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METHODS TESTED AND THEIR COSTS TO CONTROL RE-GROWTH OF COPPICED *EUCALYPTUS CAMALDULENSIS* IN HARVESTED PLANTATIONS IN NAULA, MATALE DISTRICT, SRI LANKA

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ABSTRACT

Eucalyptus spp. have been widely planted for timber in the tropics and subtropics and have been promoted by both Governments and businesses. In Sri Lanka, in the semi-dry zone, north of Kandy there are extensive stands of 30-40 year old *E. camaldulensis*, some of which were planted by a company for commercial fuel wood. Poor growth, and a change in fuel technology, has made these plantings redundant. The company is returning its leased holdings slowly back to near-natural forest. In order to do this, it undertook trials to determine the best way to control coppice re-growth from cleared *Eucalyptus.* Finding a cost-effective way of controlling *Eucalyptus* re-growth will assist Government and other landholders in reviving natural forest and promoting the associated ecosystem services such as water retention, provision of herbs, and honey. The use of chemicals, light exclusion and a variety of physical control techniques was tested at two locations near Naula, Matale District. The most effective method was cutting the stems down to the ground and then covering with well-secured heavy gauge plastic. The next best method, but more expensive, and with no problems of waste disposal or recycling associated with polythene, was the cutting of any coppice growth as soon as it emerged. After 4 rounds of coppice control all stools died. Chemical controls proved ineffective and expensive. Uncontrolled coppice, almost all regrew. If possible, control without the use of chemicals is preferable.

Key words: biodiversity, ecosystem services, chemical control

INTRODUCTION

Eucalyptus spp. have been widely planted in tropical and subtropical regions as a fast-growing range of timber trees (1996; Munasinghe, 2003). With the right species in the right soil and with suitable climatic conditions, *Eucalyptus* are capable of rapidly growing significant stands of good quality timber. For this reason *Eucalyptus* have been promoted by both Governments and private businesses for timber and amenity planting (Connelly, 1990; Pryor, 1964).

In the up country in Sri Lanka there are extensive stands of tall, well-grown *Eucalyptus*, and tea plantations are liberally dotted with large Eucalyptus trees, which are planted as shade trees (Ranatunga, 1966). In the semi-dry zone north of Kandy there are extensive stands of 30-40 year old *Eucalyptus. Eucalyptus grandis* is most the commonly planted species in the up country, whereas *E. camaldulensis* is more common in semi-dry areas (Vivekanandan, 1979).

Many of the forest stands in the semi-dry zone were planted with Government support, as part of a drive for reforestation, and to provide a ready source of various grades of timber. Businesses requiring a reliable source of fuel planted *Eucalyptus* as a source of rapid growing fuel wood based on a rotational coppice regime (Little and Gardner, 2000). Under good conditions in Sri Lanka and coppiced on a 7-10 year rotation, some *Eucalyptus* species can produce a predictable supply of timber for 4 or 5 rotations (Connelly, 1990; Pryor, 1964). Note that other timber crops in the semi-dry zone are typically grown for construction or other uses rather than fuel.

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Table 1. The methods, dates and results of treatments to control coppice re-growth of *E. camaldulensis* at Maragamuwa.

Treatment and month of application	Number of stools cut and treated	Number showing signs of regrowth after 14 days or more	Number showing signs of regrowth after 4 weeks or more	Number killed	Significance of difference from no treatment control X^2
Roundup August 2008	25	25	25	0	P>0.05
Roundup water control August 2008	50	50	50	0	P>0.05
Kerosene July 2006	25	25	25	0	P>0.05
Formalin July 2006	25	25	25	0	P>0.05
Black polythene December 2007	50	10- where plastic became free	10- where plastic became free	40	P<0.05
Soil only December 2007	50	50	50	0	P>0.05
No treatment July 2006	100	100	96	4	n/a

For tobacco production which has a high fuel need, one of the main costs of production is incurred in the drying stage, as the fresh leaf is dried and cured in kilns (Peedin, 1999). Drying and curing tobacco requires a reliable supply of fuel. Originally, local timber was used, but was replaced with faster growing and more calorifically dependable crops such as *Eucalyptus.* In Sri Lanka the main commercial tobacco grower established *Eucalyptus* plantations in the up country and the Matale District in the late 1970s, with the intention of providing a reliable and cost-effective supply of fuel wood. In the Naula area 320 ha of land were acquired under lease from Government Agencies and, following their advice, they were planted with *E. camaldulensis* (Table 1), even though the net financial viability of *Eucalyptus* in such areas is questionable (Perera, 1998).

Over time, the relatively slow growth of the *Eucalyptus*, and a change in technology, allowing the use of paddy husk to dry tobacco leaves, meant that the *Eucalyptus* plantation holdings were becoming less financially viable. As a result, the company looked to re-evaluate their holdings, and how they might best be managed for the future. The possibility of returning the holdings slowly back to near-natural forest was considered. In order to do this, the company had to determine the best way to control coppice re-growth from cleared *Eucalyptus*. Cheap and effective control of coppice regrowth allows the process of natural recolonisation by native species to occur. Investigation into the most effective methods for controlling *E. camaldulensis* coppice in the semi-dry zone of Sri Lanka is necessary due to the limited information available in the literature. A cost effective method for the control of *E. camaldulensis* coppice in the semi-arid area of Sri Lanka will greatly assist restoration of large areas of native forest in the Naula area and increase the value of the ecosystem services generated by the forests in this area.

MATERIALS AND METHODS

As part of a study in forest recovery, trial plots within a 60 ha. Eucalyptus holding at Maragamuwa near Naula (Figure 1) were studied between 2006 and 2009, and one set of trial plots in the nearby Haduwa planting (Figure 2). At Maragamuwa, seven one hectare plots within the *E. camaldulensis* holding were cleared in 2006 and 2007 and a programme of experimentation started in order to observe the extent of natural forest recovery following clearing of *Eucalyptus* plantings. A single one hectare plot was cleared at Haduwa in 2008. Methods for control of *Eucalyptus* coppice regrowth were also investigated.

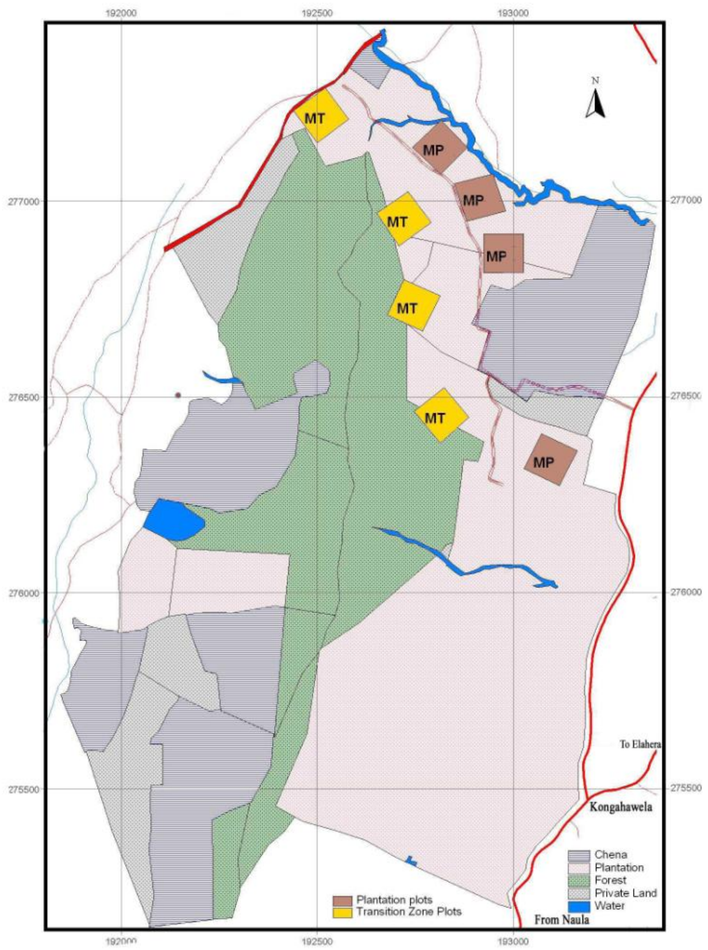

Figure 1. Map of Maragamuwa (Matale District), *Eucalyptus* plantation showing harvested blocks and the experimental areas (MT & MP) .

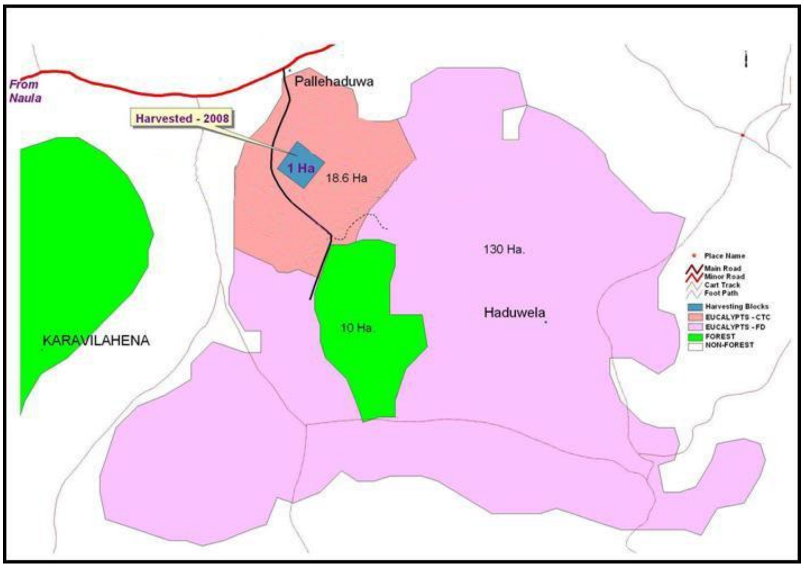

Figure 2. Map of Haduwa (Matale District) *Eucalyptus* plantation showing harvested block.

When cut down 10-20 cm above the ground *E. camaldulensis* tends to regrow multiple stems and this coppice growth quickly outcompetes other, native, tree species. In order to try and identify the most efficient way of controlling coppice re-growth, a series of treatments was carried out as small rectangular blocks of *E. camaldulensis* were cleared, and the patterns of re-growth of *Eucalyptus* in response to each treatment was monitored. Some of these treatments were labour intensive, and some involved use of chemicals.

Initially planned to run in parallel, because of problems with obtaining materials and delays in obtaining clearance permits for tree removal, not all of the treatments were carried out concurrently (Table 1). A series of treatments was trialled at Maragamuwa, and at Haduwa, where *E. camaldulensis* had been planted at an initial density of 1,200 trees per hectare, although overall survival rate had reduced the number of trees to about 500 per hectare at the time of treatments. Following each treatment, the re-growth of coppice stools was reassessed after 2 weeks to determine growth, and in most cases a second inspection was conducted after 4 weeks in case of delayed effects (Table 1). In the treatment involving cutting regrowth by hand, the active treatment continued for 6 weeks. Treatments were allocated to plots randomly. All of the treatments were applied to rectangular blocks of cleared trees.

<u>Maragamuwa</u>

Roundup: An application of 200 ml of this commercial herbicide was applied (diluted at 400 ml in 10 litres of water as recommended) to each of the stumps of 25 newly cleared trees, across the top and round the cambium margins. Roundup is the commercial name of Glyphosate manufactured by Monsanto.

Roundup control: An equivalent volume of water was sprayed in the same way on to 50 newly cleared tree stumps to act as a control.

Kerosene: An application of 200 ml of standard kerosene was sprayed on to each of 25 stools in the same way as the roundup application.

Formalin: An application of 70ml of formalin (40% Formaldehyde) was applied to 25 newly cleared trees in the same way as the roundup application.

Black polythene: After clearing, 50 stools were covered in thick 200 gauge polythene (127 micrometers), and the edges held down by soil, small stones or rocks. The plastic was not properly held down on 10 stools and became loosened during the course of the study.

Soil coverage: After clearing, 50 stools were covered in soil to act as a control for the polythene experimentation.

No treatment: After clearing 100 stools were left and no other treatments were applied. This treatment acted as a control for all others.

<u>Haduwa</u>

Gramoxone: Five holes 1cm wide and 5cm deep were bored in each of 25 *Eucalyptus* stumps and 20 ml of undiluted Gramoxone applied to the hole and the opening was sealed with clay. It was also applied round the cambium margins. Gramoxone is the commercial name for Paraquat, manufactured by Syngenta International AG.

Gramoxone control: As a form of control, 25 *Eucalyptus stumps* were sprayed with water on the stump tops and around the cambium margins.

Black polythene: As in Maragamuwa above, 50 stools were covered in thick gauge polythene, and, unlike Maragamuwa, all edges were held down securely by soil or small stones or rocks.

Soil coverage: After clearing, 50 stools were covered in soil.

Hand cutting four times: 50 stools were cut close to the ground (10-20 cm above the ground) and the bark stripped to ground level. Over the subsequent six weeks coppice re-growth was removed after appearance up to four times.

No treatment: 100 stools were cut and left untreated, as in Maragamuwa.

In each treatment, the numbers of stools with regrowth was recorded initially after 2 weeks, and rechecked after four weeks. Only in hand cutting was the treatment checked for 6 weeks after initial clearance.

Comparisons between treatments

For each treatment the number of stools regrowing was counted after 14 and 28 days. The numbers regrowing in each treatment were compared with the control where no treatment was applied after cutting, using $\mathbf{X^2}$ tests. In both the Roundup and Gramoxone treatments a control of an application of an equivalent volume of water was applied. Comparisons were not made between other individual pairs of treatments.

RESULTS

Maragamuwa

In all treatments at Maragamuwa liquid chemical controls (Roundup, kerosene and formalin) failed to kill the *Eucalyptus* stools, resulting in coppice re-growth. Spraying with water (a simple control treatment for Roundup application) also failed to have any effect on inhibiting coppice re-growth. Covering with soil did not inhibit growth (Table1).

Covering the cut stools with a sheet of thick gauge polythene secured to the ground 30-40cm beyond the cut trunk, and excluding light from getting to the base of the trunk and any live bark, proved an effective inhibitor to coppice growth. In 10 cases the plastic sheets were not properly held down, and winds were able to raise the edges and allow light in. In these instances the coppices grew out from the exposed opening. Where light was only initially excluded by covering with soil, there was no effect on preventing coppice recovery. In all cases the response observed at 14 days was maintained over a period of 28 days.

Haduwa

The trials at Haduwa followed those at Maragamuwa. Some of the trials that failed comprehensively at Maragamuwa were not repeated again. There were two new trial variants: drilling holes in the stool of cut *Eucalyptus* and filling these with Gramoxone, and hand cutting the bark on cut trees down to soil level, and cutting off any coppice shoots that subsequently emerged weekly for a minimum of four weeks (Table 2). In addition, the regrowth of coppice on *Eucalyptus* not controlled by hand cutting was monitored over the same duration as the hand cutting and the results compared.

At Haduwa the use of thick gauge polythene, effectively secured to the ground and with no edges left exposed to wind disturbance, was able to stop regeneration of coppice. Leaving the stools covered with soil had no effect. As an alternative chemical application to those used at Maragamuwa, drilling the low cut stumps of *Eucalyptus*, and filling each with Gramoxone, and wiping the cambium margins failed to control regrowth. Repeated rounds of removing emerging coppice stems from 50 stools proved effective after 4 cuts. For the 100 stools used as a comparison over the same period, only four failed to grow coppice when left uncut.

Table 2. The methods, dates and results of treatments to control coppice re-growth of *E. camaldulensis* at Haduwa.

Treatment and month of application	Number of stools cut and treated	Number showing signs of regrowth after 14 days or more	Number showing signs of regrowth after 4 weeks or more	Number killed	Significance of difference from non treatment control X^2
Black polythene February 2008	75	0	0	75	P<0.05
Soil only February 2008	75	75	75	0	P>0.05
Gramoxone June 2008	25	25	25	0	P>0.05
Gramoxone water control	25	25	25	0	P>0.05
Hand cutting coppice ≤ 4 times September 2008	50	After 2 cuts 30	0	50	P<0.05
Tree cut, coppice left uncontrolled September 2008	100	100	96	4	n/a

DISCUSSION

Fast-growing exotic tree species have frequently promised the potential for consistent high yields of timber for industrial or other uses and have been extensively planted in many continents. For the tobacco industry *Eucalyptus* spp. have been extensively used to grow fuel for drying tobacco, and to reduce the demand for native tree species with higher societal and biodiversity value (Peedin, 1999). Where species or variety is correctly matched to a site, growth achieved can be impressive, as with many 30m or taller *E. grandis* in the up country.

In the Naula area, the choice of *E. camaldulensis* has proved to be problematic: yields have not been high, and the size and quality of timber trees do not compare at all well with *E. grandis*. From observations elsewhere in the district, very few of the extensive tracts of *E. camaldulensis* planted in line with Government advice are growing well, and many appear stunted by either climatic or edaphic conditions on all but the dampest and most fertile of soils, with the result that the poorly yielding coppice cycles may approximate 15-20 years, rather than the expected 7-10 years. Note that *E. camaldulensis* was reported as performing poorly in a series of trials in the dry zone (Vivekanandan, 1979), so that the disappointing growth in the area is in some senses unsurprising.

The combination of poor growth, high production costs per cubic metre of wood harvested, and the availability of sustainable cheap alternative fuels such as paddy husk, have meant that *Eucalyptus camaldulensis* is no longer attractive as a source of fuel and timber. In addition, the tendency for *Eucalyptus* to be water-hungry (Riha and McIntyre 1999), and with relatively poor associated biodiversity when compared to adjacent native forest has meant that for the study area, and most likely for others also, *Eucalyptus* have ceased to be a viable business crop. Unlike other agricultural and many tree crops, *Eucalyptus* do not die when cut to the ground. Their capacity to regrow from coppice or pollard is sometimes an attractive silvicultural option (Little and Gardner 2003), but controlling or killing coppicing stems can be problematic.

Finding a cost-effective, ecologically suitable, method of stump control is a potential problem for many locations with failing *Eucalyptus,* both in Sri Lanka and beyond. Curiously, given the widespread planting of *Eucalyptus* around the world, there is a limited, and contradictory, literature on methods of *Eucalyptus* control, much of which is based on the blue gum *Eucalyptus globulus* in California.

Morze (1971) noted that *Eucalyptus* were relatively robust in their response to chemical control, and might require several direct applications to standing trees, and that cutting and subsequent applications was preferred. Little and van den Bergh (2007) found good (88-95%) success rate for Glyphosate or metsulfuronmethyl when applied to stumps of *E. Macarthurii*, and Little (2003) found up to 90% success with a range of chemicals on cut *E. grandis* in South Africa. Leitner (1984) noted the limited effectiveness of Roundup, even when attempting to account for possible errors in formulation or application. Stott and Parker (1995) and Ballard and Nowak (2006), Troth *et al.* (1986) and Zedaker *et al.* (1987) found a high degree of variability of responses to Glyphosate in hardwoods, with success varying between seasons according to tree species. Given the failure rate in the current study it is worth noting that a two year study of mortalities on cut stumps treated with Glyphosate at different times of year gave broadly similar results of between 49% and 56% (growth period) and 46% and 66% mortality (dormant period) (Zedaker *et. al.*, 1986). The current study took place in early summer, when growth might be expected to be vigorous, and later in the year when chemical or physical control might also be expected to be effective.

Given the potential for the coppice to shade out other tree saplings – in an area next to the Haduwa plot coppice re-growths averaged 3.5m after one year, based on photographic inspection- leaving for this period would be unsuitable in the current study area as return to native forest is sought. From the trials it was clear that coppice growth started within a few days of a tree being cut, and could exceed 1 m within a period of 4 weeks, with re-growth coming from multiple, coppice stems. Note, individual data on stump growth rates were not collected. Ballard and Nowak (2006) reviewed the variation of responses according to concentrations used, noting that frequency of application was as important as concentration in helping to raise mortality levels. In the current study the lack of repeated applications may have been a critical factor in affecting mortality rates. Whether the failure of chemical agents in the current experiment was due to insufficient application (although the recommended guidance for use was followed), timing in the year, or an unknown cause is unclear.

Even if effective, chemicals are relatively expensive if applied over extensive tracts of cleared plantations (Table 3), but according the determination of a suitable spray regime might still be less than cutting by hand. Costs for each method were based on time and local costs of materials and labour (at Sri Lankan rates) required to carry out each round of treatment.

Table 3. Comparative costs of attempting to control *Eucalyptus* regrowth at Maragamuwa and Haduwa. (Costs represent labour and materials after initial tree clearance.)

Treatment	Number of stools cut and treated	Mean cost per hectare at Jan 2009 costs		
		£ UK	$ US	Rs Sri Lanka
Hand cutting/pulling 4 times	50	62	89	10,591
Black polythene	50	45	64	7,616
Kerosene*	25	44	62	7,378
Roundup*	25	40	57	6,783
Soil only*	24	31	45	5,355
Roundup water control*	50	30	44	5,236
Gramoxone*	24	2.15	3.36	400
Formalin*	25	2.86	4.20	500
Coppice re-growth uncontrolled*	100	0	0	0

* Control of coppice re-growth ineffective

Non chemical control has several potential advantages: it is targeted, it does not require heavy investment and technology, and is highly localised, with fewer immediately obvious side-effects. The use of heavy gauge polythene to control light access to the cut trunk base – trunks were typically cut to within 10- 20 cm of the ground or lower- was designed to both stop photosynthesis and also physically limit shoot growth. Where the plastic was well weighted down, no coppices were able to push through the cover, and all stems that had started to grow failed. Where the plastic cover was poorly restrained, light acted to stimulate growth and coppice shoots grew on the open side. Although plastic sheets were effective, and can be re-used (heavy gauge polythene showed little mechanical damage after a year), there is a requirement for regular monitoring, and an initial out lay and supervision during the month or so needed to confirm effective control of coppice shoots. Polythene was left in place for more than a year, with no signs of regrowth from casual visits. Subsequent removal was carried out as part of normal site maintenance, with minimal time input and was not costed separately. If additional labour were costed separately, this would suggest manual control as the most cost-effective form of control where chemicals were ineffective. Although initial coppice regrowth is vigorous, if all shoots pulled from the tree base or are cut, subsequent re-growth is less strong, and 4 rounds of cutting or pulling is enough to kill the stump and stop regrowth. This method has the advantage that it requires low skill, no chemical inputs, and can be applied across a wide range of circumstances. Leaving cut tree stools to regrow tends to result in coppice recovery, although in four cases in each location the stress of cutting the trunk low to the ground (10-20 cm) and the removal of the trunk and material around the tree, exposing the stool to hot sunlight, did lead to death.

From a practical perspective, controlling by cutting or pulling, or polythene are both effective, but cutting is potentially the more expensive per hectare, assuming four cuts are needed, and also that the polythene could be re-used again elsewhere. If a high proportion of the coppice stools are killed after three cuts, then costs for the two methods will be approximately similar (Table 3). The exact choice will be determined by practicality: labour availability and costs and the ability to hold down plastic around the stumps. Increases in labour or material costs can be expected to vary from place to place and over time. An additional complication of polythene-based control would be the visual impact, as well as subsequent recycling needs.

From a biodiversity standpoint, the failure of chemical control methods may be positive, especially where there is a risk both to the plant and animal communities in the immediate vicinity of the stumps and to locations where there is a chance of surface runoff entering into water courses. Additionally, because it does not rely on dry conditions (chemical applications cannot be used effectively in rainy conditions) physical control extends the period of the year when cutting and control can be undertaken, although it would be expected that if the plastic option is used then heat stress in the dry season under thick black plastic squares in a period of soil water deficit would be especially effective. Increased efficacy in hot periods might equally apply to other methods if repeated with sufficient frequency, but at potentially higher cost.

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