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# **Review of woody biomass recovery following chemical clearing: implications for modelling of carbon sequestration**

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**Key words:** land clearing; woody regrowth; herbicide; Box; Brigalow

## **Abstract**

Clearing of woody regrowth for pasture management has implications for livestock production, carbon sequestration and biodiversity. Clearing activity includes mechanical and chemical clearing. Chemical clearing is through selective or broadscale application of herbicide, while mechanical clearing typically is through ‘pushing’ or ‘pulling’ trees over or blade ploughing. Anecdotally the use of broadscale chemical clearing of regrowth for pasture establishment has increased over the past decade, however, there is limited information on changes in woody biomass recovery following chemical clearing which may be slower relative to mechanical clearing. This paper will focus on a review of existing knowledge to inform modelling of the carbon sequestration consequences of chemical clearing in Queensland.

Existing information was synthesised from the literature and case study data from two grazing properties. There was relatively limited data on biomass recovery post-chemical clearing and blade ploughing. Rates of aboveground biomass carbon recovery varied depending on the herbicide used. Recovery rates following application of the herbicide tebuthiuron (Graslan®) were typically lower than those from other herbicides. Further, recovery rates of aboveground biomass carbon post chemical clearing with tebuthiuron were typically 2-28% of those after mechanical pulling, while those from other herbicides ranged from 38-76%. In addition to herbicide type, factors such as the soil type, timing of application (season), grazing pressure and use of fire can affect the recovery rates of post-herbicide application.

Our findings suggest that models calibrated for mechanical clearing will overestimate the recovery of biomass following chemical clearing, particularly when the herbicide tebuthiuron has been applied. We recommend additional field surveys and monitoring, preferably through establishing permanent sampling plots to quantify the rate of carbon sequestration in regrowth of woody vegetation specific to post-chemical and blade plough clearing in rangelands.

## **Introduction**

Land clearing is the direct human-induced removal of vegetation cover from forested areas, including primary clearing of undisturbed forest and reclearing of forest regrowth, to allow for other land uses such as agriculture. In the past decade, Australia’s Land Use, Land Use Change and Forestry sector has changed from a net source of greenhouse gas emissions to a net sink largely driven by the decline in emissions from land clearing (DCCEEW 2025). Queensland accounts for about 58% of Australia’s total land clearing (DCCEEW 2025), mostly for pasture management in the Brigalow Belt and Mulga Lands (SLATS 2025).

The Full Carbon Accounting Model, FullCAM, predicts carbon (C) sequestration in regenerating woody vegetation, including regrowth resulting from clearing. Currently in FullCAM, mechanically cleared sites are represented in the calibration set for regeneration of woody biomass of native vegetation post-removal of grazing suppression and/or cessation of clearing (Paul and Roxburgh 2020), but none of the calibration sites are known to have been chemically cleared or blade ploughed. The extent of chemical clearing in Queensland recently mapped by the Statewide Landcover and Trees Study (SLATS) comprised 8% of all clearing activity in 2022-23 (SLATS 2025). Anecdotally, chemical clearing of regrowth for pasture establishment has increased over the past decade, and biomass recovery following chemical clearing may be slower relative to mechanical clearing. However, there is limited information available to assess this. Thus, the aim of this study was to review existing knowledge to inform modelling of the C sequestration consequences of chemical clearing in Queensland.

## Methods

Information on biomass recovery following chemical clearing was synthesised from a literature review and case study data from two extensive grazing properties in Queensland. Published literature was searched using databases in the 'Web of Science' (Clarivate Analytics) platform. Different combinations of the following search terms were used: “chemical clearing” AND “vegetation” OR “forest” OR “woodland” OR “rangeland\*” OR “shrub\*”; “clearing” AND “stem injection” OR “tebuthiuron” OR “picloram” OR “Tordon” OR “Graslan”. Additional references were identified by searching the reference lists of relevant publications for secondary references of interest. Overall, about 150 references were identified. Where available, data on live aboveground biomass C (AGB C) recovery following chemical clearing were collated. When a study did not provide stand AGB C ( $\text{Mg C ha}^{-1}$ ), it could be calculated if stand basal area (BA,  $\text{m}^2 \text{ ha}^{-1}$ ) was provided. Different equations were used depending on the stand variables available and the region as per Forrester *et al.* (2025).

Data were also collated from two case studies in the Fitzroy region, Queensland. The first property ‘Coonabar’ had been previously cleared by pulling, and from 2000-2007, strips of brigalow (*Acacia harpophylla*) regrowth were cleared by aerial application of tebuthiuron herbicide pellets (Bray *et al.* 2016). The second property ‘Oaklands’ had significant areas of Box (mostly *Eucalyptus moluccana* and some *E. populnea*) regrowth from previous mechanical and chemical clearing in 2002 (Bray *et al.* 2015). Measurements were initially made in 2012-2014 (Bray *et al.* 2015; 2016), and again in 2023 (this study) to compare regrowth from areas of chemical and mechanical clearing. Species and stem diameters at either 130 cm (*Eucalyptus*) or 10 cm (*Acacia*) were recorded for all woody plants. Live AGB was calculated applying relevant plant functional type allometrics (Paul *et al.* 2016) and dry-mass values were converted to C mass by multiplying live biomass by 0.5 (Gifford 2000).

## Results

Relatively few studies were identified on biomass recovery following chemical clearing, with most reporting the proportions of trees/shrubs killed post-treatment in relation to factors such as herbicide type, application method or tree size (e.g. Burrows 1973; Johnsen and Raymond 1990; Johnson and Back 1974). Many studies reported on the effects of chemical clearing on pasture production rather than recovery of woody vegetation (e.g. Burrows *et al.* 1994; Hall *et al.* 2016; Walker *et al.* 1986). Further, most studies reported on responses in mortality and herbage only in the first 1-3 years post-application.

Rates of AGB C recovery varied depending on the herbicide used (Table 1). Recovery rates following application of tebuthiuron (Graslan®), which ranged from 0.02-0.21  $\text{Mg C ha}^{-1} \text{ yr}^{-1}$ , were typically lower than those from other herbicides such as hexazinone (Velpyr®) and picloram + triclopyr (Tordon®), which ranged from 0.41-0.90  $\text{Mg C ha}^{-1} \text{ yr}^{-1}$ . Further, rates of recovery of AGB C were typically lower following chemical clearing compared with mechanical pulling on the same site (Table 1, Figure 1). Relative rates of recovery post-clearing with tebuthiuron compared with pulling typically ranged from just 2-28% of those after pulling, while those from other herbicides ranged from 38-76%.

## Discussion

This review found that rates of AGB C recovery varied following chemical clearing depending on the herbicide used, with lower rates following application of tebuthiuron compared with other herbicides. Tebuthiuron is a ‘rate selective’ herbicide that kills woody root stock and most individuals including suppressed juvenile plants, due to broadcast application; there is a range of woody species susceptibility related to the rate of application. Residues have been detected in the soil more than a decade after application (Johnsen and Morton 1991), thereby minimising regrowth potential. In addition, other factors such as soil type, timing of application (season), grazing pressure and use of fire (e.g., see Figure 1) can affect the relative recovery rates of post-herbicide application.

Rates of AGB C recovery were typically lower following chemical clearing compared with mechanical pulling on the same site. Mechanical clearing in the studies identified was mostly pulling alone where juvenile trees can survive and root bases can resprout. Only a single study was identified that compared chemical clearing with blade ploughing studies, finding that 28 months after blade ploughing there was no recovery of canopy area (Back 1998). Unlike pulling, blade ploughing severs woody root stock of

large and juvenile trees, therefore regrowth will likely be slower than from pulling alone and may result in similar rates of recovery to broadscale chemical clearing with tebuthiuron.

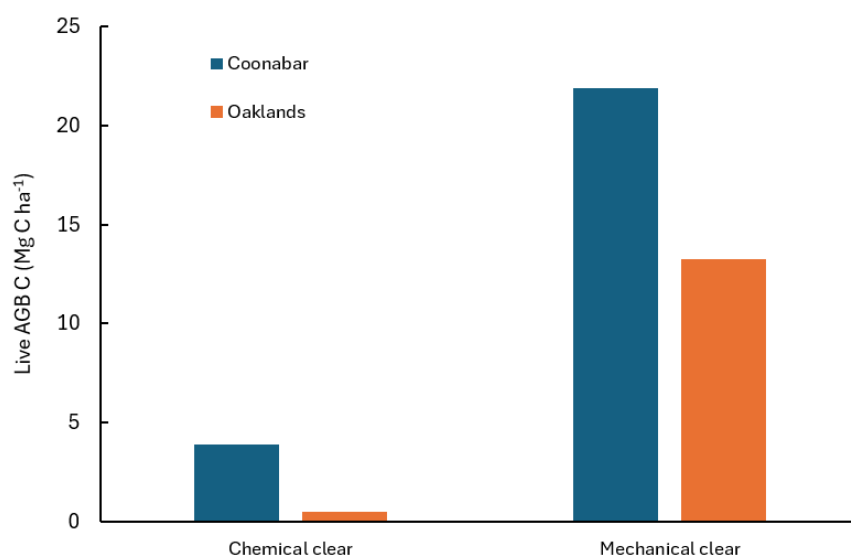


Figure 1. Comparison of live aboveground biomass C (AGB C) recovery in 21-year-old chemical cleared and mechanical cleared regrowth at the case study properties. Note: At Oaklands, the chemically cleared area had been burnt several times post-clearing by 2023. The fire was likely of higher intensity due to higher grass biomass than at the other sites, resulting in slowing of regrowth.

Currently in FullCAM, mechanically cleared but not chemically cleared or blade ploughed sites are represented in the calibration set for regeneration of woody biomass of native vegetation post-removal of grazing suppression and/or cessation of clearing (Paul and Roxburgh 2020). Based on the minimal recovery following chemical clearing identified here in the first 20 years, it is likely that current calibrations will overestimate the recovery of biomass following chemical clearing, particularly when the herbicide tebuthiuron has been applied. To assess the rate of C sequestration in woody regrowth specific to post-chemical clearing and likely blade ploughing in Queensland rangelands, we recommend additional field surveys and monitoring, preferably through establishing permanent sampling plots. Further work to investigate partial clearing (e.g., where only shrubs are targeted or where silvopastoral systems are thinned) versus full clearing, is needed. These data could be used to better calibrate C accounting models such as FullCAM. Further, because the rate of regrowth can be much lower after chemical clearing, chemically cleared areas will likely be detected by remote sensing as non-woody for longer. Therefore, future work could consider how chemically cleared areas are classified by the remote-sensed woody/non-woody time series.

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