1 Overview and recommendations

1.1 Introduction

Australian households burn between 4.5 to 5.5 million tonnes of firewood per year. With the addition of firewood for industrial use, this figure rises to 6-7 million tonnes (ANZECC 2001). The majority of this firewood is harvested by small businesses and individuals, from dead standing and fallen timber on privately held native eucalypts forests (Driscoll et al. 2000). The ecological sustainability of this large and extensive harvest of native vegetation is largely unknown.

In order to address the ecological sustainability of firewood harvesting, a Firewood Taskforce was formed, under the auspices of the former Standing Committee on Environmental Protection (SCEP) and Standing Committee on Conservation (SCC). The Taskforce had State and Commonwealth representatives, including participation from CSIRO. The Taskforce developed a *National Approach to Firewood Collection and Use* in Australia endorsed by The Australian and New Zealand Environment and Conservation Council (ANZECC 2001). The first of the six broad strategies of the document is to *Improve the information base*. Actions under Strategy 1 include:

- Determine the impacts of different firewood collection practices in regional forest and woodland ecosystems;
- Determine the impact of firewood collection on biodiversity in particular regional ecosystems, and develop management guidelines.

CSIRO Sustainable Ecosystems was commissioned by the Department of Environment and Heritage (formally Environment Australia), with funding from the Natural Heritage Trust, to address these two actions. Specifically, CSIRO was commissioned to address the following knowledge gaps identified in Strategy 1 of the National Approach document:

- What are the rates of accumulation of fallen timber, and sustainable rates at which to harvest it?
- What are the amounts, availability, and economics of alternative firewood sources?
- Guidelines for calculating a sustained yield of firewood.
- Data are required on the dead and live wood component of vegetation communities used for firewood collection and reconciled with firewood collection levels.
- Assessment of the rate of natural regeneration and tree mortality in vegetation communities subject to firewood collection.
- A model is needed to guide the sustainable harvest of timber resources.
- Is firewood collection likely to cause a decline in biodiversity in particular ecosystems?

CSIRO focused its study on estimating the amounts, availability and potential environmental impact of harvesting firewood from different sources. The study was limited to analysing firewood sources within the Murray Darling Basin (MDB), an area in which 2-2.5 millions tonnes of firewood is harvested per year from private land and in a generally unregulated manner (Driscoll et al. 2000).

1.2 Objectives

The key objectives of the project were to:

- Develop regional exploitation criteria for sustainable harvesting of firewood from woodland and forest communities in the MDB, based on three scenarios for future harvesting of firewood.

- Identify the location and sustainable yield of firewood from those woodland and forest communities in the MDB that meet the exploitation criteria of each scenario.
- Analyse the possible ecological impacts of the harvesting scenarios, particularly the green-wood scenario.

1.3 Approach

The analysis of the sustainability of firewood supply in the Murray-Darling Basin (MDB) was conducted using a scenario approach. In consultation with a broad range of stakeholders, three harvesting scenarios were developed:

1. *Dead-wood* – Continued reliance on firewood harvested from standing and fallen dead timber from native forests on privately held land;
2. *Green-wood* – Firewood harvests of live trees thinned from existing stands of native forests and woodlands on privately held land;
3. *Plantations* – Firewood harvests from plantations of native hardwoods on privately held, presently unforested land.

The area of native forest required to meet current firewood demand from private land in the MDB was estimated using a forest growth and yield model, constructed specifically for this project, based on data from fieldwork across previously unsurveyed lower rainfall forests, and running the model on data derived from geographic information system (GIS) datasets of forest and non-forest cover in the MDB. This provided the spatial context to enable the most current forest cover data to be used to estimate the number of hectares of any forest type available for firewood harvest, subject to a rigorously defined set of exploitation criteria. The potential environmental impact, particularly of the green-wood scenario, was examined by ecological surveys of low rainfall forests thinned of live trees. State Forests were excluded from the scenarios as firewood harvest from these are regulated through a system of licensing, permits and fees.

1.4 Outputs

Analysis of Firewood Harvesting Scenarios

We present the results of analyses of the spatial extent and yield of firewood based on the three broad types of harvest: maintenance of the *status quo* - the dead-wood scenario, the green-wood scenario, the plantation scenario. Detailed exploitation criteria were developed to determine where in the MDB each scenario might be applied (Section 3).

Geographical Information Database

We constructed a GIS database (Section 4), based on a grid dataset representing broad woodland or forest vegetation types, within which the exploitation criteria were applied for the three harvesting scenarios. Implicit in the GIS was the location of potential sources of firewood within broad vegetation types defined by the National Forest Inventory (2003). This enabled the three harvesting scenarios to be spatially explicit, based on the most current forest cover data available for the MDB. This information was not sufficient to reliably assess forest density and age so estimates were based on our assessments.

Forest Growth and Yield Model

We developed a new stand-based, empirical growth and yield model for native species (mallee and non-mallee) for forests and woodlands in the MDB (Section 6). The development of this model required extensive collection of data on stand age, stand wood volume and amounts of coarse woody debris across a broad productivity gradient (Section 5). The field data contributed to the characterisation of the low rainfall forests and woodland of the MDB (Section 5). The model predicted yields from non-mallee forests, utilising existing measures of site productive capacity (maximum annual net primary production of plants). A separate growth and yield model was developed for mallee forests from published data, to predict potential firewood yield from harvesting mallee. The area of plantation required to meet curent firewood demand from the MDB was estimated using an already existing plantation growth and yield model and linking it to our GIS datasets.

Prediction of potential firewood supply

The model (Section 6) and data from the GIS (Section 4) were used to provide long-term predictions of the firewood supply available from the three harvesting scenarios (Sections 7, 8 and 10). The GIS provided estimates of the current spatial extent of native forests, or land suitable for eucalypt plantations, available to meet the sustainable yield from each scenario.

Potential ecological impacts

Wildlife, soil surface condition, habitat complexity and plant and animal survey data were collected from the few privately managed native eucalypt forests in MDB in which timber had been thinned and harvested for a range of purposes. The data were used to suggest the possible ecological impacts of harvesting firewood from thinning live trees, the green-wood scenario rather than removal of dead trees, the dead-wood scenario. The ecological impacts of removal of coarse woody debris were also evaluated (Section 9).

1.5 Outcomes

1.5.1 Dead-wood scenario

Approach

Harvest regimes were based on standard accepted forestry management practices intended to maintain both firewood supply and sufficient coarse woody debris for biodiversity. This approach uses i) a growth and yield model to predict firewood on a stand basis, ii) an estimate of forest type and productivity, iii) selection of an appropriate management regime and iv) combining the above for an estimate of the long term sustainable supply of coarse woody debris on an annual basis.

Harvestable area

The area considered for the dead-wood scenario is defined by the exploitation criteria: exclusion of the 8.2 million hectares of woody cover further than 500 kilometres from the capital cities that access firewood from the MDB; exclusion of the 1.2 million hectares of mallee forests, which are unsuitable for harvest of dead timber (mallee is considered for the green-wood scenario); exclusion of firewood sourced from publicly owned land. The rationale for these exploitation criteria are presented in Section 3.

Firewood supply

The analysis for the dead-wood scenario (Section 7) estimated that 12.3 million hectares of privately held land in the MDB is potentially available for harvest of standing and fallen dead timber (dead-wood scenario). An appropriate firewood harvest regime for eligible forests could involve about 30 harvests of coarse woody debris (dead timber) over the lifetime of any forest stand, at intervals of 5-10 years, and with the first harvest occurring when a stand is 20-25 years of age. It was estimated that, over the next 100 years, the maximum annual supply of firewood from the MDB under this scenario would average 10 million tonnes per year, with a deviation from this amount in any year of no more than 1.1 million tonnes.

Key firewood supply issues

This is far more than the present harvest from the MDB, currently estimated to be between 2-2.5 million tonnes per year (Section 2). As little as 3 million hectares of the eligible forest area could be sufficient to meet the existing demand. If the maximum of 10 million oven dry tonnes per year of firewood was harvested, the long-term average amount of coarse woody debris which would remain in the forest after firewood harvesting would be 3 tonnes per hectare, far less than the average 20 tonnes per hectare that would remain were there no firewood harvesting.

Biodiversity implications

This loss of coarse woody debris reduces the availability of habitat for biodiversity and the material required for the ecosystem processes which contribute to sustainable landscape function. A summary of these ecological implications can be found in Section 1.5.4.

1.5.2 Green-wood Scenario

Approach

An estimate was made of the maximum and long-term sustainable supply of firewood which might be obtained from the privately owned, native forests of the MDB for the green-wood scenario, under which firewood is obtained only by felling live trees and no coarse woody debris is removed as firewood. The general approach taken for the green-wood scenario follows that of the dead wood scenario.

Separate firewood harvesting regimes were developed for mallee and non-mallee forests. For mallee forests, the regime involved clear-fell harvesting on a 50 year rotation, with regeneration by coppice. For non-mallee, the regime involved “flexible selection” management, with two or three thinnings over the life-time of a stand and with 50% of the standing tree basal area removed at each thinning. Management based on flexible selection should encourage maintenance of forest stands which contain a wide range of tree sizes and ages, consistent with contemporary community expectations for native forest management.

Harvestable area

It was estimated that there are 9.8 million hectares (1.1 M ha mallee and 8.7 M ha non-mallee) of forest in the MDB suitable for harvesting under this scenario. This estimate of available forest was based on the following exploitation criteria: exclusion of forest cover more than 500 kilometres from capital cities; forests on public land; forests within 50 metres of rivers; forests on slopes greater than 15^{o}; forests with less than 30% cover across a 10 square kilometre “window”; and patches of forest less than 100 hectares in size. The ecological and economic rationale for these exploitation criteria are presented in Section 3.

Key firewood supply issues

The model predicted that, over the next 100 years, the sustainable maximum annual supply of firewood from the MDB under the green-wood scenario would average 2.3 million tonnes per year, with a deviation in any year of no more than 0.2 million tonnes. About 22% of this supply would come from mallee forests and the remainder from non-mallee. This level of supply is about the same as the amount of firewood harvested presently from the MDB, which is estimated to be 2-2.5 million tonnes per year.

Biodiversity implications

Because the green-wood scenario does not involve removal of woody debris from the forest (Figure 1.3), it was considered that the green-wood approach to firewood harvest in the MDB should have significant benefits for biodiversity conservation and maintenance of landscape function.

1.5.3 The plantation scenario

Approach

For this scenario, we estimated the minimum area of plantation forests in the MDB needed to provide a long-term, sustainable annual supply of 2.25 million tonnes of firewood, wholly replacing the supply obtained presently from the native forests of the MDB. Estimates were made using a generic growth and yield model system for *Eucalyptus globulus* plantations.

Key Firewood Supply Issues

It was estimated that if the most productive sites along the eastern and southern boundaries of the MDB were used for plantations, a total of just over 0.2 million hectares of plantations, grown on 10 year rotations, would be required. If plantations were restricted to the less productive areas of lower rainfall (<900 mm yr^{-1}), or to areas where land clearing for agriculture has been particularly intensive, just under 0.35 million hectares of plantations, grown on 11 year rotations, would be required. If planting was restricted to the less productive areas of the MDB, on soils at high risk of salinisation from agriculture, a total of about 0.6 million hectares of plantations, grown on a 20 year rotation, would be required.

Implications

Plantations established solely for firewood are likely to be economically unsustainable. It is more likely that firewood would be a secondary product from plantations. Multi-purpose plantation areas larger than the minima specified above are likely to be required to economically provide the total firewood supply required from the MDB. It appears that there is limited prospect for growing commercially viable plantations which have firewood as their principal product, unless growers receive substantial subsidies, either directly or indirectly, through payments for the environmental benefits that accrue, through mechanisms such as salinity, biodiversity or carbon credits. The practicalities of plantation development in the drier regions of Australia are still in early development, so uptake is likely to be slow.

1.5.4 Ecological impacts

We developed a sampling protocol to quantify the ecological impacts of harvesting firewood of both live and dead timber. We applied this protocol to 19 sites selected from four privately owned properties located within a 100 kilometre radius of Canberra, upon which various harvesting regimes had been practiced over the past 50 years or so. We were only able to find one property with some pre-thinning ecological data. Thus we were unable to make any scientifically rigorous analysis of the impact of forest thinning for firewood. However, we were able to use our survey results to suggest some of the likely ecological impacts of harvesting of live trees compared to harvesting of dead timber from the dry sclerophyll forest of the Southern Tablelands of NSW (Section 9).

We found that the different vegetation communities characterised as “dry sclerophyll forest” contain a rich diversity of flora and fauna species, which have historically been poorly surveyed. They have been periodically disturbed, particularly by ring-barking during the late 1800’s and early 1900’s. Older ring-barked sites were typified by dense, even-aged stands of trees, with limited regeneration, few old growth trees and low habitat complexity, including limited shrub and ground cover. Little active management of these forest stands have occurred subsequently.

Bird species richness across the full range of dry sclerophyll forest types was high, although older ringbarked sites had limited habitat structure. As a consequence, bird species richness tended to be lower at these sites in comparison with sites which have undergone more recent harvesting disturbances. For example, bird species richness and abundances at younger pulled/chained and bulldozed sites were generally greater than at the older ringbarked or control sites.

Plant species richness within densely stocked sites was relatively low. Plant species richness after harvesting is likely to increase only slowly. Regeneration of trees after harvesting treatments was significantly related to treatment type; thinned sites had the highest regeneration by coppicing, pulled/chained sites had regeneration, primarily from seed.

The species richness and abundance of small ground dwelling mammals was low across all surveyed sites reflecting the low nutrient status of these forests. Other research indicates that these small mammals favour more structurally complex sites, with dense understorey, particularly along drainage lines, which are areas currently exempt from harvesting under forestry practice guidelines.

Coarse woody debris loads were between 0.3 and 48 tonnes per hectare. Loads under 10 t ha^{-1} were considered depleted, 10-30 t ha^{-1} at the lower end of "average" and = 30 t ha^{-1} were higher than "average". The type of harvest (chaining, bulldozing, or ringbarking) was a significant predictor of coarse woody debris loads. Management history was more influential than other environmental factors in determining coarse woody debris loads.

Landscape function analysis indicated that thinned and pulled/chained sites were relatively functional. However, there has been some loss of infiltration and nutrient cycling where thinning and coarse woody debris removal or bulldozing were the methods of harvest.

Surveyed forest stands varied considerably in terms of basal areas, stems per hectare, diameters and management history. Fifty to one hundred year old, even-age stands are those likely to be closest to maximum density, have the fewest habitat values, and are potentially suitable for harvesting by thinning methods, such as chaining in narrow strips, which maximise residual loads of coarse woody debris and stimulate regeneration.

1.6 Implications for Management and Policy

1.6.1 Dead-wood scenario

Our estimate that the maximum sustainable yield of coarse woody debris from the MDB private forests is about four times greater than current demand indicates that there is reasonable scope to manage the intensity of harvest from coarse woody debris. There are at least two broad options; the intensity of harvest could be reduced from any one stand, or large areas could be excluded from coarse woody debris harvesting. We recommend that highly cleared areas of the MDB be excluded from further harvesting of standing and fallen dead timber. Our model estimates that about 1.5 billion tonnes of coarse woody debris has already been lost through clearing. The continued removal of coarse woody debris is of conservation concern, not because any particular patch of woodland or forest has been depleted, but because so much has been lost over all of the landscapes of the MDB since European settlement, through extensive clearing and agricultural development. Fallen and dead timber is a renewable resource only while the forest remains. Much of it is gone, particularly in the most productive areas of the MDB, with the most fertile soils and highest rainfall. Clearly there is a need to conserve what little coarse woody debris is left in these highly cleared regions of the MDB. The load of coarse woody debris in any one remnant is of secondary importance. Any load of coarse woody debris is a scarce resource in a highly cleared region. We argue that there is scope for continuing the firewood harvest of coarse woody debris in regions with an extensive forest cover, but not in regions where clearing, as well as firewood removal, has greatly reduced this important component of forests and woodlands.

This project has developed the modelling capability to analyse the yield of firewood and residual levels of coarse woody debris from any combination of alternative management regimes. We only modelled a few simple options. Other regimes and guidelines need to be developed by land managers and state agencies that are responsible for legislation regulating timber harvesting.

1.6.2 Green-wood scenario

We suggest that it is feasible to meet a long term demand for firewood exclusively by thinning live trees only in non-mallee forests and clear-felling mallee forest. In doing so we considered suitable only those forests away from major water courses, on shallow slopes less than 15°, and from forests patches of at least 100 hectares that occur in regions with at least a 30% forest cover. An exclusive harvest of live trees in non-mallee forests would eventually create mixed age stands and allow for substantial accumulation of coarse woody debris. Averaged across the entire modelled area, loads of woody debris in non-mallee forests would vary between 15-20 tonnes per hectare over the next 100 years. This would result in 5-7 times greater post-harvesting loads of coarse woody debris than under the dead-wood scenario, which on average left only 3 tonnes per hectare of woody debris after harvest of dead standing and fallen timber. Mallee forests contain little coarse woody debris whether harvested or not.

We suggest that the environmental impact of forest thinning for firewood can be minimised if the thinning operation leads to greater structural complexity. Thinning of forests can increase the structural complexity of forest if it leads to tree regeneration, which in time will create mixed-age stands. Thinning can also increase structural complexity if it leads to greater loads of coarse woody debris left after the thinning operation and if opening of the forest canopy stimulates the establishment of a greater density and diversity of shrubs, grasses, forbs and orchids.

1.6.3 Plantation scenario

On the most productive sites for eucalypt plantation forestry in the MDB, it was estimated that 21,000 hectares of plantations would have to be established annually for 10 years to reach the final estate size of 0.21 million hectares needed to wholly replace firewood obtained from native forests in the MDB. If plantings were restricted to sites at risk of soil salinisation, 29,000 ha would have to be established annually for 20 years to achieve the final estate size required. Planting rates of this magnitude constitute an appreciable proportion of the 80,000 hectares per year of new plantations required to achieve the objectives of the 2020 vision for Australian forest plantations.

To initiate and manage plantation programs of the size required for firewood production across the vast area of the MDB and amongst the many private land owners would be a very difficult undertaking. Perhaps the best that might be achieved over the next ten years is the establishment of some plantations, on sites across a range of conditions represented by the various options considered by our project. This might ultimately achieve a total plantation area sufficient to partly replace the firewood supply presently taken from native forests in the MDB, particularly if firewood was a secondary product, i.e. from thinnings.

1.7 Recommendations

Recommendation 1. Commercial harvesting of firewood from fallen and standing dead timber should be phased out in those regions of the MDB where coarse woody debris is highly depleted, particularly in the cropping zone.

Recommendation 2. Firewood could be sourced from thinnings of live trees in densely stocked regrowth forest if harvesting was done under defined exploitation criteria and improved harvesting guidelines (see Recommendation 7).

Recommendation 3. Active and sustained marketing of firewood from densely stocked regrowth forests (e.g. stringy barks) is required if the demand for firewood from coarse woody debris (dead wood) from traditionally preferred species (e.g. Red Gum/Box mix) is to be reduced.

Recommendation 4. Active and sustained marketing of firewood sourced from plantations is required to assist in the reduction of demand for firewood from coarse woody debris (dead wood).

Recommendation 5. Long term and rigorous research is needed that experimentally manipulates levels of coarse woody debris in a diversity of vegetation types in order to quantify the environmental impacts of commercial scale removal of fallen and standing dead timber on a range of taxa and ecosystem processes.

Recommendation 6. Within regions where harvest of dead timber could continue, guidelines and regulations are needed to create "refugia" free of dead timber harvesting.

Recommendation 7. Scientifically-defensible harvesting guidelines need to be developed which promote regeneration, improve forest structure and maintains landscape function, in order to improve the management of low rainfall forest stands.

Recommendation 8. A combination of strategies should be modeled then adopted to reduce the impact of firewood harvesting. A combined strategy includes excluding the harvest of coarse woody debris from areas where such a harvest is deemed to be ecologically unsustainable; thinning live trees from regions with extensive regrowth; and investing from hardwood plantations which supply firewood as a secondary product.

1.8 Conclusions

The heavily-cleared areas of the MDB, where only fragmentary forest remains, are particularly at risk of loss of biodiversity and landscape function if harvest of dead-wood continues within them.

Four times the existing annual demand (about 2.5 million tonnes per year) for firewood from the MDB could be met from intensively harvesting coarse woody debris from only 3 million of the available 12 million hectares of non-mallee forests. Alternatively, a larger area of these forests could be harvested less intensively, ensuring the retention of sufficient coarse woody debris to maintain biodiversity and landscape function.

The supply of firewood which could obtained by from the harvest of live trees from mallee and non-mallee forests is about equal to the current demand. The stands of non-mallee forests most appropriate to a green-wood harvesting approach are also the stands most likely to benefit ecologically from harvesting, as the preferred methods of thinning encourage regeneration and increase in habitat complexity, which are likely to in turn encourage maintenance of landscape function and species diversity.

Small ground-dwelling mammals occur at low density in these forests, reflecting the dryness and low soil fertility. The ecological sustainability of the forests would be best served by the exclusion of wood harvesting from riparian areas which provide the best habitats for these animals.

Approximately 200,000 hectares of plantation, grown on a 10 year rotation, would have to be established in the MDB to meet the present demand for firewood from the MDB. However, plantation forestry is unlikely to be economical where plantations are established principally for firewood production. However, firewood could be a useful by-product from plantations, as they become more generally established in the MDB, over the next 10-20 years. Firewood from plantation sources would gradually supplement the levels of firewood available from the harvesting of live trees in MDB to a level which would easily meet the future demand.

There is considerable opportunity to sustainably obtain firewood from the privately-owned forests in the MDB through the harvest of live trees, by-products from plantation forestry and limited continued collection of coarse woody debris. Diversification of industry in this way should have benefits in maintaining biodiversity and landscape function, that is, maintaining ecological sustainability. However, substantial planning and the introduction of government regulation will be necessary to achieve this.