Greening Australia

Biochar and Energy From Trees Project

Background, results and future opportunities for landscape restoration from the strategic establishment of mixed native species plantations in Habitat 141°

Produced by Greening Australia via funding provided by

ALCOA FOUNDATION

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Biochar and Energy from Trees
Alcoa Foundation Research Project

INTRODUCTION & BACKGROUND
Hang on a minute, this really is serious

Australia is a big country. We are a small nation. In the relatively short time since European settlement we have drastically altered the natural landscape: we have cleared the land for agriculture, industry and housing; we have polluted rivers with sediment and run-off; we have extirpated native fauna by destroying habitat and introducing predators and pests; and we have compromised the soils as a result of pollution, erosion and salinity. If we are serious about addressing land degradation and preserving biodiversity on a continental scale, first we need to acknowledge the magnitude of the problem.

Over-clearing of native vegetation in the pursuit of agriculture is one of the greatest causes of land degradation[1]. Approximately 53% of the continent, (407 million hectares[2]) is used for agriculture, and estimates of the total extent of degradation vary between 100 million hectares[3] (roughly the size of South Australia) to 250 million hectares[4] (roughly the size of Western Australia). The damage is most severe in the intensively managed agricultural regions where vegetation clearance is greatest (Figure 1). More than 50% of the sub-regions in the intensive use zone contain less than half of the original native vegetation; more than 30% of the sub-regions in the intensive use zone contain less than one-third remaining native vegetation[5].

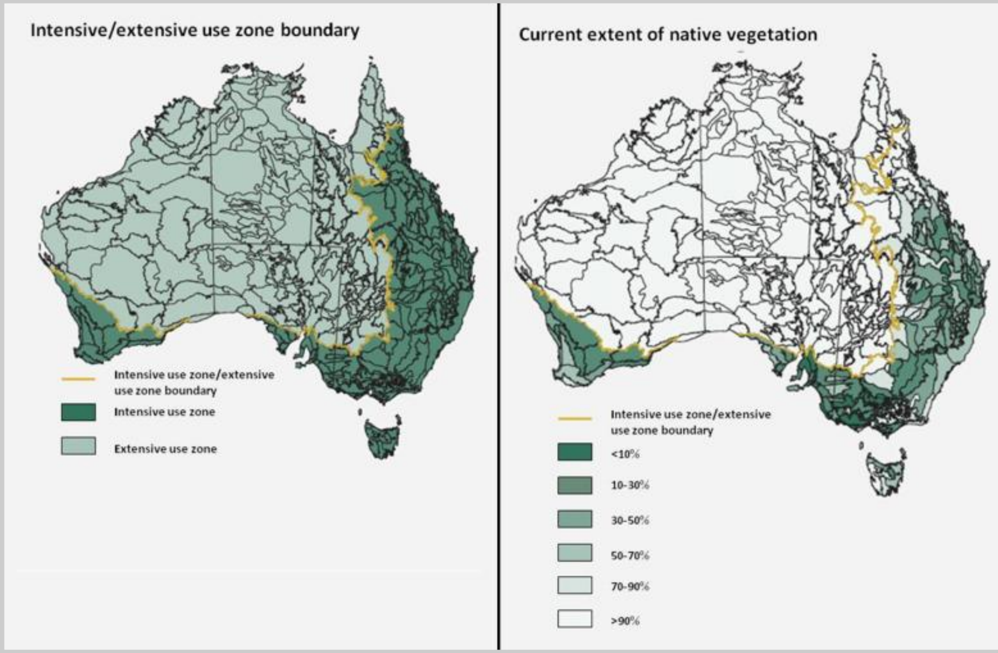


Figure 1. Land use zones (a) and rates of vegetation clearance (b) in Australia mapped by sub-region[6]

[1] See for example, Lindenmayer, D. (2007) '*On Borrowed Time – Australia's Environmental Crisis and What We Must Do About* It' Penguin Publishing
[2] www.tradingeconomics.com/australia/agricultural-land-percent-of-land-area-wb-data.html accessed July 2014
[3] National Land and Water Resources Audit (2002) *'Australians and Natural Resource Management 2002'*
[4] www.australiancollaboration.com.au/pdf/.../Land-degradation-FactSheet accessed July 2014
[5] Morgan G (2001) '*Landscape Health in Australia: A rapid assessment of the relative condition of Australia's bioregions and subregions'*
[6] Adapted from Morgan G (2001) '*Landscape Health in Australia: A rapid assessment of the relative condition of Australia's bioregions and subregions'*

To even begin to address the environmental problems that confront us, we must, first and foremost, tackle the recovery and restoration of natural assets in the heavily modified agricultural zones. We must act at a scale far exceeding our current efforts or the condition of our continent's natural assets will continue to deteriorate.

One of the consequences of extensive clearing is habitat loss and fragmentation: previously connected areas become fragmented and isolated by agricultural land-uses, which restricts movement of species and flow of genetic material.   Contributing factors to land degradation such as adjacent land use, soil and stream health, weed infestations, invasion of feral animals and the number of threatened ecosystems or species, can be summarized to provide an overall picture of landscape condition (Figure 2).

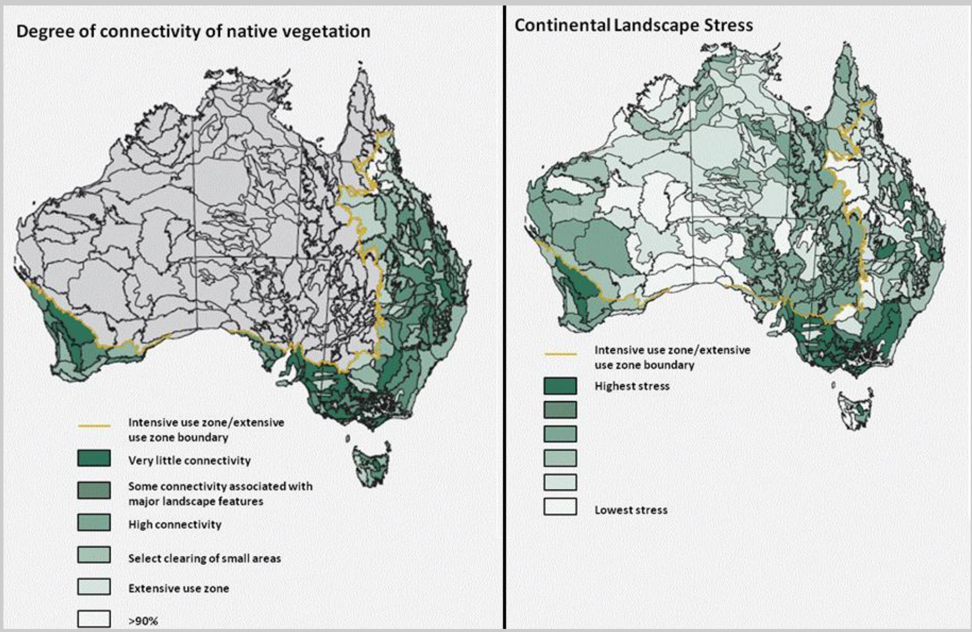


Figure 2. Degree of connectivity (a) and landscape stress (b) in Australia mapped by sub-region[7]

This picture is not pretty. Across Australia, 37 sub-regions (10% of the total land mass) fall into the two highest stress classes, all of which are in the intensive use zone. It is in these regions where salinity, declining soil quality, altered water regimes, and ongoing loss of native flora and fauna are most pronounced. The greatest declines in bird populations in Australia have occurred in the agricultural area of south-western and south-eastern Australia, where 80% of the woodlands have been cleared[8].

Recent research suggests that while 10-15% native vegetation cover may be a useful intermediate goal for restoration of landscapes that currently have little native vegetation (<5%), a long-term goal of 30-35% native vegetation is needed in rural landscapes to maintain resilient populations of most bird and mammal species[9]. Conserving remaining vegetation, and the ecosystems and species they support, is the obvious first step towards addressing landscape health and preserving biodiversity; however, in the intensive land-use zone in particular, large-scale reinstatement of native vegetation is central to reverse the long-term impacts from the over-clearing of native vegetation.

[7] Adapted from Morgan G (2001) '*Landscape Health in Australia: A rapid assessment of the relative condition of Australia's bioregions and subregions*'
[8] Birds Australia (2005) '*The State of Australia's Birds 2005: Woodlands and Birds*'
[9] Bennett, Dr. A. and Radford. Dr. J. (2004) '*Landscape thresholds in rural environments*' Final report to Land and Water Australia

So what are we doing about it?

The challenges to mitigate long-term environmental damage are immense, and are being addressed to varying degrees with a range of methods, but are our current approaches enough?

The Australian Bureau of Statistics estimates that farmers collectively spend $3 billion per annum on addressing land degradation, and approximately half of this goes towards controlling weeds, with the remainder spent controlling pest animals and addressing soil degradation[10]. Commonwealth investment in biodiversity programs averaged $465 million per annum across Australia between 1990 and 2013[11], while States and Territories also contribute funding towards other environmental programs.

On this basis, the current annual investment of almost $4 billion is clearly not enough to address land degradation and biodiversity decline. Investment and funding is traditionally directed towards priority actions that have a significant impact on specific problems within discrete areas, but it is large-scale reinstatement of native vegetation that is of critical importance to reverse loss of species and biodiversity decline.

Approximately 280,000 tonnes of soil have eroded from this one kilometre section of the Crawford River in south-west Victoria since 1850, at a rate of approximately 5 tonnes per day. There are many rivers in similar condition throughout Australia.

Increasing native vegetation cover by just one percent across the entire intensive use zone in Australia, at a minimum cost of $2000 per hectare for broad-scale revegetation (based on Greening Australia's experience over 30 years), represents an investment of at least $5 billion to achieve 2.5 million hectares of revegetation; a daunting mathematical proposition and a huge budgetary imposition.

Clearly, to achieve the best outcomes for biodiversity, we need to identify and concentrate our efforts on parts of the Australian landscape that have outstanding natural values, and where we are confident that we can make a meaningful and lasting impact. The restoration objectives for priority landscapes must be clearly defined and associated with measurable outcomes, and above all provide best value for investment.

Importantly, to encourage uptake of large-scale restoration by farmers, we need to investigate new ways to integrate environmental repair into agricultural systems that minimize the opportunity-costs of converting land from conventional food and fibre production, into delivering ecosystem goods and services that are currently perceived as intangible, such as the provision of healthy soil, healthy habitats, and clean air.

[10]Australian Bureau of Statistics (2008) '*Natural Resource Management on Australian Farms 2006-07*'
[11]HC Coombs Policy Forum (2011), '*Synthesis of broad issues and opportunities: Document I*', HC Coombs Policy Forum-Fenner School of Environment and Society NRM initiative, The Australian National University

How can we make it happen?

Creating markets for environmental goods and services underpins global carbon trading schemes, currently estimated to be worth $30 billion and involving over 40 countries[12], including schemes encouraging farmers to participate in broad-scale revegetation programs to sequester carbon in Australia. Not only does large-scale revegetation have the potential to reduce atmospheric carbon, if appropriate species are planted in the right place, these plantings can also provide clean water, reduced salinity, and additional habitat for native flora and fauna.

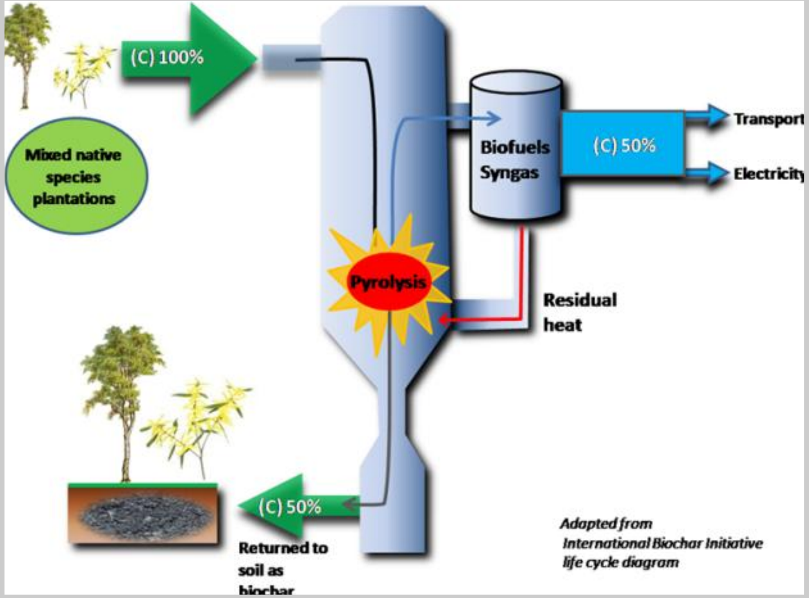


Figure 3 The bioenergy/biochar closed loop concept[13]

Environmental damage and degradation is not one single issue. Restoration does not comprise one single solution. multiple problems, provides multiple benefits, and is delivered as a scalable concept: the provision of habitat for biodiversity; carbon sequestration for climate change mitigation; a range of ecosystem services such as soil improvement, landscape resilience and social and economic benefits; and potential renewable resources for energy production.

A BETR idea

Current approaches to landscape restoration and repair are falling short of the magnitude required to achieve conservation goals. If Plan A is not working, we need a Plan B, and we believe that the Biochar and Energy from Trees (BETR) concept may eventually form part of Plan B.

The (BETR) project comprised an innovative concept to research practical solutions to environmental decline and climate change mitigation. The concept focussed on a 'closed loop' idea to achieve improved biodiversity outcomes, long-term carbon sequestration via trees and biochar, and bioenergy opportunities.

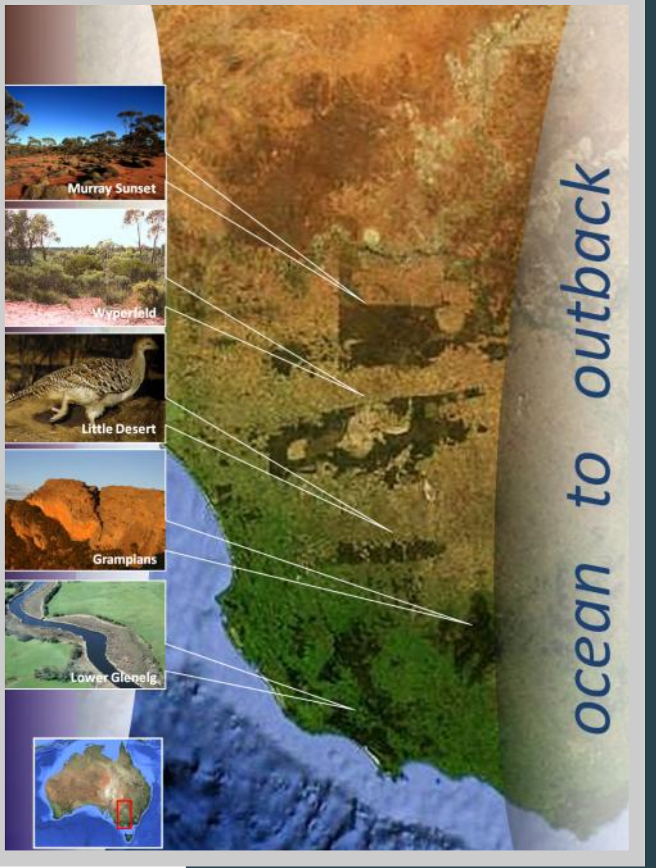
The BETR concept outlines landscape-scale establishment of diverse native species, which provide multiple benefits across agricultural landscapes: biodiversity benefits via increased habitat, connectivity and provision of ecosystem services; significant quantities of carbon sequestered across the landscape within the vegetation biomass; harvest of plantations in small proportions to provide locally generated bioenergy outputs; and production of biochar, a type of charcoal that can be applied to soil for long-term carbon storage and soil health benefits. The 'closed loop' bioenergy approach is demonstrated in Figure 3 where biochar generated through bioenergy production is returned to soil in farming and revegetation.

[12] www.abc.net.au/news/2014-07-09/tony-abbott-emissions-trading-around-the-world-fact-check/5559430 accessed July 2014
[13] Adapted with permission from International Biochar Initiative (www.biochar-international.org)

The demand for bioenergy and carbon sequestration represents powerful new market factors with the potential to drive the strategic restoration of vast areas of land as well as tackle issues like salinity, erosion and biodiversity loss.

The BETR research project looked at influencing future markets to facilitate the significant change required to achieve such enhanced landscapes. Greening Australia believe that further investment is necessary to shape and direct emerging carbon and bioenergy markets with a focus on landscape restoration and multiple environmental benefits; there is a risk that markets could otherwise evolve that do not address landscape restoration, or in a worst-case scenario possibly deliver negative outcomes, (e.g., monocultures of ‘weedy’ introduced plants).

The Biochar and Energy from Trees project research focussed on finding new ways of using native vegetation to tackle climate change and biodiversity decline, by exploring the feasibility of integrating mixed native-species bioenergy plantations into agricultural systems to enhance, rather than displace, food and fibre production. With a long-term view towards emerging ecosystem services markets, agricultural landscapes can be reconfigured – changed ratios of cropping and grazing; provision of habitat for biodiversity; and the utilization of woody perennial vegetation, to deliver a range of ecosystem services and land-care benefits plus additional income for farmers.



Habitat 141 - restoring landscape connectivity across a highly fragmented agricultural landscape

The project undertook the research by working with farmers across one of Australia’s most important ecological regions, Habitat 141°. H141° is a 50-year visionary project to restore and reconnect the iconic landscapes adjoining the SA/Victorian border, stretching 700 km from the coast to the rangelands of southern NSW. The H141° landscape is one of few regions in Australia where intact examples of pre-European vegetation remain in the major public parks and reserves along such a vast north-south axis, surrounded by some of the most heavily cleared and modified agricultural landscapes in Australia. Restoring and reconnecting the landscapes throughout H141 will allow movement of species and genes to occur as they once did, and increase native species’ chances of adaptation and survival in the face of climate change.

Greening Australia undertook a spatial mapping exercise to identify where in the landscape biodiverse revegetation could achieve multiple environmental benefits, such as erosion and salinity control, whilst also enhancing habitat for a number of native species. The energy yield and growth rates of local trees and shrubs from known-age plantations across western Victoria was measured to determine bioenergy potential. The potential of biochar, one of the important by-products from the bioenergy process, was also assessed as part of the carbon/bioenergy loop as a stable form of carbon storage, and its benefits to soil health.

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Why we did it

The intent of the project was to get people thinking about how a better future might look. The concepts outlined in the BETR project certainly created a lot of discussion amongst colleagues, environmentalists and farmers. The multiple benefits to biodiversity, primary productivity and environmental restoration envisaged by the project generated interest amongst diverse audiences.

The BETR project allowed us to take a long-term view imagining a future of a sustainable 21st century landscape where commercial imperatives are used to bring about positive landscape change. The project's intent was to challenge people's thinking – including our own - and dare to be different.

The project compelled people to think about putting a value on native vegetation, and on the environment in general; to generate positive outcomes for natural systems, while ultimately still deriving short and long-term commercial benefits. We believe that in the long term this approach may well be one of our best chances at reversing current trajectories of landscape damage and decline.

The BETR project highlights a solution to environmental repair and restoration lacking in current land access models that do not operate at the required scale or magnitude. Greening Australia's focus on BETR was initially as a proof-of-concept; we were keen to explore further if this approach could work, and drive the design and on-ground implementation of plantation and revegetation systems to maximize ecological outcomes in alignment with our mission. The clear intent of our research in this area was to look at integration of mixed native vegetation into mainstream farming operations for multiple benefits, to realize long-term conservation goals for our landscapes.

Greening Australia have long been recognized as experts in revegetation and landscape restoration. Our opportunity now is to translate that knowledge and expertise into scientifically-focused and whole-of-landscape approaches to overcoming the threats to our unique natural landscapes. The BETR concept provides an opportunity to continue to build on our highly regarded profile as revegetation specialists, and engage in new and emerging opportunities, such as the BETR model, and at the same time fulfilling our goal to restore and conserve Australia's diverse natural landscapes to allow people and wildlife to co-exist.

Chipping known-age trees from a plantation in south-west Victoria (above), and drying biomass samples from different species before gasification

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Our role as a Non-Government Organisation

Greening Australia is confident that, in time, many of the ideas that comprise the BETR concept have the potential to be embraced at scale with the support of other individuals, groups, communities and organizations, as economic prerequisites align with policy direction and community sentiments.

The important point of difference of the BETR concept is the provision of multiple landscape benefits. Bioenergy systems may be devised by others using exotic monocultures to deliver economic and energy benefits, but which only moderately or marginally contribute to positive environmental outcomes, and with risks including the introduction of invasive weeds. The intent of Greening Australia in devising the BETR concept was for a holistic approach with benefits across all sectors: environmental, economic, energy and climate.

Our organization is acutely aware of the implications for our native plants, animals, waterways and soils if we, as a nation, do not address environmental degradation. Continuing in a business as usual approach is not an option. As a respected and objective voice on environmental issues, Greening Australia is keen to contribute to discussions and new ideas around action on restoring our natural landscapes and mitigating against the damaging effects of climate change.

The BETR project has been easily understood and readily embraced by many landholders and others in the agricultural communities and landscapes in which the project has been active. The list of people who have contributed time and effort to this project reinforces our view that investigating topics such as this are an important role for an NGO with a long-term commitment to landscape restoration.

The appropriate financial and policy signals are not yet operational to ensure the economic feasibility of the BETR project; with appropriate commercial signals, opportunities exist to considerably reduce the budgetary impost of future natural resource management constraints. Sustained advocacy is required from organizations and individuals, otherwise innovative approaches to landscape repair like this will never become a reality. Greening Australia continues to explore opportunities to fill knowledge gaps, and leverage additional investment to implement the concept at a landscape scale.

Before (2009) and after (2012) photos of revegetation of 137 ha of formerly marginal farmland in a key H141 connectivity zone for the endangered Malleefowl, funded through a voluntary carbon offset agreement. This is one example of using market mechanisms to drive landscape restoration.

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Spreading (above) and incorporating (middle) biochar into a BETR storage and growth trial (below)

RESULTS AND FUTURE OPPORTUNITIES

Our research, supported by a review of the scientific literature, demonstrates that short rotation plantings of locally occurring species can have positive landscape and biodiversity benefits, including provision of habitat (particularly for insectivorous birds), as well as buffering and protecting valuable remnant vegetation to provide increased cover for certain species. The scientific literature also validated the ecosystem services provided by short-rotation native plantings, where a proportion of plantings may be designated as a renewable resource to generate bioenergy and for production of biochar for carbon sequestration.

Significant interest has emerged in the BETR concept from landholders, who see future benefits from deriving an income by growing local native species, especially in diversifying farm income and productivity in the face of climate change.

Opportunities for collaboration resulting from this project

Further work could be undertaken, beyond the scope of this project, to facilitate the viability of mixed native species bioenergy plantations. A selection of potential investigations that could be developed further – potentially with involvement from academic and research institutions – are listed below:

<u>Plantation design and management</u>
- *Property-level configuration and design of bioenergy plantations* - understanding in more detail how they complement conventional food and fibre production (e.g., shade/shelter benefits versus foregone grazing/cropping potential, wind erosion benefits, salinity amelioration etc).

- *Management regimes* - optimal rotation periods and other management techniques to minimize ongoing management and harvesting costs. One example includes planting fast-growing acacias on the outer rows of permanent conservation or carbon-funded plantings The acacias act as a nurse crop for harder to grow species and providing early shade and shelter benefits to farmers. Financial returns from harvesting acacias that typically senesce and die after 10-15 years may help offset some of the costs of the permanent plantings.

- *Ongoing assessment of growth rates and energy yields* - insight regarding re-growth potential of locally occurring species and additional knowledge about the carbon sequestration potential of locally occurring species.

<u>Storage potential of biochar</u>
Soil health and vegetation establishment/survival benefits - additional study warranted, on the basis of the recently completed Biochar Capacity Building Project between Monash University

[14]Monash University (2014) 'T*he contribution of biochar in increasing soil carbon in native woody bioenergy crops and on-farm revegetation*' Technical Research Report to the Australian Government Department of Agriculture

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and Greening Australia, where research demonstrated the prevalence of certain species, as well as affecting soil chemistry by increasing carbon, phosphorous and nitrogen. Of particular interest is further analysis of biochars produced under different conditions (e.g., high and low temperature from different feedstocks), including their potential as a long-term carbon store. Getting an understanding of the way biochars interact with regard to soil biota populations would also be a particularly useful future scientific examination.

Biomass production

- *Species information* - understanding in detail growth rates and coppice potentials beyond those species that were the focus of the BETR project may further broaden the biodiversity and landscape potential of these systems through increasing the diversity of mixed native species plantings.

- *Soil nutrient balance* – analysis of soil properties before and after removal of significant quantities of biomass to assist in determining future fertilizer requirements, and potentially influence harvesting techniques (e.g., utilizing stemwood only and returning slash to the site rather than harvesting the entire plant). Analysis could also incorporate any influence of biochar to soil health as a by-product of the bioenergy process.

Mass/energy balance

- *Bioenergy and biofuels analysis* - the use of woody biomass for a number of other bioenergy processes, including for biofuels and other products including bio-plastics is being explored in Australia and internationally, and this is one area where further work using native tree species could be undertaken given our project examination was confined solely to electrical output.

- *Biochar characterisation* - A number of the biochar samples produced as part of the BETR project yielded high fixed carbon measurements, and could be further assessed along with additional species for a variety of high end uses including aluminium smelting (to offset fossil fuel emissions), graphene production and water filtration.

Industry framework

- *Landscape cost/benefits analysis* - The economic returns from grazing and cropping currently outweigh any recognized or measured landscape and biodiversity benefits generated from the BETR concept. Determining the degree to which this is the case was beyond the scope of this project. A detailed cost/benefit analysis of mixed native species bioenergy production against a current agricultural baseline of cropping and grazing that captures any public and private benefits or detrimental outcomes is required to further evaluate potential uptake and drivers of a BETR concept. This analysis could incorporate a number of future scenarios including:

- landholders harvest young plantations to generate an income at 15-20 years, allowing plantations to re-grow to generate carbon sequestration credits (this would also give landholders a choice between revenue from carbon credits or biomass over time, potentially reducing risks and attracting more growers to the market);
- investigating the potential to generate soil carbon credits by returning biochar from the bioenergy process to the soil beneath the bioenergy plantations. Ultimately, it may also be possible to generate above-ground carbon credits from permanent plantings (or post-harvest bioenergy plantations that are allowed to re-grow and remain in perpetuity) that have biochar beneath them; therefore enabling the landholder to accrue credits from two different and approved methodologies from the one area of land, and significantly encourage landowner-uptake of the concept.

CONCLUSION

The BETR project has helped us to quantify how, as fossil fuels become increasingly scarce and renewable energy technologies continue to develop, the economics of bioenergy may become more attractive in future, and the role we may play in influencing its implementation to improve landscapes. Importantly, the research has also allowed us to highlight the potential benefits to landscape restoration created by a novel and innovative concept.

The BETR research outcomes provide an important foundation to further develop and implement such a concept at a landscape scale as economic and environmental priorities emerge. This important foundational thinking has heightened our awareness of the implications of constantly evolving long-term global and domestic trends, and provided us with a voice to participate in ensuing discussions, and contribute solutions and actions for significant conservation, environmental and renewable energy outcomes

The research has been both challenging and rewarding. The scope of the project allowed us to look towards an energy-constrained future, and begin to design a holistic, local, closed-loop approach towards energy independence combined with conservation and biodiversity benefits. The project and concept was audacious and visionary, and we are grateful to our long-term industry partner, Alcoa, for supporting this important initiative. We believe that over time the insight that we have gained into understanding logistical possibilities, incentives and motivations to influence positive land use change will lead to long-lasting positive biodiversity and landscape outcomes.

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CHAPTER SUMMARIES

This applied research project investigated a number of inter-related research streams aimed at developing and applying models for integrated land uses. Each research stream addressed independently relevant research topics, all relevant to addressing the dual challenges of biodiversity decline and climate change. The full report and a summary document is available from Greening Australia, but the key points for each of the research streams is presented below.

Spatial Prioritisation

The objective of this component was to determine optimal planting sites for mixed native species plantations that contribute to the H141 vision but also provide a financial return to landholders. The results are summarised in Figure 4.

The modeling overlayed a number of 'benefit' layers including erosion risk, salinity risk, sequestration potential, connectivity and fragmentation, as well as a number of 'cost' layers including agricultural profitability and cost of land use change, to produce an overall benefit:cost score on a standardized scale between one and five.

The modeling is not particularly sensitive to any of the spatial layers, and the 'sweet spots' (red areas) are largely the same when the importance of the biodiversity benefits are downplayed relative to the catchment health benefits.

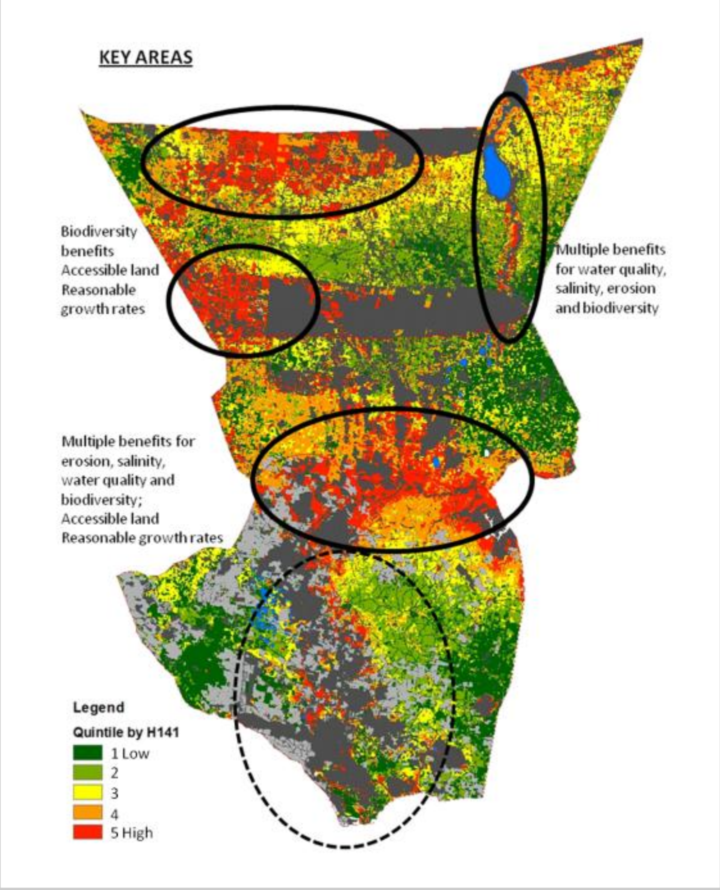

Figure 4 Areas where short rotation mixed native species plantations can provide the greatest benefit to Habitat 141

Storage Potential of Biochar

The replicated field trials were established to investigate if different rates and methods of biochar incorporation have a positive or detrimental effect on plant survival and plant growth over a period of time.

There were both negative and positive correlations between species for both plant survival and plant growth. Brown Stringybark (*Eucalyptus baxteri*) showed a strong positive survival and growth response, whereas Buloke (*Allocasuarina luehmannii*) showed a negative survival response but neutral growth response among the seedlings that did survive.

A more detailed study of these relationships in a controlled situation where environmental factors such as moisture and soil carbon can be discounted would be a valuable addition of the work performed to date.

Literature Review

The literature review discussed the potential of incorporating short-rotation mixed native species plantations into the agricultural landscape in the context of ecosystem services and financial opportunities at the paddock and farm level.

The review found that the effects of establishing bio-diverse plantations in an agricultural landscape are many and wide-ranging, at both property and landscape scale. The immediate and short-term environmental potential of establishing short-rotation plantings have not been extensively studied or documented as a comparison to biodiverse long-established plantations or remnant vegetation.

There is, however, compelling evidence to show that biodiverse native plantations established for short-rotation bio-energy production would have beneficial effects for both agricultural productivity and biodiversity conservation, provided they are designed and planned into the landscape with sufficient patch sizes and connectivity retained between rotations, structural and floristic diversity at the patch and landscape scale, and are placed to enhance native remnants that can function as buffered refugia.

Kardinia College students establishing the trial site

Carbon Schools

A comprehensive small-scale trial was implemented at Kardinia International College to investigate if biochar soil amendments have an effect on the aboveground biomass and growth response of a selection of native species indigenous to the Geelong region.

Rainfall was almost non-existent and average summer temperatures were the warmest on record from establishment (spring 2012) until autumn 2013. Addition of biochar appears to have had a positive effect on the growth response (canopy and height measurements) of Yellow Gum in this scenario. Data for Drooping Sheoak and Blackwood are encouraging with respect to seedling height, but not for canopy diameter to date (this will be monitored over time).

We may hypothesise that no amount of biochar could prove beneficial to seedling survival under these adverse growing conditions. The statistical analysis revealed that, although there were borderline to indiscernible differences in survival rates within genera, when we examined seedling survival data overall, the medium biochar treatment plots were significantly enhanced in their survival rates compared to the control plots.

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Models of Community Involvement

The project received widespread support and interest from the local community and beyond. Many landholders allowed access to revegetation sites to undertake the mass energy balance and biomass yields, and three landholders also provided land to support the field trials.

The project team also commissioned Sinclair Knight Merz to undertake economic modelling on three case study properties to determine break-even yields, prices and costs of key variables for each study.

Each financial evaluation used a series of assumptions regarding growth rates, pricing and rotation possibilities, derived from research data provided by Greening Australia Victoria, and current market pricing.

The whole farm analysis carried out for each case study property (one cropping enterprise, one cattle grazing enterprise and one mixed sheep/cattle grazing enterprise) compared whole farm profits with and without a forestry biomass enterprise. Under the current assumptions regarding growth rates and biomass pricing, the addition of forestry biomass production results in a reduction in whole farm NPV of between $0.1M and $0.38M over 50 years at a 5% discount rate, given current assumptions in market prices, biomass yields and establishment costs.

Biomass Inventory

Sixty-one revegetation sites of known age and history across Zones 1, 2 and 3 were included in this analysis to estimate the standing biomass. Sites varied in species diversity, age, and management history, thereby providing a wide range of management actions and establishment approaches. In this way, the dataset provides a useful insight into the bioenergy potential that native species may provide when established through revegetation in the landscape of the target study region.

Average above ground biomass and average age of planting is included below.

Zone	Average (mean) biomass estimate, ± standard deviation (tonnes/ha)	Average age of plantings in zone (years)
Zone 1	165.9 ± 97.1	15.2
Zone 2	183.6 ± 215	14.5
Zone 3	29.6 ± 25.8	13.8

Sampling a ten year old revegetation site in south west Victoria

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The establishment techniques data indicates that direct seeding has a strong relationship with aboveground biomass, though that may be a result of other factors (i.e. sites selected, climatic variables, etc). This information is valuable in cutting down the costs of establishing a planting. Direct seeding is the most efficient and affordable approach to revegetation, and based on the results found here, also is associated with higher aboveground biomass.

Gasification and production of biochar

Mass Energy Balance

Twelve native tree and shrub species from known-age revegetation sites across south west Victoria were sampled in order to determine their energy potential. Seven stem-wood samples and thirteen total above-ground biomass samples were obtained. All samples taken were introduced to a modern thermal gasification system to produce synthetic gas and biochar which were sampled for subsequent analysis.

All samples were successfully flared with synthetic gas and biochar recovered for analysis in each case, only the physical characteristics of the biomass samples affected the ability to optimize the gasification process. The analysis determined that to produce a nominal 250kWe of hourly electrical generation an average of 340kg of mixed native species biomass would be required.

The fixed carbon content of biochar samples varied from 45.9 to 92.9% with stem-wood samples pre-dominantly delivering the highest results, and stem-wood biochar produced from Manna Gum (*Eucalyptus viminalis*) produced the highest fixed carbon content (92.9%), lowest ash content (3.3%) and lowest phosphate content (0.03%), which may have important implications for high end uses beyond soil amendment.

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Acknowledgements

This project would not have been possible without the support of many people and organisations.

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