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Opportunities for improving plantation productivity. How much? How quickly? How realistic?

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Abstract

Biomass production may be increased through greater utilization of existing resources, planting more area, and by implementing intensive silvicultural practices. This paper reviews the potential of intensive silviculture to increase productivity of short and longer rotation hardwood and conifer plantations. Some silvicultural treatments produced long-term growth and site improvements: species and provenance choice, tree breeding, improving rooting volume, applying high rates of fertilizers, and irrigation, all showed this potential. Short-term gains resulted from changes to stocking rates, rotation length, planting practices, tillage, weed control, and applying starter doses of fertilizer or nitrogenous fertilizer to pole stands.

The largest gains came from site selection, species and provenance choice, draining wet sites and correcting nutrient deficiencies, followed by tree breeding and irrigation. Choice of stocking level and rotation length, planting practices, weed control, and fertilizing pole stands gave potentially large benefits (>25% gains) for short-rotation crops (<12–15 years). They produced lower benefits for longer rotation plantations. Starter fertilizers, tillage and utilizing thinnings had relatively low gains. Disease and insect control were difficult to assess.

Managers should consider their current management level and practices, costs and benefits, social and environmental factors, practicality, and the time required for the benefits to be achieved. Further, growth improvements measured in research studies typically are not achieved in the field, with 15–25% reductions being commonly experienced. Quality control could reduce these losses.

Keywords: Silviculture; Bioenergy; Pines; Eucalypts; Willows

1. Introduction

The past 50 years has seen considerable progress in understanding plantation productivity on both theoretical and empirical bases. This paper reviews the management strategies and barriers influencing a forest plantation manager's ability to increase productivity.

Productivity may be defined in several ways. From biological and bioenergy perspectives we can define it as the net production of biomass per unit

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area per unit time [1]. Maximum net productivity of even-aged coniferous forests in temperate regions is about 44 Mg ha^{-1} yr^{-1} and for tropical plantations may exceed 50 Mg ha^{-1} yr^{-1} [1,2]. The main factors that influence a site's natural productivity (site quality) are climate and micro-climate, soil and relief, and these in turn reflect such factors as carbon dioxide, moisture, nutrients, light and temperature. Actual stand productivity, at any time on a given site, is determined by how well trees capture resources. This is determined by genetics, stand development and degree of stocking, all three being reflected in leaf area and resource conversion efficiency. Natural site productivity may not be achieved because of genetic and other silvicultural factors, most of which can be altered by managers (Fig. 1). The actual growth rate is controlled by the most limiting factor. As Fig. 1b illustrates, the full potential from improved silvicultural practices and genetic material will not be realized if either climate or soil is limiting. However, the site limitations, and to a lesser extent climatic limitations, may also be improved through management practices. The best examples of site improvement are improving very wet sites by draining and adding nutrients to overcome deficiencies. Irrigation is occasionally used to supplement natural rainfall. Poor management practices and some natural processes may also degrade the site, but these are not covered in this paper.

The type of productivity response to silvicultural inputs can be considered as falling into one of three groups [3–5]. A Type 1 response occurs where site quality is not altered but where growth is promoted for a period, with subsequent growth following normal trends (Fig. 2). Type 1 responses often result from faster site capture by the trees. Type 2 responses occur when there is a change to the site production capacity and result in a diverging growth pattern. With a Type 3 response, a short-term gain is lost or negated, but this response type is less common. The impact on rotation-length productivity gains from Type 1 responses will be different for short-rotation tree crops compared to longer rotation crops.

In order to compare options, actual volume gains from experiments in conifer and hardwood plantations throughout the world have been reviewed. Stem volume information, rather than biomass, was most often reported. These volume gains have been roughly translated into percentage gains at the end of the rotation and are reported for short- and long-rotation crops. Results from long-term trials have been given emphasis, as they

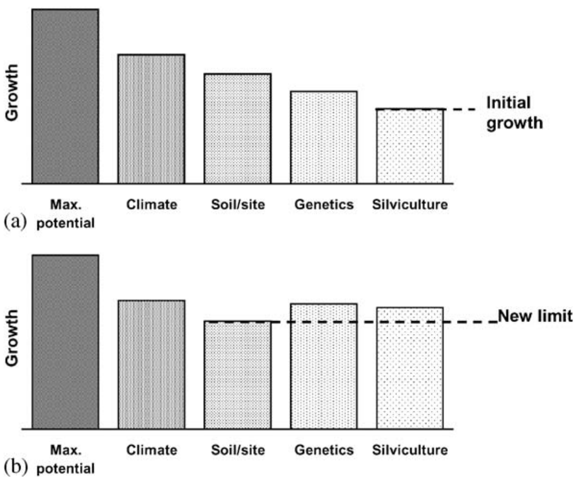

Fig. 1. The maximum growth potential of plantations is seldom achieved, being limited by a variety of factors. In Fig. 1a growth is being limited by poor silviculture and the climatic, soil/site and genetic potential that exists cannot be fully exploited. In Fig. 1b the silvicultural techniques and genetic material have been improved. The plantation growth limit is now limited by soil and site factors.

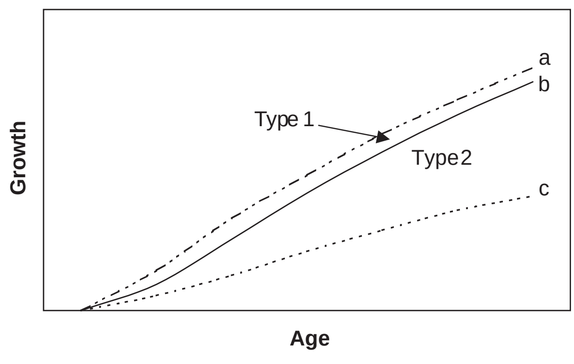

Fig. 2. Treatment growth responses usually show either a Type 1 or Type 2 pattern. With Type 1 responses (between lines a and b) the response is short-lived and subsequent growth trends are parallel. Diverging growth patterns, as between lines b and c, is characteristic of Type 2 responses. In a Type 3 response (not shown) the initial growth response is lost with time.