ABOVE-GROUND DRY-MATTER CONTENT OF A YOUNG CLOSE-SPACED PINUS RADIATA STAND

H. A. I. MADGWICK

Forest Research Institute, New Zealand Forest Service,
Private Bag, Rotorua, New Zealand

(Received for publication 10 August 1981; revision 20 October 1981)

ABSTRACT

Dry matter production was estimated in a plantation of **Pinus radiata** D. Don with rows increasing in age from 5 to 10 years and planted at a spacing of 1 × 1.5 m.

The weights of current (7.8 t/ha) and total foliage (13 t/ha) remained reasonably constant with stand age. Total branch mass increased from 11 t/ha at age 5 to 36 t/ha at age 10, and stem material from 52 to 154 t/ha over the same period. Mean annual increment increased with age and was predicted to reach a maximum of 21 t/ha at age 10 for the total above-ground biomass. Similar analyses for stem and for stem-plus-branches indicated a peak mean annual increment at age 10 of 16 and 20 t/ha, respectively.

INTRODUCTION

Increasing pressure on world energy supplies has led to a renewed interest in the use of trees as a source of fuel. In New Zealand primary emphasis has been on the conversion of plant material to liquid fuels (Harris *et al.* 1980) with *Pinus radiata* as one of the possible plants. Economic analysis of the potential of a fuels-from-biomass programme is dependent on reliable estimates of the dry-matter content of harvestable crops. Some information is available for conventionally spaced stands which have been heavily thinned (Madgwick *et al.* 1977) but additional information is needed for stands grown at closer spacings and on short rotations. Such stands are not common within easy reach of research facilities but an experimental planting programme established near the Forest Research Institute has allowed the investigation of dry-matter accumulation in young *P. radiata* stands established at about 6700 stems/ha. Sampling will continue on an annual basis for the next 3 years but the consistency of the results for the first 2 years (i.e., for a stand ranging from 5 to 10 years) suggested that a publication covering early stand development be prepared.

MATERIALS AND METHODS

Between 1970 and 1975 adjacent 50-tree rows of *P. radiata* were planted once or twice a month in the Long Mile area on the south side of Rotorua. Spacing was 1 m between trees and 1.5 m between rows. In February 1980 and 1981 the diameter of each tree was measured, excluding the five outermost trees in each row. Twenty-two sample trees were felled in 1980 and 10 in 1981. The samples covered the age range present, the lower age-classes forming the bulk of these first two samplings. The total numbers of trees in the age classes decreased in order eight (5-year-old), eight, six, four, four, and two (10-year-old). Sampling in subsequent years will result in the harvesting of a total of 8 to 10 trees for each age class. The felled trees were divided into stems, branches without needles (dead branches), needle-bearing branches, and cones. After the components were weighed green they were subsampled to obtain (i) moisture contents, (ii) the ratio of wood and bark weight in stems, and (iii) the ratio of needle and twig weight in needle-bearing branches. This enabled estimates to be made of dry weights of stem wood, stem bark, dead branches, live branches, cones, and needles of individual trees.

Preliminary regression analysis indicated that the standard procedure for estimating the logarithm of component weight of individual trees from the logarithm diameter-breast-height could be improved by adding tree age as a second regressor variable. Height was related to stem diameter for the felled trees using a modification of the Petterson height curve of the form:

$$\text{Log}_e \text{ (height} - 1.4) = a + b \cdot \text{age} + c/(\text{diameter breast height})$$

where height is in metres, diameter breast height in centimetres, age in years, and a, b, and c are constants. Bias due to logarithmic transformation of data was allowed for (Finney 1941).

The regressions were applied to the diameter and age measurements for each row of trees using both the 1980 and 1981 stand measurements. The estimated weights of each row of trees for both years were then merged and sorted by tree age. Mean stand values were obtained by averaging successive groups of 10 values.

RESULTS AND DISCUSSION

Basal area increased from about 30 m^2/ha at age 5 to about 53 m^2/ha at age 10 years. Mean height increased from 7.7 m at age 5 to 14.9 m at age 10, suggesting a site index of about 32 m according to the growth curves of Burkhart & Tennent (1977). Mortality was negligible at 5 years but rose to about 5% in 10-year-old trees.

Average weights of current (first-year) and total needles remained reasonably constant across the age range, at 7.8 t/ha and 13 t/ha for current and total needles respectively (Fig. 1). The weight of current needles was similar to that on an unthinned 6-year-old stand in Kaingaroa Forest (Madgwick *et al.* 1977) growing at 2200 stems/ha.

Live-branch weight increased with age from about 9 t/ha to 13 t/ha (Fig. 2). These values agree with previously reported estimates for stands of comparable age (Madgwick *et al.* 1977) but are higher than might be expected from extrapolating the relationship of live-branch weight against stocking. Total branch weight increased from 11 t/ha at age 5 to 36 t/ha at age 10 (Fig. 2). Branch material had accumulated at a faster rate than reported for more open stands of *P. radiata* of the same age range (Madgwick *et al.* 1977).

Stem wood weight increased from 46 t/ha at age 5 to 138 t/ha at age 10 (Fig. 3). Total bark weight increased also and was about 10% of the stem wood weight (Fig. 3). These rates of accumulation were approximately double those reported for a stand of the same age stocked at more conventional rates (Madgwick *et al.* 1977).

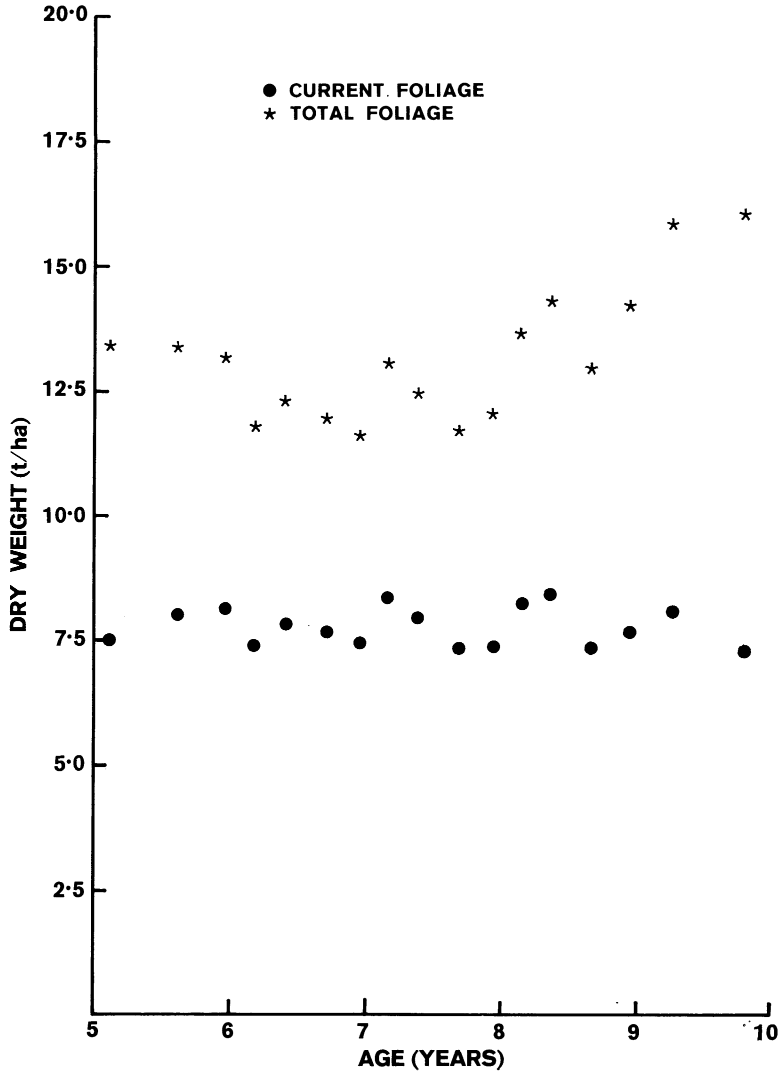

FIG. 1—Weight of current and total foliage per hectare.

Total above-ground biomass increased almost threefold from about 73 t/ha at age 5 to almost 210 t/ha at age 10 years. Current annual increment of above-ground woody material (stems plus branches) was about 28 t/ha/year between ages 5 and 10 years. These values are higher than those reported earlier for *P. radiata* and reflect the higher stocking level in this study. Mean annual increment (M.A.I.) of above-ground biomass also increased with age (Fig. 4). Fitting a quadratic curve of M.A.I. on age suggests a maximum M.A.I. of about 21 t/ha at about age 10 years. Similar analyses for stem and for stem-plus-branch material indicate peak mean annual increments of 16 and 20 t/ha respectively at age 10 years.

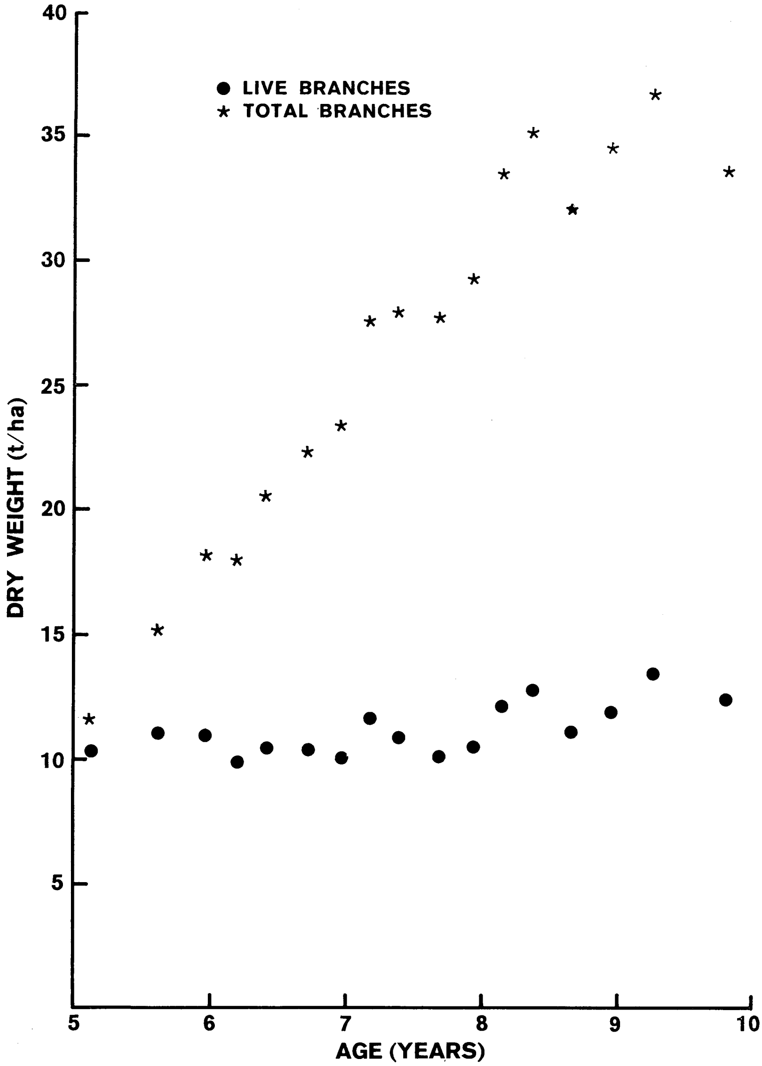

FIG. 2—Weight of live and total branches per hectare.

Mean annual increment of the close-spaced and unthinned trees in this study reached a maximum about 25% higher than the best stand reported by Madgwick *et al.* (1977) and attained it earlier in the rotation. Maximum M.A.I. slightly exceeded those of 4-year-old *Eucalyptus fastigata* Deane et Maiden and *E. nitens* Maiden growing in close-spaced stands at Rotoehu Forest (Madgwick *et al.* 1981) though the latter stands had probably not reached maximum M.A.I.

Any consideration of these preliminary data in relation to the use of *P. radiata* as a source of fuel must take several other factors into account. Total-tree harvest of young

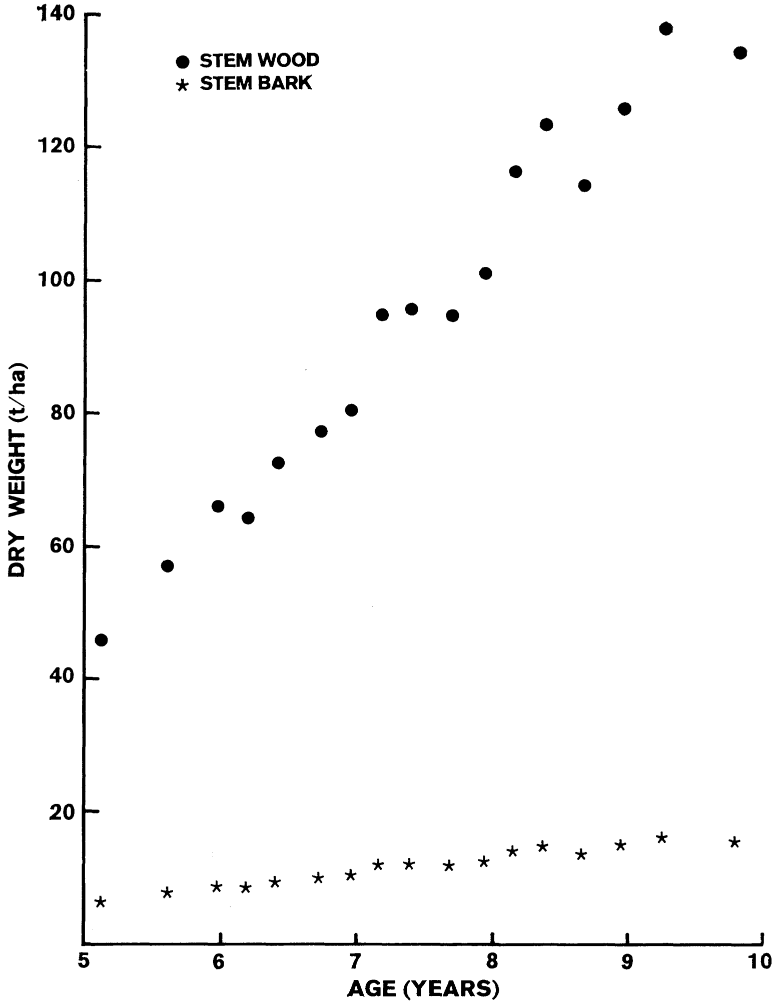

FIG. 3—Weight of stem wood and stem bark per hectare.

stands will remove considerable quantities of nutrients from the site as the young trees contain a relatively high proportion of nutrient-rich foliage compared to older trees (Madgwick *et al.* 1977). The final report on the current study will include results of detailed chemical analyses to more closely define the potential impact on the site of harvesting at different intensities at different ages.

Almost all existing dry-matter productivity data for *P. radiata* in New Zealand have been collected on highly productive sites in the central North Island. There is a need to extend this data base to less productive sites if a realistic assessment is to be made of the use of *P. radiata* as a source of fuel. The relative yields of different fuels from tree components by various processing routes must be determined before accurate models of energy forests can be developed.

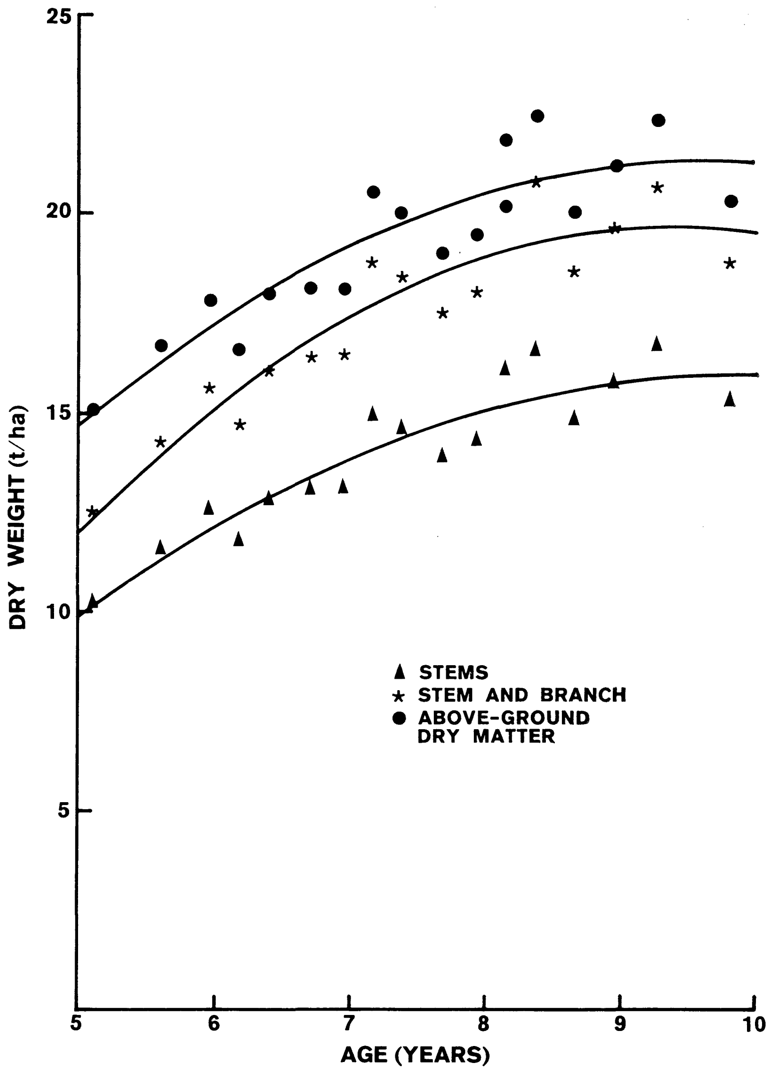

FIG. 4—Mean annual increment of stems, stems plus branches, and total above-ground dry matter.

ACKNOWLEDGMENTS

Graeme Oliver and John Chittenden are thanked for their assistance in collecting the data for this study.

REFERENCES

BURKHART, H. E.; TENNENT, R. B. 1977: Site index equations for radiata pine in New Zealand. **New Zealand Journal of Forestry Science 7(3):** 408–16.

FINNEY, D. J. 1941: On the distribution of a variate whose logarithm is normally distributed. **Journal of the Royal Statistical Society, Series B7:** 155–61.

HARRIS, G. S.; LEAMY, M. L.; FRASER, T.; DENT, J. B.; BROWN, W. A. N.; EARL, W. B.; FOOKES, R. W.; GILBERT, J. 1980: The potential of energy farming for transport fuels in New Zealand. **New Zealand Energy Research and Development Committee, Report No. 46.**

MADGWICK, H. A. I.; BEETS, P.; GALLAGHER, S. 1981: Dry matter accumulation, nutrient and energy content of the above-ground portion of 4-year-old stands of **Eucalyptus nitens** and **E. fastigata**. **New Zealand Journal of Forestry Science 11(1):** 53–9.

MADGWICK, H. A. I.; JACKSON, D. S.; KNIGHT, P. J. 1977: Above-ground dry matter, energy, and nutrient contents of trees in an age series of **Pinus radiata** plantations. **New Zealand Journal of Forestry Science 7(3):** 445–68.