Available online at www.sciencedirect.com

ScienceDirect

http://www.elsevier.com/locate/biombioe

Evaluation of short-rotation coppicing fuelwood production systems for Papua New Guinea

I.K. Nuberg [a,*], B. Gunn [b], M. Tavune [c], A. Sumareke [c], O. Kravchuk [a]

[a] University of Adelaide, PMB 1 Glen Osmond, South Australia 5064, Australia
[b] CSIRO, Locked Bag 10, Clayton South, Victoria 3169, Australia
[c] PNG Forest Research Institute, P.O. Box 314, Lae 411, PNG, Australia

ARTICLE INFO

Article history:
Received 17 March 2013
Received in revised form
5 February 2015
Accepted 9 April 2015
Available online 16 May 2015

Keywords:
Papua New Guinea
Short-rotation coppice
Fuelwood
Charcoal
Eucalyptus
Casuarina

ABSTRACT

A 2 year short-rotation coppicing (SRC) fuelwood production system was evaluated, at 2 tree densities (3333 and 6666 trees ha^{-1}) for the Western Highlands Province (WHP) and National Capital District (NCD) of Papua New Guinea. Of the 10 species tested, the best production of firewood was from *Eucalyptus grandis* and *Eucalyptus robusta* in WHP and *Eucalyptus tereticornis* in the NCD, with values of 2.97 m^3, 2.55 m^3, and 0.92 m^3 for a 500 m^2 woodlot respectively at the denser spacing. *E. grandis* and *E. robusta* produced best tree form in WHP while *Eucalyptus pellita* produced best form in NCD. Best coppice performance was observed in *E. robusta* in WHP and *E. tereticornis* in NCD. The burning characteristics of SRC firewood and charcoal were also assessed, as well as how SRC firewood will appeal to consumers. In the highlands SRC firewood and charcoal yield higher estimated returns to labour (USD20.00 and USD11.16 $person^{-1}day^{-1}$) compared with main alternative crops of sweet potato and coffee (USD9.77 and USD6.98 $person^{-1}day^{-1}$ respectively). SRC pole production has a low return to labour (USD7.44 $person^{-1}day^{-1}$) but could complement SRC production as part of a thinning regime. The main limitation in promulgating SRC systems could be market acceptance and finding a small-business model that integrates well with the indigenous non-market economy. The poor growth rates around the NCD due to limiting biophysical conditions make a 2 year rotation cycle unfeasible.

1. Introduction

Fuelwood is a crucial, but undeveloped, component of the domestic economy of Papua New Guinea (PNG), especially in the rural areas. Fuelwood stress occurs around major urban areas and in several areas in the rural highlands where population densities can exceed 100 persons km^{-2} [1]. The volume of the fuelwood used in just the fuelwood-stressed regions of the country, which represent 11% of the population, is estimated as at least 2.1 M m^3 y^{-1}, and the national value of fuelwood traded is estimated to be USD 8.8 M y^{-1}. Fuelwood is the primary energy source for cooking and heating, especially in the highlands where over 40% of the population live. Fuelwood also represents a component of the economy in which 3% of urban and 10% of rural people participate on either a full or part-time basis. Fuelwood consumption in PNG is estimated to be 1.8 m^3 $person^{-1}y^{-1}$, which is 6 times greater than the average consumption of 16 south and south-east Asian countries in the FAO Regional Wood Energy Development Program (and only exceeded by Bhutan) [2].

* Corresponding author.
http://dx.doi.org/10.1016/j.biombioe.2015.04.010

Many districts in PNG are under intense agricultural pressure coupled with socioeconomic disadvantage, and fuelwood collection has led to increasing pressure on the environment [1]. A significant amount of firewood is harvested from non-forested lands and therefore not a key factor behind deforestation [3]. However in PNG the estimated population growth of 2.7% is increasing at 3 times the rate at which the area of land in significant use is increasing. Consequently the intensity of land use is increasing and the availability of non-forest firewood is decreasing [4]. This is putting pressure on, for example, the mangrove forests near Port Moresby and the already bare hills in the more heavily settled districts of the highland provinces. Even the existing highland bush fallow systems do not provide adequate fuelwood as evidenced by the inferior firewood often used (e.g. bamboo and grass) and the long hours spent in fuelwood gathering. In many districts competition for fuelwood resources leads to conflict [2].

Domestic fuelwood supplies are based entirely on collected fuelwood and to a small extent sawmill waste from native forest; there is no plantation sector providing fuelwood. The fuelwood economy in PNG is informal in that there is no public engagement in supply, marketing, distribution, pricing, taxation, and use (except for instances of the prohibition of fuelwood use in some urban areas). The fuelwood economy has a relatively flat structure with a very short and direct supply chain. There is no significantly organized private sector or charcoal market [2]. While alternative energy sources are becoming increasingly available, the cost differential is such that fuelwood will remain the primary energy source for the majority of the population for the foreseeable future. There is a need for sustainable farm-grown fuelwood and a great opportunity exists for developing small businesses in the fuelwood sector. Although PNG landholders plant a lot of multipurpose trees on their land, some of which will be used for fuelwood, they are usually in scattered or linear configurations, and not in numbers to sustain a small fuelwood business. Conventional forestry woodlots are beyond the planning horizons of landholders who are used to annual and short-term perennial crops.

It is proposed that short-rotation coppicing (SRC) systems, that provide fuelwood in 2 year cycles, may be more readily adopted than alternative tree growing systems by landholders interested in growing fuelwood on small areas. Such systems have been widely investigated in both tropical [5–11] and temperate regions [12–19]. The research reported here evaluates the potential for a range of coppicing fuelwood species to be grown in both the lowlands and highlands of PNG. The evaluation includes: their survival and growth rates; their burning properties as both wood and charcoal; and their acceptance by domestic users and in the fuelwood market.

2. Methods

2.1. Site establishment and management

There were 3 field sites: Pugamp near Mount Hagen (approximately 5° 46′ 25″ South by 144° 11′ 13″ East, 1800 m elevation, 2586 mm mean annual rainfall spread throughout the year), Bautama (9° 28′ 13″ South by 147° 17′ 23″ East) and Bomana (approximately 9° 23′ 2″ South by 147° 15′ 29″ West) in the National Capital District (NCD surrounding Port Moresby, 200 m elevation, 995 mm mean annual rainfall strongly seasonal with the wet season from December to April).

In all three sites 6 month old seedlings were planted at 1.5 m × 1.0 m and 1.5 m × 2.0 m spacings in a randomised strip-plot design in four blocks, with spacings arranged in strips across the 9 m long main plots of species. There was a 20 tree buffer around each plot. The number of trees planted in each site was 1600 at Pugamp, 2300 at Bautama and 1664 at Bomana. Pugamp was on an Alfisol situated on a broad open ridge. Bautama and Bomana were on an Entisol on alluvial flats close to rivers. All trees were planted within a day at each site because of community participation. No fertilisers were added and it was not necessary to water the seedlings in.

The Pugamp site had recently been a sweet potato plot. The 0.3 ha site was prepared by manual cultivation and partial filling of drains to leave a relatively flat area for tree planting. A pig-proof fence was constructed. Weed control was by way of gardening as the landowner planted an intercrop of *sako* (or choko vine, *Sechium edule*) in the first year before canopy closure. The Bautama (0.48 ha) and Bomana (0.37 ha) sites were situated in kunai grassland (*Imperata* spp.). The sites were prepared by slashing and burning, but no cultivation. Before planting, the regrowth was controlled with glyphosate and grass-clump removal. After planting weed control was by slashing with bush knives. Wild fire is a common problem in this area so 10 m firebreaks were maintained around each site.

Establishment of seedlings was very high at Pugamp but the survival rates were lower at Bautama because of leaf-eating insects and a fire through part of the site. The Bomana site experienced a flood over the entire site, followed by fire and later theft of some healthy stems.

2.2. Species selection

The selection criteria for fuelwood species were: fast growth, ability to coppice; and some record in the literature as being suitable for firewood and/or charcoal. *Eucalyptus grandis* and *Eucalyptus robusta* are both exotic species planted widely in the highlands of PNG, while *Eucalyptus tereticornis*, *Eucalyptus pellita* and *Eucalyptus alba* are endemic to parts of Australia and lowland of PNG. *E. alba* was selected for the NCD sites because of its natural distribution in NCD and use as a local fuelwood. The traditional firewood species for highlanders is the native Yar or *Casuarina oligodon* [20]. In lowland areas Coastal Yar or *Casuarina equisetifolia* is sometimes used. Unfortunately, neither Yar coppices so they cannot become SRC species. They are included at Pugamp and Bautama for comparison against *Casuarina junghuhniana*. This species was introduced into PNG for this trial. It is native to Indonesia and is grown in Thailand for fuelwood and reported to coppice and pollard well [21].

Neem (*Azadirachta indica*) was included because it is a common street tree in Port Moresby and harvested for fuelwood. It is reputed to coppice and producing excellent charcoal and firewood [22,23]. *Calliandra calothrysus* was included as a nitrogen-fixing species with excellent reputation for