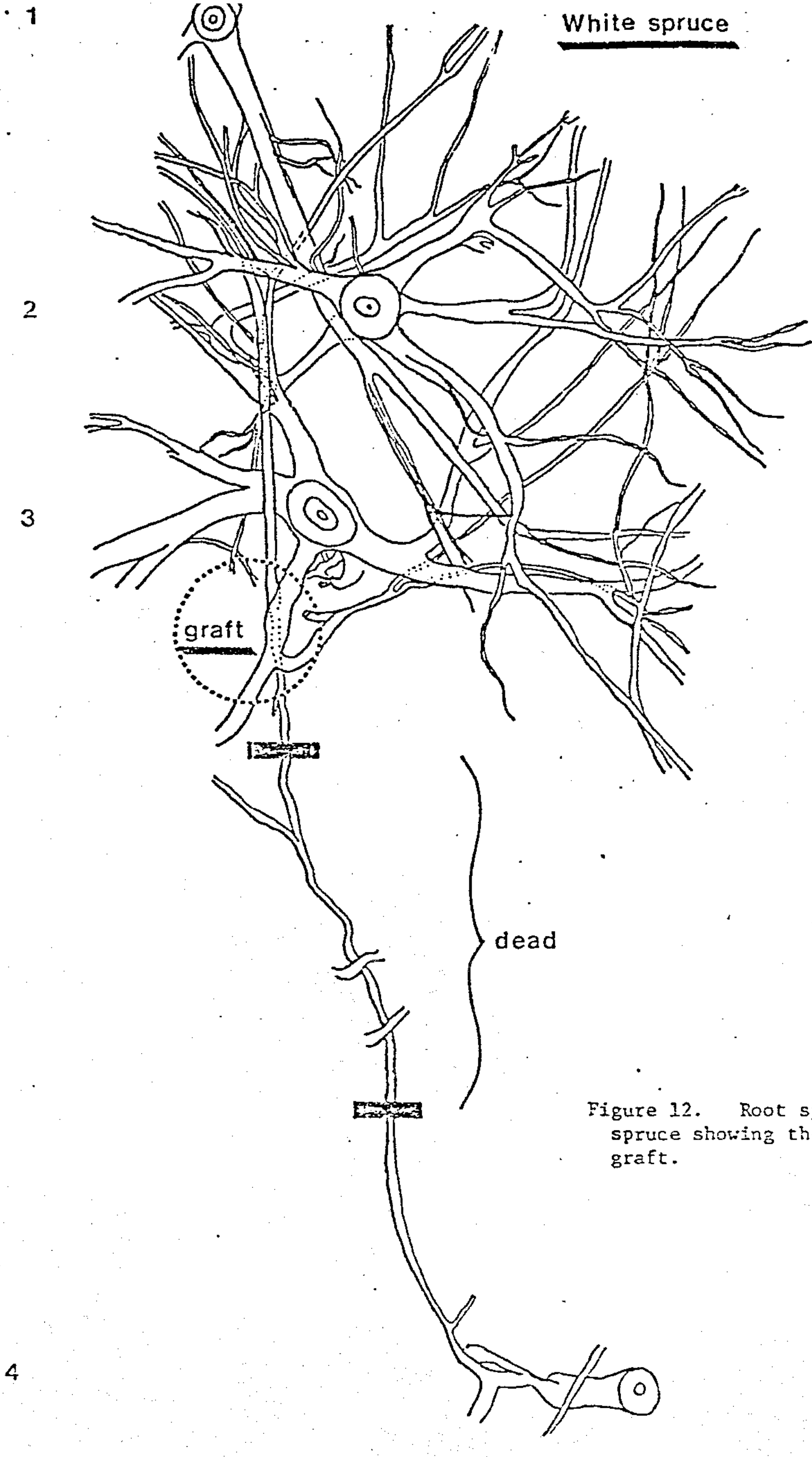

Figure 12. Root systems of white spruce showing the location of a graft.

Light Limitations

Trees situated at the edge of repressed stands grow normally particularly if an opening such as a road improves the light regime. The difference in height is dramatic but note that the zone of unrestrained growth is only 10 to 20 centimeters wide (Figure 13). Light or possibly moisture could be a limiting factor.

Moisture Limitations

We observed that regeneration in burns is not successfull adjacent to the original stand. Root excavations suggest that competition for moisture may contribute to stagnation. Roots from the original repressed stand extend into the burn and usurp the moisture so rapidly that regeneration fails to thrive within a distance of 4 or 5 meters (Figure 14). The diameter and height growth of the repressed trees do respond to the sudden availability of water and nutrients (Figure 15). We can conclude that moisture is a potential cause of repression.

Distribution of Biomass

The total biomass of 18-year-old stands peaks for plots established with 50,000 stems per hectare, and declines rapidly as the initial density approaches 1,000,000 trees (Figure 16). The weight of the bole, foliage, branches, bark and roots bears a similar relationship (Figure 17). The entire system appears to become overloaded and slow down if too many trees are established. The relative distribution of biomass does not change much although there is a shift from the production of foliage and branches in favor of the bole and roots (Figure 18). The distribution of biomass reflects the impact of repression but not the cause.

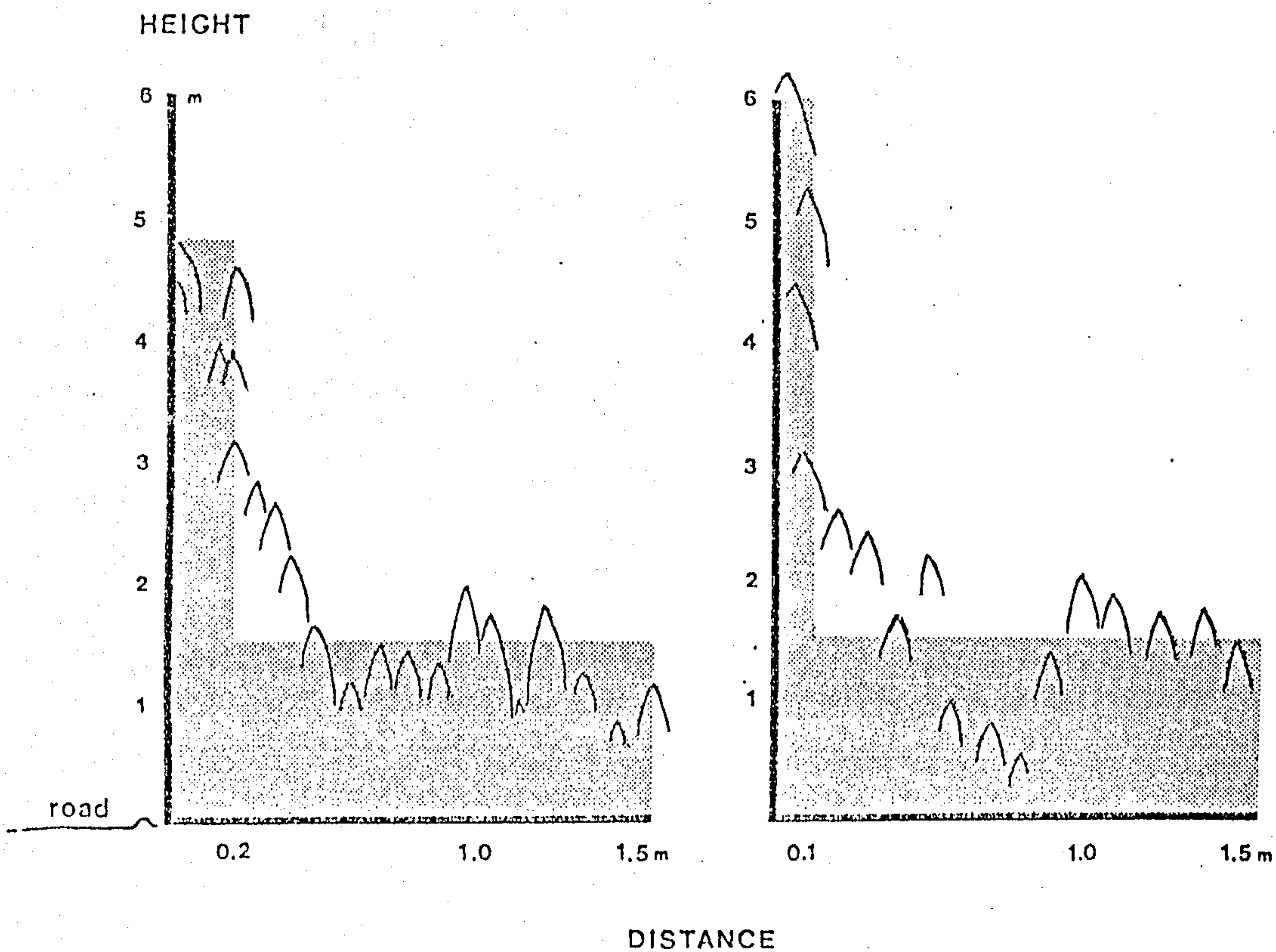

Figure 13. Height of trees in relation to the distance from a road constructed when the stand was regenerated.

(a)

(b)

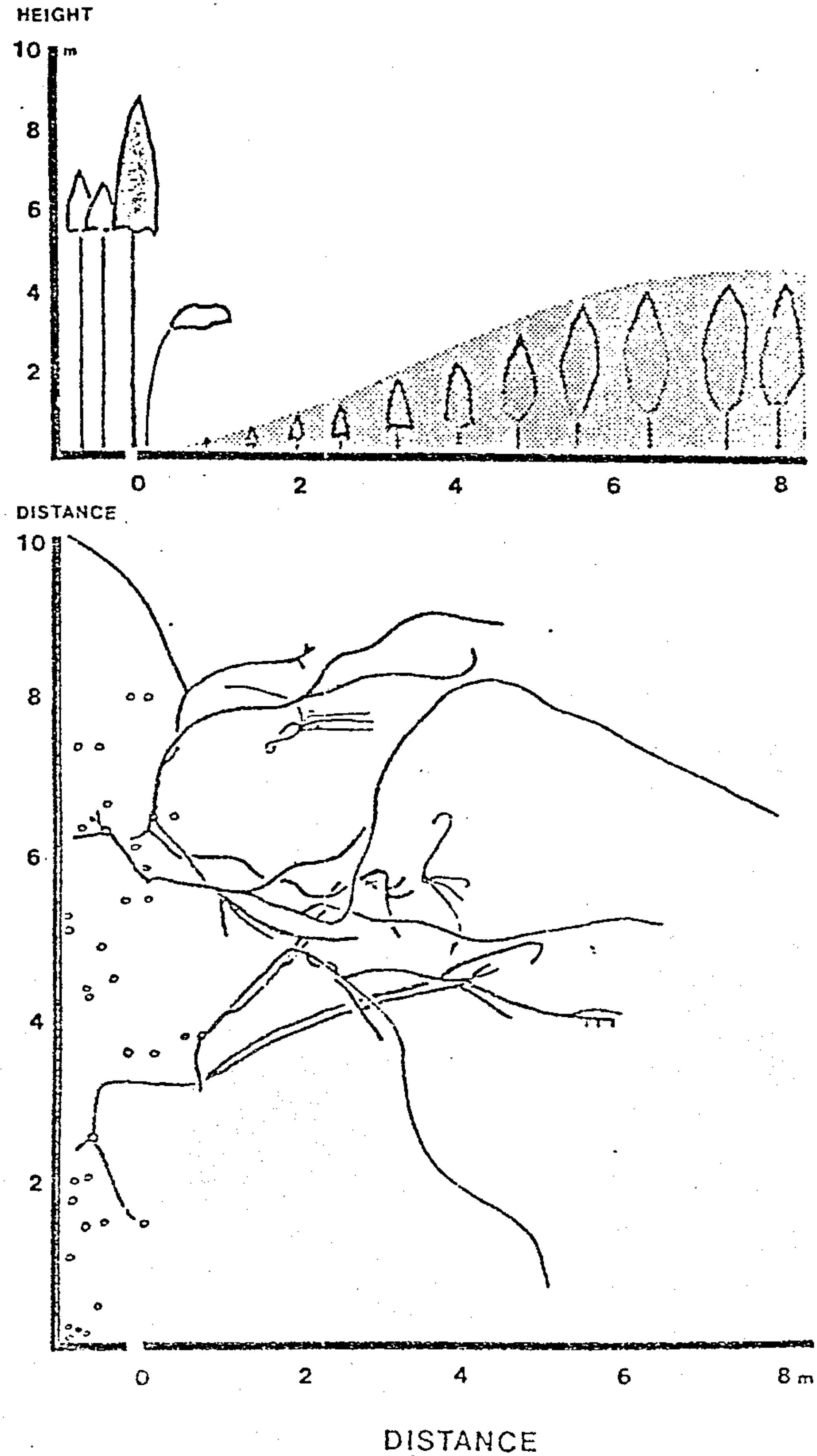

Figure 14. Diagram depicting (a) the decrease in height of regeneration towards the original stand and (b) the root systems of sample trees in the original and regenerated stands.

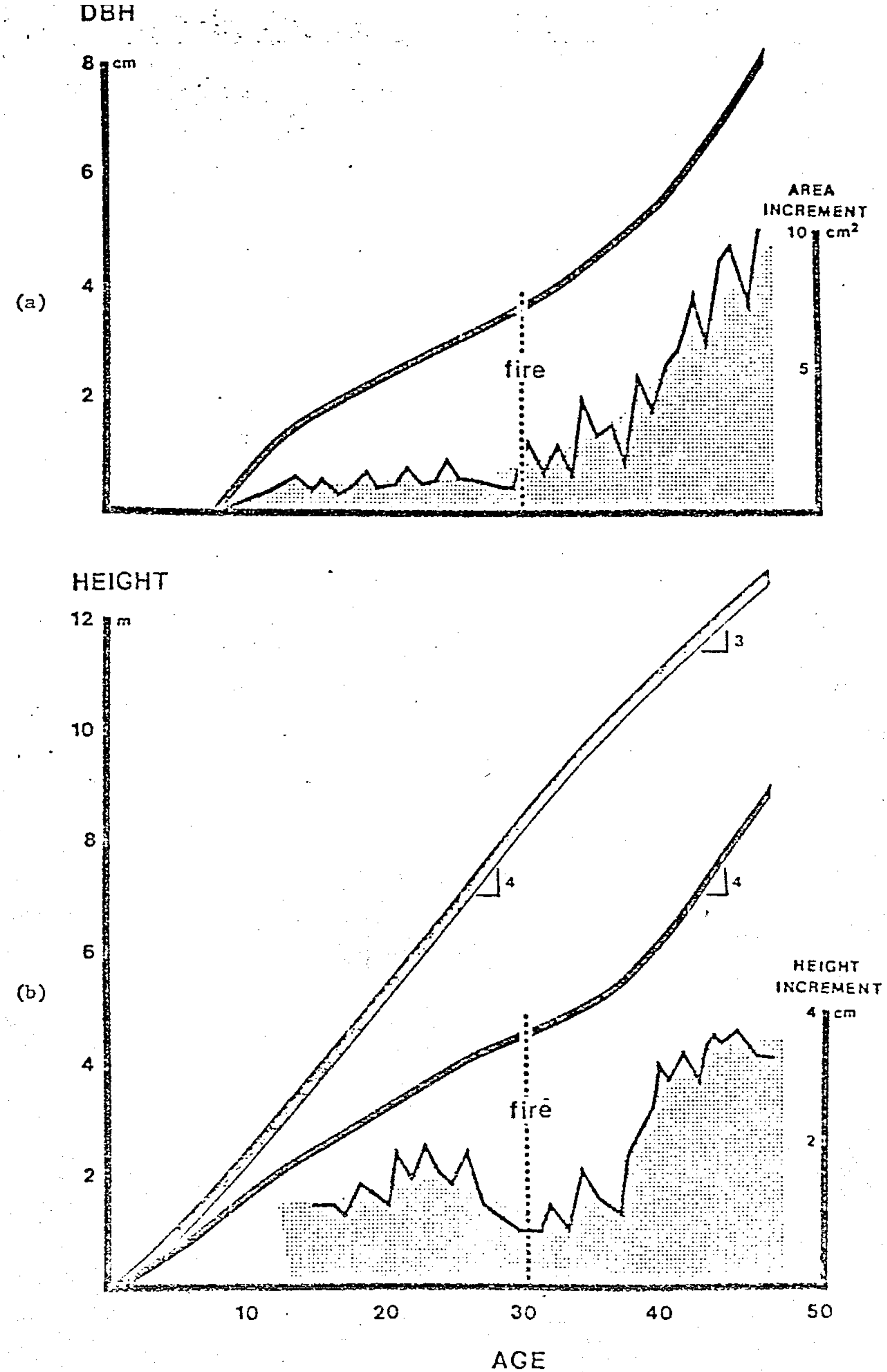

Figure 15. Response of (a) diameter and cross-sectional area increment, and (b) height and height increment to release.

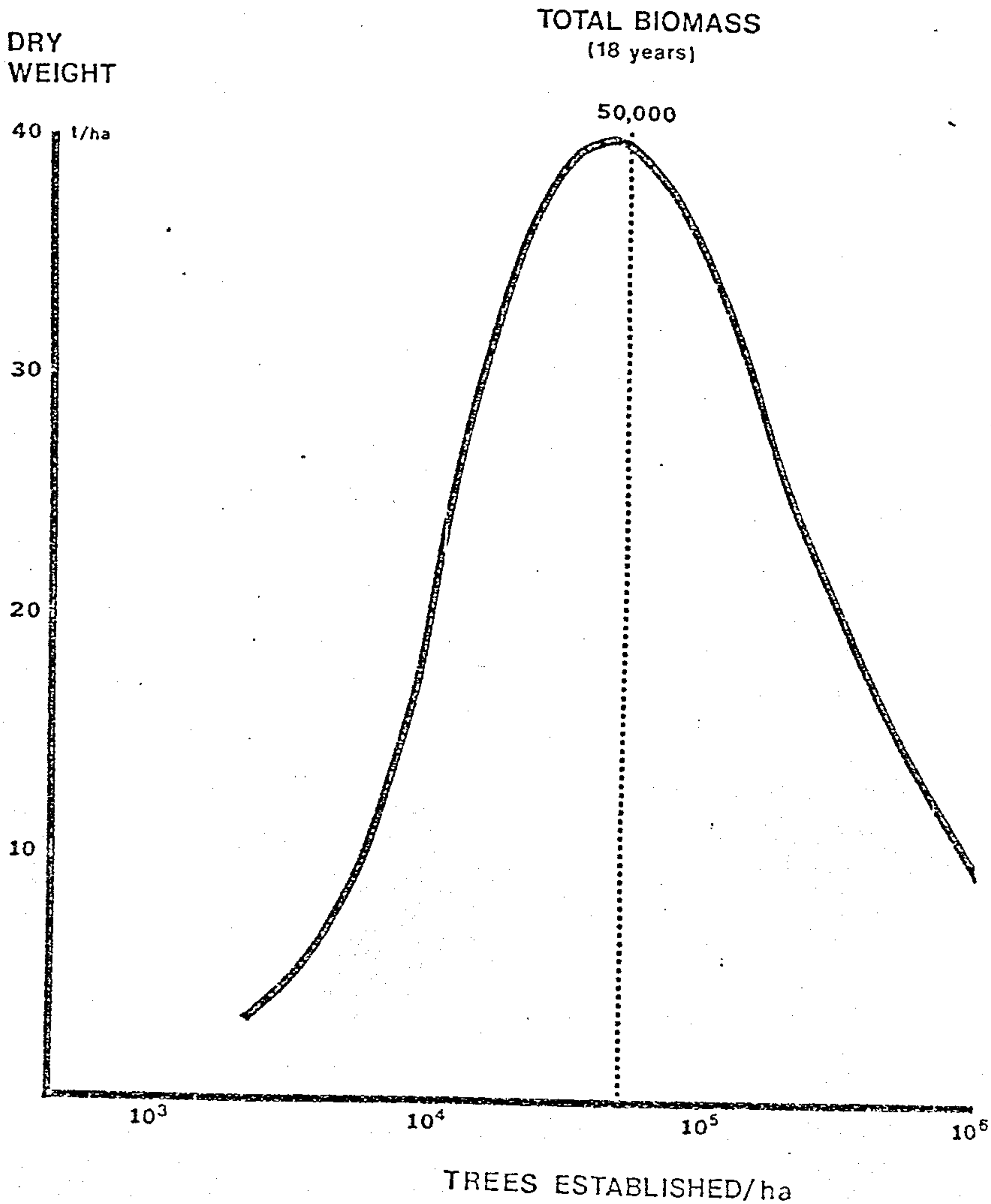

Figure 16. Relationship of dry weight to number of trees established in 18-year-old stands.

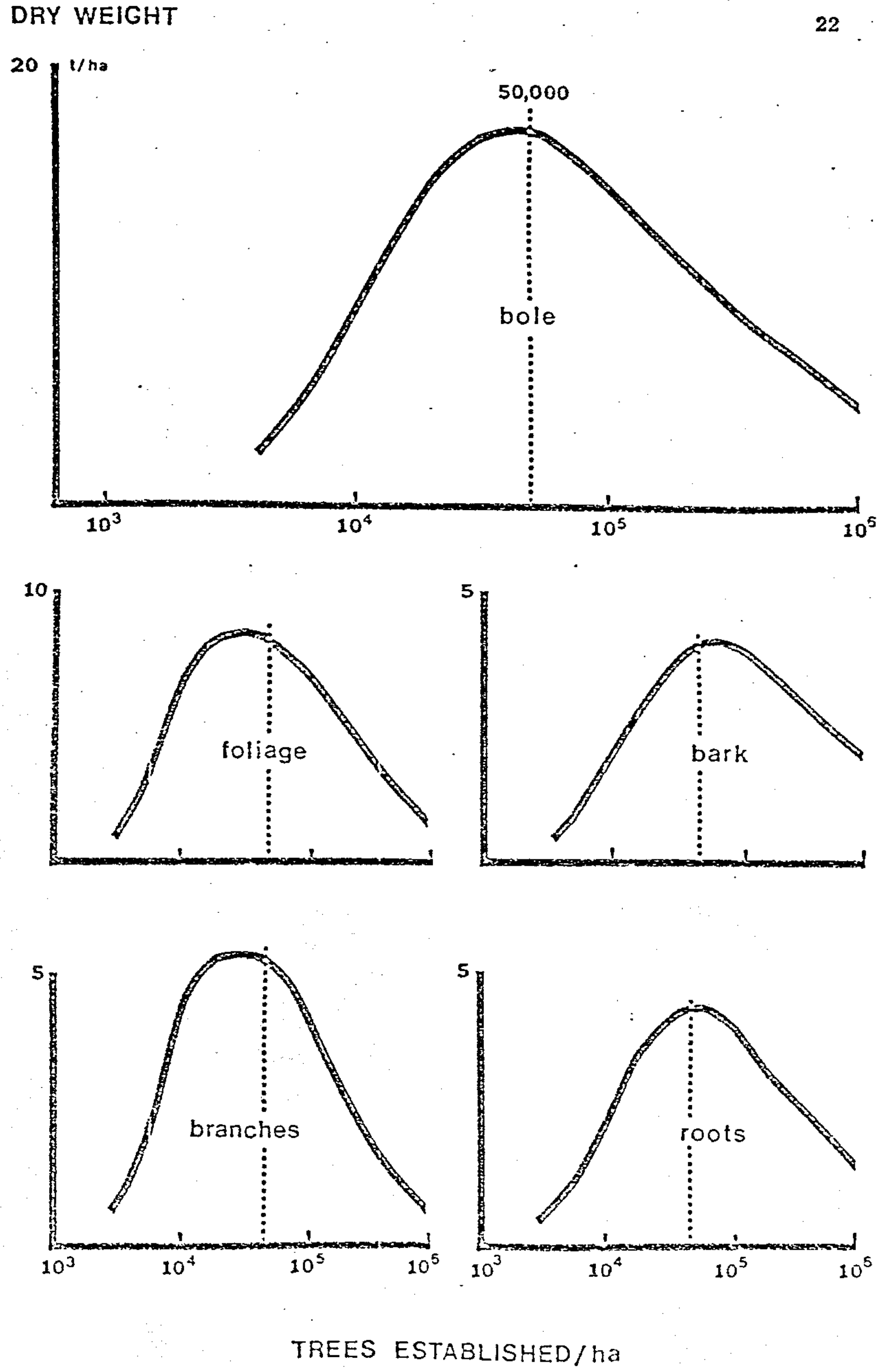

Figure 17. Relationship of the dry weight of stand components (bole, foliage, bark, branches and roots) to number of trees established in 18-year-old stands.

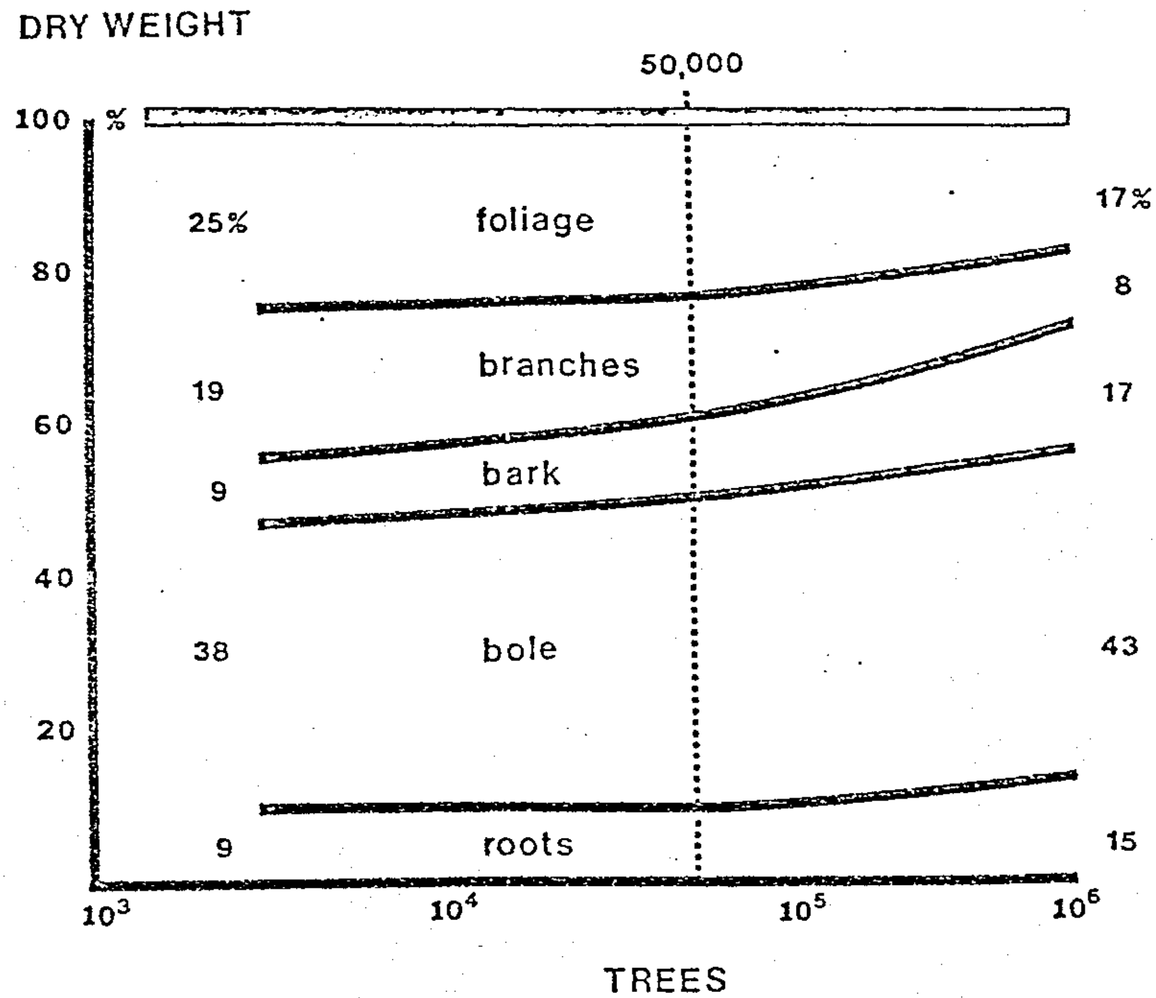

Figure 18. Percent dry weight of foliage, branches, bark, bole and roots in relation to the number of trees established in 18-year-old stands.

Excessive Respiration

It has been hypothesized that a dense stand with many small trees has a much greater respiring surface area than a normal or widely spaced stand, and must devote its energy to respiration at the expense of height growth. This theory warrants further investigation because the bole surface area of the 18-year-old stands examined increases as the number of trees increases (Figure 19a) whereas the weight of foliage and other components culminates and declines. The biological system is illustrated in Figure 19b. Light, carbon dioxide, moisture and nutrients are taken in by the foliage and roots, and converted into photosynthates which are allocated to the various components of tree growth according to their priority. Respiration demands must be satisfied if the tree is to stay alive. The remaining photosynthates, if available, are diverted to height, branch and root growth followed by bole increment and seed production. A shortage of photosynthates will cause a reduction in bole increment before height growth although both will be affected if supplies are very limited. Foliage and absorbing roots must be replaced continuously and therefore depend on the growth of the crown and roots which require photosynthates from the foliage. This feed-back loop can cause the entire system to slow down if respiration claims a disproportionately large amount of the photosynthates produced by the crown.

Figure 19b suggests that the repression of height growth may begin when the proportion of total photosynthates respired reaches a critical level. The direct measurement of photosynthate production and respiration is beyond the scope of this study. However, indirect measurements may suffice in spite of their limitations and might provide the

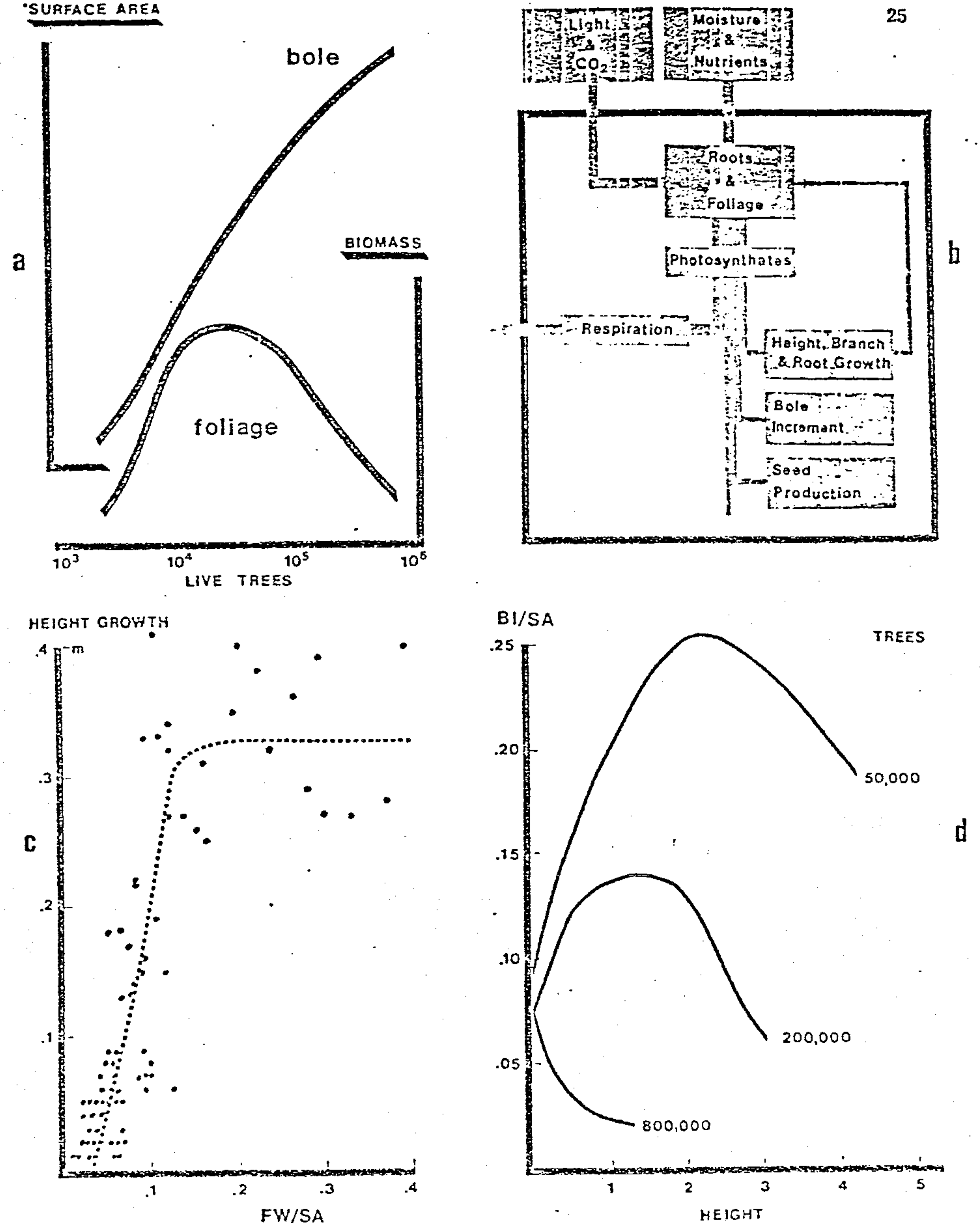

Figure 19. Investigation of respiration as a potential cause of stagnation.

insight needed to design future studies. Photosynthates and respiration are assumed to be proportional to the weight of foliage (FW) and the surface area (SA) of the bole respectively. The reciprocal of the proportion of photosynthates consumed by respiration (FW/SA) is related to the current height growth of 70 trees in Figure 19c. There appears to be a point where respiration demands begin to interfere with height growth which quickly declines from its potential of 0.32 meters to 0. in these 18-year-old trees. Unfortunately, FW/SA cannot be traced throughout the life of a tree using stem analysis techniques. The following analysis assumes that bole increment (BI) is proportional to foliar weight and photosynthate production.

The ratio of bole increment to surface area (BI/SA) of each of the 18-year-old dominant trees in Figure 19d appears to start near zero, increase, culminate and subsequently decline as the trees grow taller. The height-age curves (Figure 7) suggest that the repression of height growth occurs when BI/SA falls below a critical value somewhere between 0.10 and 0.15.

Figure 20a shows the height-age relationship of dominant trees from 70-year-old stands in which there was a considerable range in the number of living trees per hectare. Tree 37 was released by a fire which killed all competitors on one side when 17 years old. The corresponding change in BI/SA is presented in Figure 20b. Resolution in the first few years is very low because a relatively large proportion of the increment is within the stump which was not analyzed. Theoretically, the ratio of increment to area should start at zero and initially increase at a reasonably constant rate. Tree 26, which grew in a very widely spaced stand, and Tree 37, which was released by fire, appear to

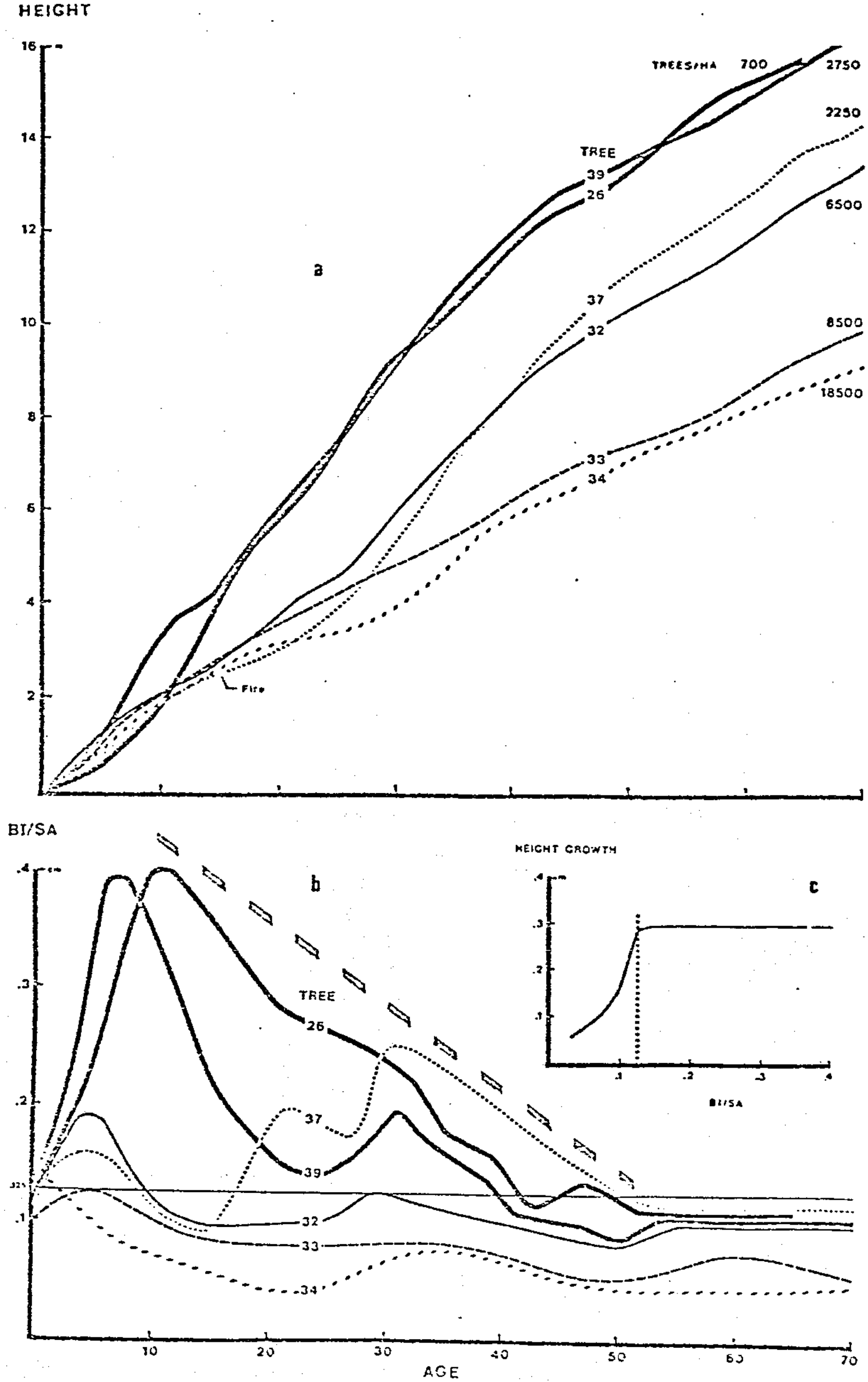

Figure 20. Relationship between (a) height and age, (b) bole increment/surface area ratio (BI/SA) and age, and (c) height growth and BI/SA.

reach a limit which forces them to decline to a ratio of about 0.11 which is then maintained. The height growth of Trees 32, 33, 34 and 37 drops below their potential (Figure 20a) when BI/SA (Figure 20b) falls below a critical ratio near 0.125. The relationship between height growth and BI/SA is depicted in Figure 20c which is a composite of many trees. The curve is reasonable stable below a ratio of 0.125 but somewhat variable at higher levels because the potential height growth of the trees varies. Trees 32, 33 and 34 level off at increasingly lower ratios which reflect their degree of repression. Ratios as low as 0.02 were maintained in younger stagnant stands (Figure 19d). Trees 26 and 39 level off at similar ratios of about 0.11 which is below the critical value and at the same level as Tree 32 even though they are from widely spaced stands. Analysis in progress suggests that the BI/SA relationship may influence the shape of site index curves, and trigger a reduction in the height growth of those trees in a stand destined to fall into the lower crown classes and eventually die. That is, BI/SA may have a bearing on crown differentiation.

Preliminary analysis of trees growing on sites of higher quality in the Cranbrook study area indicates that the critical ratio of BI/SA is somewhat higher than 0.125, possibly 0.16. It is not known whether the ratio is affected by site quality regional differences or other factors.

Our search for a biological explanation of stagnation suggests that excessive respiration and a shortage of moisture may cause the entire system to slow down even though it develops normally in other respects. We are watching stands grow in slow motion, and observing the oriental art of Bonsai on a rather large and disturbing scale.

POTENTIAL SOLUTIONS

It is imperative that we find a way to release stagnant stands. Spacing and burning are promising methods. Hand spacing or strip thinning offers a potential solution for several reasons.

Firstly, crown differentiation occurs in stagnant stands. The dominant trees have well developed crowns and root systems capable of rapid release. The prospects would be dim if all trees were in a suppressed condition and unable to respond in a reasonable period.

Secondly, dominant trees along fire boundaries recover from their repressed condition (Figure 21). Both diameter and height growth respond. However, the degree of release requires more research.

Thirdly, the roots of leave trees penetrate the space utilized by adjacent competitors long before they are removed. It is unnecessary to wait while the roots invade this space.

This analysis suggests that leave strips should be about 2 or 3 <u>trees</u> wide since only those trees adjacent to the openings respond.

Burning offers a drastic but possibly inexpensive solution to stagnation in young stands which have not accumulated a large quantity of cones. The moderately dense regeneration that comes in after the fire will quickly out perform the stagnant parent stand (Figure 22).

We have made considerable progress and intend to keep working. I hope we do not have to wait for our kids to unravel the perplexing problem of stagnation or repression.

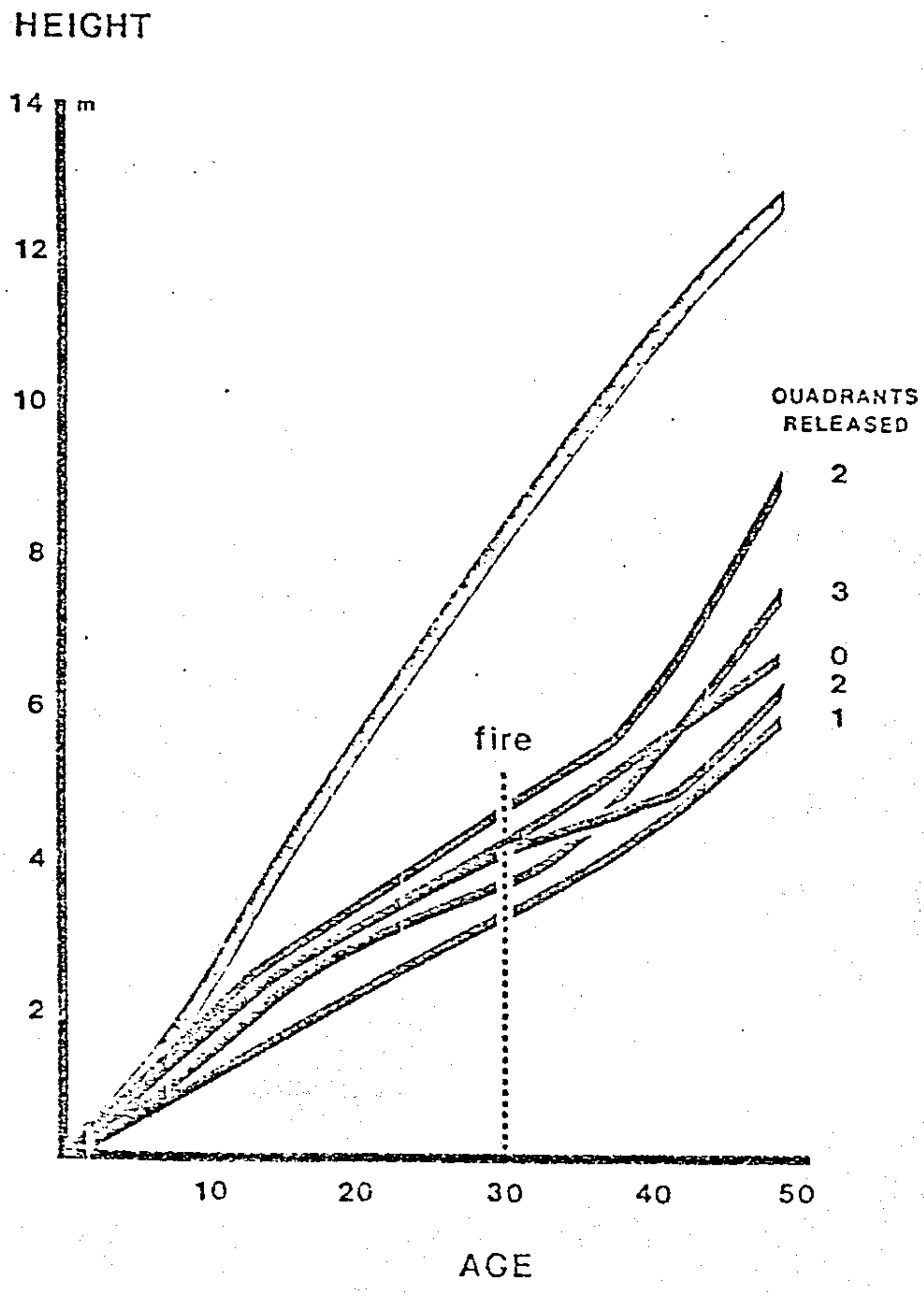

Figure 21. Height-age relationship of 48-year-old trees released by fire in various quadrants at age 30.