Market-Based Instrument approaches to implementing priority revegetation in the South Australian Murray-Darling Basin[1]

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Abstract

Resource condition targets have been specified for river salinity, biodiversity conservation, and wind erosion mitigation in the South Australian Murray-Darling Basin (SA MDB). The revegetation of cleared, privately owned agricultural land with deep rooted perennials has been widely promoted as one approach to satisfy the resource condition targets. Current estimates indicate the scale of revegetation necessary to meet the targets is extensive and associated with high establishment and opportunity costs, largely borne by private landholders. In this paper we evaluate the potential of three classes of market based instruments (MBI) to motivate private revegetation of deep-rooted perennials.

We conclude: that a singular reliance on an auction or tender based instrument without associated commercial opportunities to augment farm incomes, will yield a small contribution to natural resource management targets given current levels of funding. There is limited potential for quantity based cap and trade instruments due to limited differential in the marginal costs of revegetation, and limited numbers of potential traders. Revegetation needs to form the basis of an alternative farming system that is commercially viable. The elimination of institutional barriers to provide better access to existing and newly created markets provides the best opportunity to motivate revegetation-based farming systems.

We develop quantitative, spatially explicit models of the economic viability and resource condition contributions of biomass production and carbon trading for the entire SA MDB. Our results demonstrate that both biomass and carbon production are potentially economically viable alternative farming systems and make substantial contributions to regional natural resource management targets.

For large scale adoption of these alternative farming systems three actions need to occur. Firstly, a biomass industry needs to be developed in the region. Secondly, institutional barriers to trade in the European carbon market need to be removed (or an Australian Market expanded). Thirdly, widespread uptake of these alternative farming systems by private individuals is required. We recognise that the actual level of adoption is partially contingent on a number of complex, interacting factors. These include individual attributes and behaviours, cultural norms, traditions and conventions, social institutions, the ease and predictability of land use change, and the effectiveness of communicating the economic benefits of new farming systems relative to current agricultural production These are aspects of ongoing and future research.

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1 Introduction

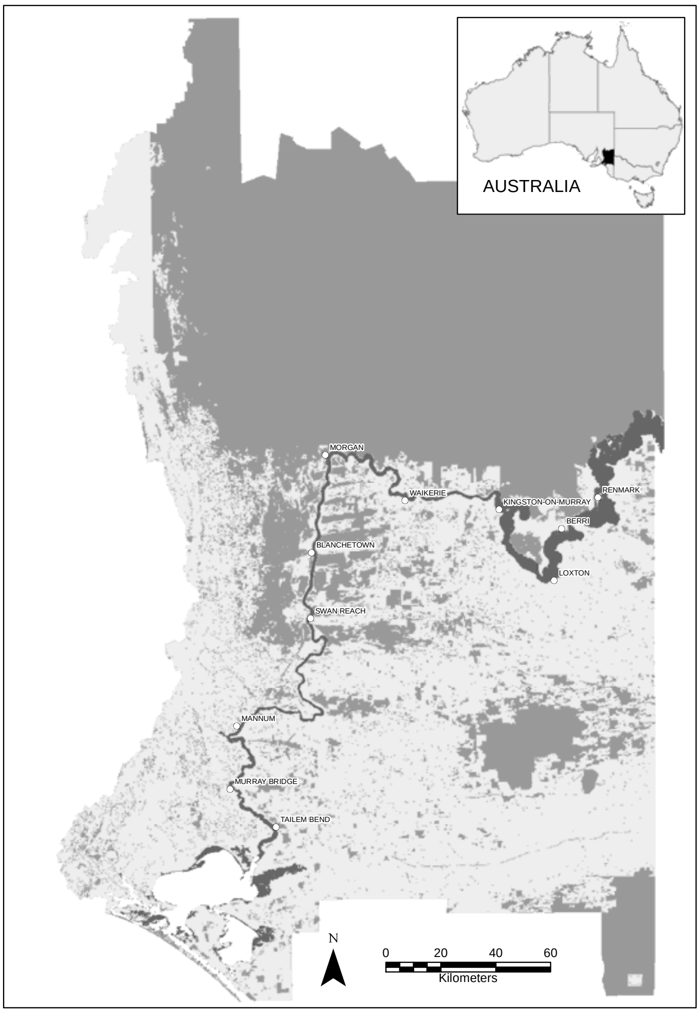
Natural resource management objectives in the South Australian Murray-Darling Basin (SA MBD, Figure 1) have been specified for river salinity, biodiversity conservation and wind erosion mitigation. The revegetation of cleared, privately owned agricultural land with endemic, deep rooted, woody or broad-scale perennials has been widely promoted as an effective land management approach to satisfy the resource condition targets. Current estimates indicate the scale of revegetation necessary to meet the targets is spatially extensive and associated with high establishment and private opportunity costs. The scale of revegetation has fallen far short of the levels necessary to meet the prescribed multiple resource objectives when motivation for land use change has been reliant on traditional policy instruments such as uniform payment for input action.

Market based instruments are increasingly endorsed across an array of agency jurisdictions as cost effective policy instruments to address environmental targets. Despite recent advances in market based instrument design and analysis, simple *ex ante* rules and design specifications regarding the relative advantages over other instruments are not yet available.

In this report we integrate economic and natural resource data and analysis and evaluate the potential of price and quantity based instruments and the removal of market barriers to motivate revegetation in the South Australian Murray-Darling Basin. The report focuses on revegetation efforts at a scale sufficient to satisfy the resource condition targets.

Figure 1 – Location of and broad land use in the South Australian Murray-Darling Basin

Dark grey represents the floodplain, medium grey remnant vegetation, and light grey the dryland areas



1.1 Resource condition targets

The clearance of native vegetation for agricultural development in the South Australian Murray-Darling Basin, inclusive of the River Murray Corridor, has lead to environmental problems such as biodiversity degradation, wind erosion and increased salinity in the River Murray. The South Australian Murray-Darling Basin Integrated Natural Resource Management Group (INRM Group) is responsible for regional natural resource management in the South Australia region of the Murray-Darling Basin. The INRM Group has identified the major environmental assets and threatening processes in the region and has articulated a set of *resource condition targets* to address these threatening processes. The relevant resource condition targets addressed in this study concern the objectives of salinity of the River Murray, biodiversity and wind erosion (INRM Group 2003a,b,c). Those targets are:

- By 2020, have salinity of water in the River Murray less than 800 EC for 95% of the time at Morgan to ensure drinking water standards
- By 2020, have salinity of water in the River Murray less than 543 EC for 80% of the time at Berri Irrigation Pump Station to ensure drinking water standards
- By 2020, have salinity of water in the River Murray less than 770 EC for 80% of the time at Murray Bridge Pump Station to ensure drinking water standards
- By 2020, reduce the area of agricultural land at risk of wind erosion during June each year by 40%.
- By 2020, improve or maintain condition of terrestrial native vegetation focussing on identified priority areas and improve condition of 50% of remnant vegetation on private land as well as increasing vegetation cover by 1% in the agricultural region.
- By 2020, maintain and improve the conservation status of all threatened National and State listed species and regionally threatened communities and species.

The specific biodiversity targets for the SA MDB are detailed in Table 1.

Table 1 Biodiversity targets for the SA MDB (from Bryan *et al*. 2005c)

Region	Revegetation	Protect vegetation	Improve vegetation condition
SAMDB	• Increase cover by 1% in agricultural region, 2020. • Establish 25,000ha of *perennial* vegetation, 2006/07. • Re-establish 950ha of vegetation to provide links in priority areas, 2006.	• Protect and enhance 10,000ha of vegetation, 2006/07. • 50% of 7 specific threatened communities protected, 2006. • Increase area of priority vegetation protected to >2,000ha, 2006.	• Protect and enhance 10,000ha of vegetation, 2006/07. • Improve condition of 50% of vegetation on private land, 2020.

In formulating these targets, natural resource management agencies and decision makers have been informed by both regional requirements and national strategies and initiatives. For example, South Australia has ratified national targets for water quality, salinity and the health of riparian and riverine ecosystems to manage the lower reaches of the Murray-Darling Basin. The National Action Plan in concert with the Murray-Darling Basin Integrated Natural Resource Management initiative has identified salinity reduction in South Australia as a priority area. As a signatory to the Murray-Darling Basin Commission's *Basin Salinity Management Strategy* (MDBC 2001), the South Australian Government is obligated to maintain river salinity at pre-2001 levels. In addition, *The Water Allocation Plan for the River Murray* (South Australian Government 2001) requires the protection of ecologically significant River corridor floodplains and wetlands and prescribes the offset or mitigation of identified adverse consequences of irrigation.

The resource condition targets represent environmental objectives that are framed by social and policy aspirations. In translating the condition targets into an operational dimension, the INRM Group has proposed a number of management actions and approaches. Vegetation management, habitat protection and more environmentally benign farming systems have been identified as important elements of an overall natural resources management strategy.

The revegetation of cleared, privately owned agricultural land with endemic, deep rooted, woody or broad-scale perennials has been widely promoted as another remedial approach, providing multiple resource benefits and attributes (INRM Group 2003a).

1.2 Economic options for revegetation

Bennell *et al.* (2004) and Hobbs (2005, unpublished data) describe a regional industry potential analysis conducted by the FloraSearch Project provides information on the potential viable area and likely landholder annual equivalent returns (AER)[2] of a range of biomass-based industries in south-eastern Australia. A subset of that data has been analysed for the SA Murray-Darling Basin region and the results are presented in Table 2. The data provides a benchmark for evaluating the relative economic value of potential biomass industries in the region. The authors estimate there are potentially 3,221,660 hectares of dryland (non-irrigated and non-floodplain) cropping and modified annual pastures available for perennial revegetation.

The analyses suggest that fodder shrub-based industries (especially *in situ* grazing) are likely to be the most profitable dryland perennial revegetation options for the much of the region and have the potential for further expansion. “Bioenergy Only” and “Eucalyptus Oil and Bioenergy” options also have great potential across large parts of the Murray-Darling Basin requiring relatively modest investments in infrastructure. Bennell *et al*. (2004) indicate there is potential to expand highly valued export pulpwood plantations into the region using low rainfall pulpwood species such as *Eucalyptus occidentalis*, *E. globulus* ssp. *bicostata* or *E. porosa* especially in the eastern slopes of the Mount Lofty Ranges.

Further returns from fodder shrub-based industries may be derived from their ability to sequester carbon dioxide from the atmosphere. Hobbs and Bennell (2005) measured the biological productivity and carbon sequestration rates of a range of mallees, wattles and heavily grazed and ungrazed Oldman Saltbush (*Atriplex nummularia*) in the River Murray dryland corridor. Using the carbon sequestration rate of the heavily grazed fodder shrub system (roots and stems only) and spatial models of primary productivity (Hobbs, unpublished data) for all areas where fodder shrub systems are economically viable would result in a carbon sequestration rate of 3.5 million tonnes of carbon per year for the SA Murray-Darling Basin. Bryan *et al*. (in review) estimate the $C0_2^e$ reductions resulting from methane reduction due to displacing sheep grazing with revegetation for biomass industries.

Table 2 - Viable area, landholder annual equivalent return (20 year scenario) and relative value of potential perennial biomass-based industries in the SA Murray-Darling Basin area using existing and new infrastructure

Industry type (infrastructure)	**Viable[1] hectares**	**Mean[1] AER (\$ ha^{-1} $year^{-1}$)**	**Relative[2] Value**
In situ Fodder Shrubs (existing)	3,110,073	214	430%
Bioenergy Only (new)	2,779,141	123	221%
Feedlots / Stock Feed Manufacturing (new)	2,764,534	116	207%
Australian Pulp (new)[3]	2,792,838	90	162%
Eucalyptus Oil and Bioenergy (new)	2,276,056	68	100%
Eucalyptus Oil Only (new)	363,140	27	6%
Fibreboards (new)	333,588	18	4%

[1] where AER > 0; [2] compared with the Eucalyptus Oil and Bioenergy scenario; [3] unlikely to be viable in this region due to high costs of mill establishment and water consumption requirements: (based on results of Bennell *et al.* 2004 and Hobbs, 2005, unpublished data)

The analysis by Bennell *et al*. (2004) is primarily focussed on the economic potential of biomass based industries in the South East of Australia and the SA Murray-Darling Basin. Using a systematic regional planning methodology, Bryan *et al*. (2005b) integrate the

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[2] Annual equivalent returns are an estimate of the annual returns per hectare expected from biomass over and above those from existing agriculture expressed in today’s dollars

economic analysis of biomass in the SA River Murray Corridor with estimates of the contributions made by commercially viable revegetation to the multi objective resource condition targets. Estimates by Bryan *et al* (2005b) suggest large scale plantings are required to reach the prescribed resource condition targets. The costs of establishment and loss of revenue from existing farming enterprises involved for these large scale plantings are also estimated to be substantial. For example, in prioritising revegetation strategies in the River Murray corridor, Bryan *et al.* (2005b) estimate an additional 99,751 ha of managed remnant vegetation (at an estimated cost of between $49-300 million) are required to satisfy the 50% remnant vegetation target. The current target for revegetation in the Corridor is 1% increase in native vegetation. The authors recommend a minimum[3] 15% of biological and physical environmental zones as an alternative target for revegetation. They estimate 21,578 ha of revegetated land (at an estimated costs of $14 - 83 million) are needed to satisfy this target. Estimates of the revegetation levels in high groundwater recharge regions required to maximise salinity mitigation range from 10,000 ha (Bryan *et al*. 2005b) to 25,000 ha (RMCWB 2003).

1.3 Policy challenges for market based instruments

From an ideal economic perspective it would be possible to determine the optimal scale of land use change, ensuring that the additional environmental benefits outweigh estimated costs. However, estimates of the economic value of environmental benefits gained are often only partial, rudimentary and of variable reliability. This has meant that answering questions on the relative merits of the cost effectiveness of policy choices and instrument design to achieve land use change of this magnitude have not been made with much precision or certainty.

The challenge for natural resource management policy makers is to introduce cost effective instruments that stimulate behavioural change and land management actions, resulting in predictable environmental outcomes. In meeting that challenge, policies seek to promote regional management actions that both maintain economic returns to the farmer and contribute to the sustained increase in environmental assets or reduce environmental threats articulated in the resource condition targets. To encourage increased participation by private land holders, successful policy aims to:

- motivate persistent land use change appropriate to the specified resource condition;
- encourage change at scales that contribute substantially to resource targets;
- mobilise high levels of participation in strategically beneficial localities and,
- achieve targets at the lowest cost to society.

In addition to direct payment to landholders for conservation services provided, environmental management and policy has traditionally relied on regulatory, statutory and legal remedies and instruments. Since the mid 1990’s (Tietenburg and Johnstone 2004), market based instruments (MBI) have been increasingly endorsed across an array of agency jurisdictions as effective policy instruments to address environmental targets and protection at a more affordable cost to society. MBI are aspects of regulation or laws that encourage behavioural change through the price signals of markets, as opposed to the explicit directives for environmental management associated with regulatory and centralised planning measures (Stavins 2003). The primary motivation of market based instrument approaches is that if environmentally appropriate behaviour can be made more rewarding to land managers, then the best private choice will correspond to the best social and environmental choice.

The recent advances of MBI as policy tools for managing diffuse source environmental problems, has also meant limited opportunities for policy makers to gain experience and expertise in their design, testing and implementation. Appraisals of their relative importance

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[3] A minimum 15% representativeness of biological and physical environmental zones has been proposed by Bryan et al. (2005b) for the River Murray Corridor. The notion is closely aligned to the JANIS comprehensive, adequate and representative native forest reservation criteria (Commonwealth of Australia 1997).

in policy portfolios have also been informal and *ad hoc*. Although the analysis of market based instrument performance has improved, simple rules and evaluation protocols to identify *a priori* the relative advantages over other instruments to resolve specific environmental problems have not yet emerged.

Several commentators note that MBI are not widely viewed as a panacea: recent developments in instrument design have recognised that successful MBI schemes have not necessarily substituted for regulatory approaches but are more generally complementary (Stavins 2003, Tietenburg and Johnstone, 2004, Tisdell *et al*. 2004, Young *et al*. 1996). In many cases MBI may be advantageous, but in others the relative advantages over other instruments may be limited, poorly defined, state contingent and subject to change through time. For example a market based instrument may be cost effective, but may not perform well in the dimensions of adoption rates, administrative and transaction costs, concentration of environmental consequences and political feasibility. When these are important policy objectives, the single model terrain of economic efficiency or cost effectiveness may not be sufficient to reliably inform policy makers of instrument performance.

Following on success with MBI policy for point source environmental issues such as the US SO^2 credit trading program, the US EPA’s emission trading program and the water quality trading program (see for example Hahn 1989, Stavins 2003, Stephenson *et al*. 1998, Tietenburg 1991) there has been increasing interest in using MBI to meet a range of environmental targets. Interest in resolving non-point sources effecting water quality (Taylor *et al*. 2004), salinity reduction, groundwater recharge and the promotion of renewable energy has been sufficient to warrant further investigation and in some cases field trials. In Australia, the recent NAP funded MBI trials have bolstered interest and facilitated extensive theoretical analysis and field application.

The primary focus of this paper is to evaluate the potential of market based incentives to motivate private revegetation efforts in the SAMDB. We focus on revegetation actions that are of are of sufficient scale to:

- improve land holder revenues;
- provide additional public environmental benefits and,
- help meet the stipulated resource condition targets.

The scope of the analysis has been limited to:

- proposed revegetation efforts in dryland (non-irrigated, non-floodplain) areas;
- biomass based industries previously identified as being of sufficient scale to deliver substantial contributions to the resource condition targets set for the South Australian Murray-Darling Basin (SAMDB) (Bennell *et al.* 2004, Bryan *et al*. 2005b, Ward and Trengove 2004).

Sections two to four of the report describes the importance of revegetation in the context of the SA MDB, a brief synopsis of MBI and their recent development and application in natural resource management. We discuss MBI according to their general categorisation as either price based or quantity based instruments and policies to remove barriers to “frictionless” markets. The section underpins the analytical results and aims to highlight the diversity of MBI, the need for careful design and evaluation and the current trend of designing instrument blends for complex environmental issues. Section five reports on the evaluation of the relative merits of the broad categories of MBI and their costs and potential to contribute to the resource condition targets.

Sections six and seven of the report provide a detailed analysis of large scale revegetation in the South Australian Murray-Darling Basin. In a spatially explicit manner, we quantify the economic returns and associated contribution to resource condition targets of biomass based enterprises and carbon sequestering and trading. The revenue streams and benefits are estimated using a systematic and integrated spatial analysis of revegetation options based on the economic and biophysical attributes of the South Australian Murray-Darling Basin. Economic models are built in GIS using layers describing biomass productivity, opportunity costs, transport costs, harvest costs, maintenance costs and fertiliser costs. The economic performance is expressed as Net Present Value (NPV) and Equal Annual Equivalent (EAE).

In the analysis we make an important distinction in the environmental outcomes of revegetation actions. Management regimes of low rainfall native tree plantations that aim to access specific existing markets may *not* be compatible with all resource condition targets. For example the three year harvesting cycle proposed for biomass electricity generation (Bryan *et al*. 2005b, Ward and Trengove 2004) may provide salinity reduction benefits and renewable energy certificates but is unlikely to translate into substantial biodiversity contributions. In contrast revegetation actions designed to access carbon trading markets, characterised by non-harvest management regimes, are likely to contribute substantially to biodiversity, salinity and wind erosion targets but are not able to supply feedstock for biomass based industries. We therefore identify the likely markets and estimate the potential economic and NRM benefits of revegetation actions suitable for either biomass enterprises or carbon trading.

2 A brief history of MBI in environmental management

In a general sense environmental policy instruments are the tools available to policy makers to influence societal processes and behaviour such that they align with and remain compatible to defined environmental and social targets. These are made operational as policy objectives and their level of success expressed as measures of effectiveness, efficiency and equity.

Traditionally, environmental management has relied on regulatory, statutory and legal remedies and instruments. The regulatory and centralised planning approach employs explicit directives, making mandatory specific behaviour and actions and has included a range of standards, bans, permits, quotas, zoning and use restrictions. Examples might include maintaining minimum riparian buffer strips along stream channels, limited use of specific herbicides and restrictions on the location of new irrigation developments.

Environmental policy analysts dating back to Dales (1968) have advocated tradeable permit approaches based on the argument that such approaches can increase economic efficiency and are more cost effective relative to approaches that allow less flexibility such as uniform standards. As a general rule market-based instruments (MBI) use the price signals of markets and market like mechanisms to influence the choices made by land managers. In contrast to policy approaches using explicit directives, they are designed to encourage innovative behaviour through the price signals of market exchange. An additional function of MBI is the raising of revenue through the imposition of taxes on activities that pollute or increase environmental damage (Turner and Opschoor 1994). We focus on the application of MBI to encourage changes in individual behaviour, expressed as land management actions, that are better aligned with policy objectives.

The suite of available MBI have two components in common. Firstly, they include carefully designed incentives to elicit the accurate disclosure or revelation of individual information regarding the cost of abatement or environmental provision. Secondly, in response to revealed information, they provide a mechanism to collectively coordinate decision making into outcomes that are economically efficient and better aligned to policy objectives. In response to well designed MBI incentives, the best private choices coincide with the best social choice. Rather than rely on regulations to identify the best course of action, individuals are able to select actions that best meet the environmental target, based on typically superior individual information. Generally, reliable and accurate information on the individual costs of provision or abatement is not readily available to policy makers or is cost prohibitive to obtain.

Additionally, well designed policies that incorporate MBI provide persistent technological innovation and diffusion, relatively low administration costs, flexibility to address distributional and equity concerns, and incentives to equalise abatement or provision costs. The potential advantage of MBI approaches is that through flexible decision making, they can achieve environmental goals at a more affordable cost to the community. The primary motivation of MBI approaches is that if environmentally appropriate behaviour can be made more rewarding to land managers, then changing attitudes and ensuing land management behaviour will better align with more socially desirable alternatives.

Although theoretical consideration of MBI dates to the 1960's, development and on ground application to manage natural resources has mainly occurred over the last 10 years or so (Stavins 2003, Tientenburg and Johnstone 2004). Commenting on attitudes to economic instruments for environmental policy, Tietenburg (1991 p. 86) states:

> *"As recently as a decade ago, environmental regulators and lobby Groups with a special interest in environmental protection looked upon the market system as a powerful adversary. That the market unleashed powerful forces was widely recognised and that those forces clearly acted to degrade the environment was widely lamented. …..Groups seeking to protect the environment set out to block market forces whenever possible."*

With insight into the current natural resource policy arena he further elaborates that:

> *"Among the more enlightened participants in the environmental policy process the air of confrontation and conflict has now begun to recede in many parts of the world. Leading environmental Groups and regulators have come to realise that the power of the market can be harnessed and channelled toward the achievement of environmental goals, through an economic incentives approach to regulation".*

The noted change in attitude culminated in widespread recognition that carefully designed markets could be turned into a powerful ally and paradoxically correct past market failures. Subject to controversy and debate ten years ago (Keohane *et al.* 1998), MBI have evolved to the point of becoming received wisdom in many environmental policy circles (Stavins 2003). The National Action Plan for Salinity and Water quality and the National Heritage Trust exemplify a federal impetus for the increasing application of market based solutions in Australia.

3 A typology of MBI

There are four general instrument approaches available to policy makers to promote increased levels of revegetation in the SA Murray-Darling Basin. Regulatory instruments are one type, which may be based on output performance standards or input restrictions, zoning and development caveats. Policy instruments to craft community governance[4] (or forming cooperative social contracts), and education (often called suasive) approaches are also instruments that do not use economic or market like approaches.

MBI are differentiated into three broad categories:

1) Charges, payments or price based instruments: they include, levies (such as the drainage levy / biodiversity offset scheme in the Upper South East of South Australia), taxes on emissions or effluent, payments for environmental provision or conservation and in some cases charges on components or practices associated with production outputs that affect the level of environmental performance. The removal of subsidies can also be located in this category of MBIs.

   There is increasing interest in the distribution of public payments for environmental management actions according to competitive tender schemes (Milgrom 2004, Latacz-Lohman and Van der Hamsvoort 1997). Recent Australian experience (Stoneham, *et al. 2003*, Bryan *et al.* 2005a) suggests that a competitive tender should reveal the true costs of revegetation efforts and act as a cost effective contribution to conservation or biodiversity targets. Current Australian applications of tenders for conservation provision

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[4] Ostrom (1998), Bromley (1991), Vatn and Bromley (1995) have proposed a fourth category of management instruments known as community governance or institutions for collective action. Community governance relies on voluntary, community crafted social contracts to manage environmental resources which are characterized as common pool resources or public goods.

have relied on a sealed bid[5], discriminant price tender format (Stoneham *et al*. 2003, Bryan *et al.* 2005a, to both reveal individual valuations in a competitive environment and to minimise public expenditure. *Ex post* analysis of the tender schemes indicates cost savings of approximately 25% - 34% (when budget constrained) compared to hypothetical uniformly set payments for similar conservation efforts (Bryan *et al*. 2005a). As tender payment schemes are generally characterised by budget constraints, an important policy benefit is the certainty of the payment level.

2) Tradeable credits or quantity based instruments: involves establishing an enforceable threshold for management, either as maximum effluent levels, prescribed resource usage or minimum environmental provision; distributing entitlements among participants or sources as specific units and allowing trade of those units among those in the scheme. The environmental objective is to ensure the total quanta do not exceed the prescribed threshold for a given accounting period (usually one year). To satisfy compliance obligations, each participant in the scheme must be able to surrender units equal to their entitlement at the end of the accounting period. Therefore, participants can choose to alter land actions in response to individual management capacity, landscape attributes and production costs. Non-compliance incurs individual penalties greater than the costs of complying.

While imposing a cost on individuals, the opportunity to trade has the potential to compensate that loss or reduce the cost burden. Some individuals will choose to use more than their quantum (and incur a debit), and others will choose to use less (being rewarded with credits). A challenge for policy is to create the opportunity for a “frictionless” market setting where participants could quickly learn to understand the advantages of trade with low learning and exchange costs relative to trade benefits. Savings to landholders through market exchange between individuals with surplus credits and those in deficit may be considerable. Information from market exchange would reveal any differences in returns to management options that reduce environmental consequences and these would be immediately discovered and exploited.

An important advantage of quantity based instruments over other policy options is a greater level of environmental certainty as a result of the prescribed and enforceable threshold or cap. Tradeable permits, such as water trading in the River Murray or the potential for salinity trading in the Murray-Darling Basin and environmental offsets represent the two main variants of quantity based instruments: There are a number of preconditions for a functioning and effective cap and trade scheme. They are:

- There is credible and reliable science to establish a threshold level that is clearly understood and matches the resource condition target.
- There are cost effective monitoring schemes in place that are transparent, consistent and credible to all participants. There must also be a clear link between land management actions and the subsequent environmental outcome. In cases where the environmental outcome is not readily visible (for example recharge into groundwater aquifers) a proxy indicator may be necessary (such as the type of revegetation, success of establishment and maintenance).
- The nature (toxicity) of the pollutant is such that market exchange will not result in localised concentrations, which may cause excessive environmental degradation or hoarding of entitlements.
- There is sufficient differentiation in individual abatement costs across the catchment. If there are no differences there is no incentive to trade.
- There are regulatory agencies with effective regional jurisdiction to monitor and audit compliance levels and effectively enforce individual breeches.
- There are sufficient numbers of participants to ensure cost effective exchange opportunities and satisfaction of trading requirements;

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[5] A sealed bid attempts to reduce the possibility of collusion to seek excessive profits when a tendering agency is confronted with a small number of land managers in a spatially constrained catchment.

- The transaction costs of monitoring, gathering information, enacting the exchange and enforcement are low in relation to the potential benefits gained;
- There are adequate and effective administrative institutions to ensure a functional market and;
- It is politically feasible to develop transferable, enforceable and tradeable private property rights, to minimise government intervention and allow flexibility of decision making.

3) Market barrier or impediment removal: these market based policy approaches focus on improving environmental outcomes by increasing consumer awareness of environmental attributes of products they may value, or removing barriers to market activity. Product labelling schemes are perhaps the most widely applied market creation economic instrument approach (Tietenburg and Johnstone 2004). They involve providing information about the environmental outcomes of production so that those who value those improvements can express their preferences through market choice.

   Policy initiatives can also identify and facilitate access to newly created or existing markets for producers changing from existing farming systems to revegetation establishment and long term management. Of the first type are the products that generate revenue over the life of the revegetation investment such as the sale of biomass feedstock to a newly established processing plant capable of renewable electricity generation and oil processing. The second type is the production and trade of goods and services into existing markets subject to institutional barriers, such as the trade of Australian-produced carbon in the European carbon market.

4 Criteria for evaluating the performance of MBI

The tendency has been to evaluate policy instruments generically or in isolation. There is however a complex array of interactions among policy instruments and the economy, environment and societal processes. The implementation of instruments and their operation initiates a cycle of innovation, resulting in evolving and dynamic economic and environmental objectives, as are the applicable instruments and evaluation criteria (Turner and Opschoor 1994). Recent developments in instrument design have recognised that successful MBI schemes have not necessarily substituted for regulatory approaches but are more generally complementary. As a consequence, carefully designed blends and tactical sequencing of regulatory, MBI and suasive instruments are commonly advocated. Generally these instrument blends should account for the institutional, political and social context of the environmental resource in question. Good institutional design should rely on the one policy objective, one policy instrument feature (Young and McColl 2003). To ensure the successful implementation of a market instrument reform agenda, Cordova (1994) states:

> "*A reform program will be successful if there is economic rationality in its design, political sensitivity in its implementation, and close and constant attention to political-economic interactions and social-institutional factors, so as to determine in each case the dynamics to follow (Cordova 1994, p. 277).*

The analysis of competitive markets is premised on the assumptions that the exchange outcomes are highly excludable, divisible, transferable and fully internalised by those engaged in the exchange process. In an idealised market, agents acting as profit maximisers responding optimally to coherent, accurate and reliable price signals can reach collective decisions resulting in an ordered, predictable outcome which is superior to other possibilities and dispositions. Therefore those benefiting can adequately compensate those adversely affected (who would consent as they would consider adverse affects and compensation as commensurable). If these preconditions are satisfied, the measures of economic efficiency are reliable indicators of resource allocation and policy performance. In reality the preconditions necessary for efficient market outcomes are rarely achieved.

Natural resource policy objectives often include social and environmental issues of procedural justice, equity and fairness, distribution of benefits and appropriate environmental scale. A favourable economic solution therefore would entail a reliance on market processes to efficiently achieve specified policy objectives, determined as a multi-objective index of social and environmental goals. The evaluation criteria for policies reliant on economic instruments have traditionally focussed on economic efficiency and effectiveness. However, the sole measure of economic optimality may not provide information of sufficient analytical and descriptive scope to enable informed, comprehensive evaluation of policy decisions commensurate with multiple objectives.

In an attempt to account for multi-attribute policy objectives, a composite index of criteria to evaluate instrument performance has been proposed by several proponents including the OECD (1997). Turner and Opschoor (1994) broadly categorise the criteria as notions of concordance and optimality. Concordance refers to compatibility and acceptability within the existing social, political and institutional arena and by vested economic agents. Optimality criteria are concerned with the issue of instruments achieving acceptable performance levels, measured as effectiveness and efficiency. The optimality measures of market efficiency have been extended to include equity, flexibility, innovation, and an assessment of dependability under risk and uncertainty. The OECD (1997) lists a number of criteria by which the performance of environmental policy instruments should be evaluated, articulated by Tietenburg and Johnstone (2004) and summarised in Table 3. Evaluations of recently introduced MBI in Australia (Tisdell *et al*. 2004, Connor and Ward 2005) are increasingly employing this expanded set of performance criteria.

Table 3 Evaluation criteria for Natural Resource Policy instruments (Adapted from Tietenburg and Johnstone 2004, Young 1997)

	General nature of the criteria
Economic efficiency	
Economic optimality	The level of stringency of the target is optimal and the instrument chosen reaches this target at lowest cost relative to all other alternatives
Cost effectiveness	The magnitude of savings to reach a given environmental target relative for the instrument chosen compared to some other alternative instrument
Market efficiency	The efficiency of the market- market outcomes of price and quantity relative to theoretical predictions
Environmental effectiveness	
Certainty of outcome	The certainty and effectiveness with which a given environmental target is reached. Dependability under conditions of uncertainty and reversibility under conditions of risk should also be evaluated.
Monitoring accuracy	The extent to which the regulator is able to ascertain whether a given environmental target has been met
Compliance and enforcement	The likelihood that the regulator will ensure transgressors are penalised
Local or temporal effects	The extent to which the policy addresses the heterogeneity of impacts of space or time
Soft Effects	
Data accuracy	The extent to which the policy affects the likelihood of having reliable; data
Bureaucratic culture	The extent to which the policy results in more pro-active management of environmental concerns in private and public bureaucracies
Dynamic Effects	
Rate of innovation	The extent to which the policy generates persistent incentives for optimal rates of innovation and the rate of diffusion
Direction of innovation	The extent to which the policy encourages a direction of innovation which is optimal
Administrative costs	
Start up costs	The costs of putting in place the programme in the first place
Running costs	The cost of overseeing and maintaining the programme in the first instance
Social costs	
Distributional impacts	The extent too which the policy results in adverse or regressive impacts
Participation	The extent to which the policy allows for broad stakeholder participation, ease of extension and levels of adoption

5 Evaluation of MBI for revegetation in the SA MDB

Several approaches and management actions have been proposed and trialled to help meet the INRM Group targets of salinity reduction, biodiversity provision and reduced wind erosion. Three examples in South Australia include:

1. In the case of mitigating increases in river salinity, Connor (2003) suggests a combination of engineered salt interception schemes, zoning restrictions to direct new irrigation developments to low impact regions and irrigation technologies to improve root zone watering as a means to meet salinity obligations.
2. Approaches to biodiversity conservation relying on public contributions and payments for the conservation of remnant native vegetation, associated with land title covenants restricting land use, have been trialled in the Lower South East (Willis and Johnson 2004).
3. The devolved grants scheme has made negotiated payments available to private land holders for the provision of prescribed conservation activities such as stock control, weed control and revegetation with native species. As a recent extension of the devolved grants scheme, the Catchment Care project in the Onkaparinga catchment (see Box 1) deployed a competitive tender system for determining land holder payments in 2004 (Bryan *et al*. 2005a). Key to the implementation of the Catchment Care scheme and crucial for any tender for conservation provision was the development of a comprehensive index of environmental benefits. The index enables the competitive ranking of individual bids according to the relative cost per environmental benefit gained.

The revegetation of cleared, privately owned agricultural land with endemic, deep rooted, woody or broad-scale perennials has been widely promoted as another remedial approach, providing multiple resource benefits and attributes. The replacement of shallow-rooted annuals with deep-rooted perennial native vegetation can make substantial contributions to the natural resource management objectives of river salinity, wind erosion mitigation and biodiversity provision in the SA MDB (RMCWMB 2003, INRM Group 2003a, Bryan *et al*. 2005b). However, the scale of revegetation and the degree of land use change has fallen far short of levels necessary to contribute substantially to resource condition targets.

The primary reason cited for a seemingly insufficient level of revegetation is that farmers are unwilling to undertake substantial and costly investments in revegetation when there is a long term loss of revenue from current land use that is revegetated. The on-farm economic benefits of salinity reduction, biodiversity improvements and to a lesser extent soil erosion are generally regarded as insufficient to compensate the required financial cost of woody perennial revegetation and native vegetation restoration. This is especially relevant in the case of revegetation based strategies to achieve multiple natural resource management targets, where the benefits accrue largely to downstream receiving environments. The result has been small scale, localised and sub-optimal amounts of regional revegetation and remnant preservation.

The reality has been that, whilst the private landowner generally incurs the costs of revegetation, many of the natural resource benefits are often realised over long time periods, the potential benefits carry some uncertainty of impact, and benefits accrue predominately off farm to the wider community. Public beneficiaries often only share in part of the up-front investment costs and the ongoing opportunity costs of foregone agricultural production. This leaves the farmer in a position of facing large establishment costs in the short run while the benefits accrue in the far future, which is likely to be highly discounted.

The attractiveness of investment options would be improved by increasing the flow of benefits in the short run to offset, at least in part, the high establishment costs of revegetation works and sufficient compensation for the opportunity costs of foregone production of existing agriculture. Sufficient economic incentive for pursuing large-scale perennial establishment is therefore partially reliant on identifying alternative compensation or enterprise opportunities to offset establishment costs and to introduce positive income streams realised within a few years of planting.

The following section evaluates the potential role of MBI in resolving the disparity between current levels of private revegetation efforts and those levels estimated to satisfy or make substantial contributions to the resource condition targets established for the SA Murray-Darling Basin. We firstly assess the potential of price based instruments in the form of publicly funded tenders, to compensate for the costs of establishment and foregone agricultural income. We then summarise the potential of quantity based instruments, expressed as the gains from trade from possible salinity, biodiversity and wind erosion markets. Lastly, we assess the market barrier removal. This involves both the creation of new resource markets (e.g. renewable energy from biomass) and removal of barriers to existing markets (e.g. carbon trading on the European market).

We take a broad scale evaluation approach, in that we separately assess a single MBI category to meet the resource condition targets specified for the whole of the SA MDB. Current limitations of the resource condition targets, which do not account for the spatial heterogeneity of biophysical and economic characteristics within regions, also restrict the scope for more precisely calibrated MBI to enhance overall environmental and economic performance.

5.1 Price based instruments (tenders and levies)

Bryan *et al*. (2005b) and Stoneham *et al*. (2003) have proposed competitive tenders as a more cost effective means than standardised payments to motivate private conservation provision and to attain prescribed environmental targets. Bryan *et al*. (2005a) estimate savings of approximately 23% - 34% compared to the devolved grants scheme in the Onkaparinga catchment. Stoneham *et al*. (2003) estimate similar budget constrained cost savings realised in the Bush tender scheme when compared to a hypothetical uniform payment. However when estimating long term cost effectiveness, Panell (2005) argues that a crucial distinction needs to be made by funding agencies between two types of public incentive payments to private land holders for the provision of environmental services. Pannell (2005) proposes that incentives can:

1) Provide a relatively small and temporary economic stimulus to encourage private land holders to trial and undertake management practices with both public environmental benefits and sustained private net benefits. The ongoing net benefits are of sufficient magnitude to compensate for the loss of income from traditional management actions, resulting in the long term adoption of changed practices without the need for perpetual government funding. The incentive acts as an economic primer, to accelerate widespread adoption of the best private choice of land practice that also coincides with the best environmental choice.
2) Compensate land holders for undertaking land actions that result in additional public environmental benefits but impose net private costs. Without alternative income sources, the long term adoption of environmentally beneficial practices is likely to be contingent on persistent public payment to offset the foregone income benefits associated with past land management practices. Without binding contractual arrangements or legislated obligations (associated with costly monitoring and enforcement), the cessation of funding is likely to result in land holders reverting to past practices. In addition, Randall (2003) and Taylor *et al*. (2004) note that in the establishment phase, tenders of this kind are prone to incentive incompatibility. In such cases, land holders are tempted to misrepresent the actual environmental actions undertaken for a specified payment (moral hazard) resulting in payment to individuals who appear to be the most cost effective but actually under supply (adverse selection), and as a consequence, the scheme is characterised by environmental under performance.

With this distinction in mind, we review the total cost and potential cost savings of a competitive tender scheme, providing payment for individual revegetation actions at a scale to meet the resource condition targets of salinity and biodiversity.

5.1.1 Salinity

Recent findings of Bryan *et al*. (2005b) and Ward and Trengove (2004) indicate that approximately 4.14 ECs of salinity reduction will result from revegetation of 10,000 ha of native mallee species in the Lower Murray Corridor. There are very small marginal gains in salinity reduction from additional revegetation. The estimated contribution of revegetation efforts leaves the majority of the additional 110 ECs reduction estimated for the South Australian reaches of the Murray (Connor 2003) to other mechanisms. The mean establishment costs of revegetation are estimated at $7.60 million. The benefits of salinity reduction are estimated at $3.15 million in present value terms over 100 years (Bryan *et al*. 2005b). The opportunity costs of income foregone in the 10,000 ha are estimated at $29.25 million per year. Despite potential costs savings of approximately 25-30% realised in a competitive tender, the predicted costs of revegetation establishment ($5.3 million = $7.60 million less 30%) are greater than the benefits realised. Without alternative income sources, a tender scheme would also need to provide $29.25 million every year (in present value terms) whilst revegetation is maintained. Hence the cost of meeting salinity targets through a tender based revegetation scheme outweighs the benefits many times over. However the tender can potentially improve the cost effectiveness of the existing devolved grants scheme. Recent research indicates that the majority of costs savings associated with competitive tenders may be associated with the development of a quantitative and explicit measure of environmental benefits rather than a function of the tender process itself.

5.1.2 Biodiversity

Bryan *et al*. (2005b) report high levels of opportunity costs ($706,000 per annum), high establishment costs ($13.8 million to $83.0 million) and approximately 21,000 ha of revegetated land to achieve the suggested 15% representativeness target for revegetation for biodiversity in the River Murray Corridor. The 50% management of remnant vegetation target corresponds to approximately 99,000 additional managed hectares at an establishment cost of between $49 million to $300 million. Given that 25% of remnant vegetation is already managed in the Corridor, Bryan *et al*. (2005b) estimate 25% of remnant vegetation requires additional management effort. Extrapolating from the remnant vegetation data of the River Murray Corridor to the SA MDB implies an additional 384,000 managed hectares at an approximate establishment cost of between $190 million to $1.16 billion to achieve the 50% remnant vegetation target.

The incurred costs, despite spatially prioritising land parcels and the estimated 25-30% cost savings of a competitive tender, are many times higher than current State budget allocations to meet the resource condition targets. The current estimates of the economic (both market and non-market) value of the environmental benefits accruing from meeting the NRM targets are partial and in some cases rudimentary. As a consequence, the determination of the costs relative to the public benefits cannot be made with much precision. Without substantial increases in the current levels of public funding, the majority of revegetation costs will be incurred by private landholders. The singular reliance on a price based instrument (eg a competitive tender for conservation provision, or incentive payments) without an augmentative commercial revenue stream to compensate for foregone agricultural production would yield a small contribution to NRM targets at a prohibitively high public cost. Based on the reported evidence the opportunities for tender instruments for NRM provision are limited in the study region.

5.2 Quantity based instruments

The findings also indicate a limited potential for implementing a market in tradeable permits for recharge reduction (a proxy for salinity impacts) or biodiversity offsets. There appears to be little differential in abatement capacity across the landscape, the region is likely to be characterised by thin market activity and the gains from trade would be insufficient to compensate for establishment costs and lost production (Bryan *et al*. 2005b, Ward and Trengove 2004) The opportunity for trade to reduce the salinity impacts due to irrigation activity (for example between dryland farmers and irrigators) have not been fully explored. Based on the limited salinity reductions estimated to result from large scale plantings of woody perennials, there appears to be restricted scope for a cap and trade type arrangement. High levels of administrative costs incurred in developing an effective market (including the political feasibility of specifying and imposing enforceable property right obligations for recharge management) and the costs of transacting exchange relative to the gains in trade and the environmental benefits achieved are likely to prove a formidable obstacle. In addition to revegetation efforts, the recommendations of Connor (2003) for zoning restrictions on new developments, improved irrigation efficiency and engineered solutions appear to be more cost effective solutions to meet the SA salinity targets.

Our evaluation so far suggests that both price-based and quantity-based instruments are unlikely to motivate the scale of private revegetation necessary to achieve resource condition targets in the SA MDB. Rather, achieving this scale of revegetation is reliant on identifying alternative, commercially viable farming systems. Commercial viability is a necessary precursor to offset the significant establishment and an ongoing opportunity costs associated with large scale revegetation. To enhance their large scale adoption, these alternative farming systems need to introduce positive income streams to private landholders that are realised within a few years of planting.

If there is no accessible market for the product of the alternative farming system, markets need to be created. If such as market exists and there are barriers to trade, these barriers need to be removed. Thus, the third market-based instrument discussed in the context of revegetation in the SA MDB is market barrier elimination and market creation for alternative farming systems that have associated NRM benefits. The remainder of this report is focussed on two commercially viable alternate farming systems – biomass production and carbon trading. Both of these farming systems involve large-scale revegetation with attendant natural resource management benefits and hence, contribute to achieving resource condition targets.

5.3 Market creation and barrier removal

Encouraging large scale biomass production in the SA MDB is contingent on the creation of a market for green biomass in the form of the establishment of a local biomass processing enterprise. Research has shown that both production and processing of biomass may be economically viable in the SA MDB region (Bryan *et al*. 2005b, Ward and Trengove 2004). In turn, the processing enterprise produces revenue from the generation and sale of renewable electricity, eucalyptus oil, and activated charcoal into existing markets (Enecon 2001, Ward and Trengove 2004). It is essential that production and processing sides of the regional biomass industry are commercially viable and develop in parallel.

Encouraging large scale carbon production in the SA MDB is contingent on removal of the barriers to carbon trading in the global carbon market (or perhaps even the creation of an Australian carbon market). Carbon is an emerging priority in natural resource management. Accumulation of carbon dioxide, methane and other greenhouse gases in the Earth’s atmosphere is one of the major factors behind the enhanced greenhouse effect and associated global warming. Failure to ratify the Kyoto protocol on atmospheric carbon reduction precludes the recognition by signatory countries of the carbon sequestration offsets achieved in Australia. Therefore, Australia’s trading status and capacity to participate in the emerging global carbon market remains uncertain. Efforts to clarify the legal position for potential global trading are currently the topic of research endeavour.

The revegetation of cleared agricultural landscapes sequesters carbon from the atmosphere. Substantial interest exists in New South Wales and Victoria in revegetation for carbon sequestration with a view to future participation in a global carbon market. In anticipation, the attributes of effective tradeable and enforceable property rights, vested in the individual are being explored and developed.

In the remainder of this paper we quantify and analyse the potential economic and attendant NRM benefits of revegetation actions. We assess both biomass production and carbon trading in the South Australian Murray-Darling Basin because of the natural resource management benefits specific to each revegetation enterprise. Economic analysis is based on the assumption that the market barriers impeding both biomass production and carbon trading are removed. We note that for the widespread adoption of revegetation efforts this assumption is contingent upon policy initiatives to encourage biomass market creation and carbon market barrier removal.

6 Analysis of biomass production

Achieving the natural resource management objectives of river salinity and wind erosion mitigation in the SA MDB can be enhanced by the replacement of shallow-rooted annuals with deep-rooted perennial vegetation. Bryan *et al*. (2005b) identified biomass production as a potentially viable option for encouraging large scale planting of deep-rooted perennial vegetation in the River Murray Corridor in South Australia. In this section we extend the Bryan *et al*. (2005b) economic analysis of biomass production in the SA River Murray Corridor to the entire South Australian Murray-Darling Basin.

Biomass production involves monoculture plantings of *E. oleosa* harvested initially after a 6-year establishment period followed by three-yearly harvests. The crops to supply raw biomass feedstock to an Integrated Tree Processing (ITP) plant require minimal annual maintenance and fertilisation following harvest. Economic returns to biomass production depend on the production of the site and the price per tonne of biomass. The costs of biomass production include establishment costs, maintenance costs, harvest costs, fertiliser costs, opportunity costs, and transport costs. Different costs occur at different times in the production schedule. For this study, the location selected for establishment of the ITP is Kingston-on-Murray because of the proximity and plentiful supply of suitable land and it being centrally located in the areas providing the greatest salinity benefits from revegetation.

6.1 Methods

Economic models are built in GIS using layers describing biomass productivity, opportunity costs, travel costs and the scalar parameters of harvest costs, maintenance costs and fertiliser costs. The economic measures of Net Present Value (NPV) and Equal Annual Equivalent (EAE) are calculated to quantify the costs and returns to biomass occurring at irregular intervals using discounting to account for time preference. Net present value expresses future costs and benefits in present day prices. Equal Annual Equivalent expresses the value of NPV distributed as an equal annual payment. Four modelled analyses of the profitability of biomass production are calculated for the SA MDB using the parameter values listed in **Table 4** over a 100 year time period using the methods detailed in Bryan *et al.* (2005b). The four models represent factory gate biomass prices of \$30, \$35, \$40 and \$47 respectively determined from previous research (Ward and Trengove, 2004 and Bryan *et a*l. 2005b). Results are presented in terms of the areas, locations and tonnages of biomass produced at sites where biomass production is viable (i.e. where the NPV > 0 when all costs including opportunity costs of foregone agriculture are considered).

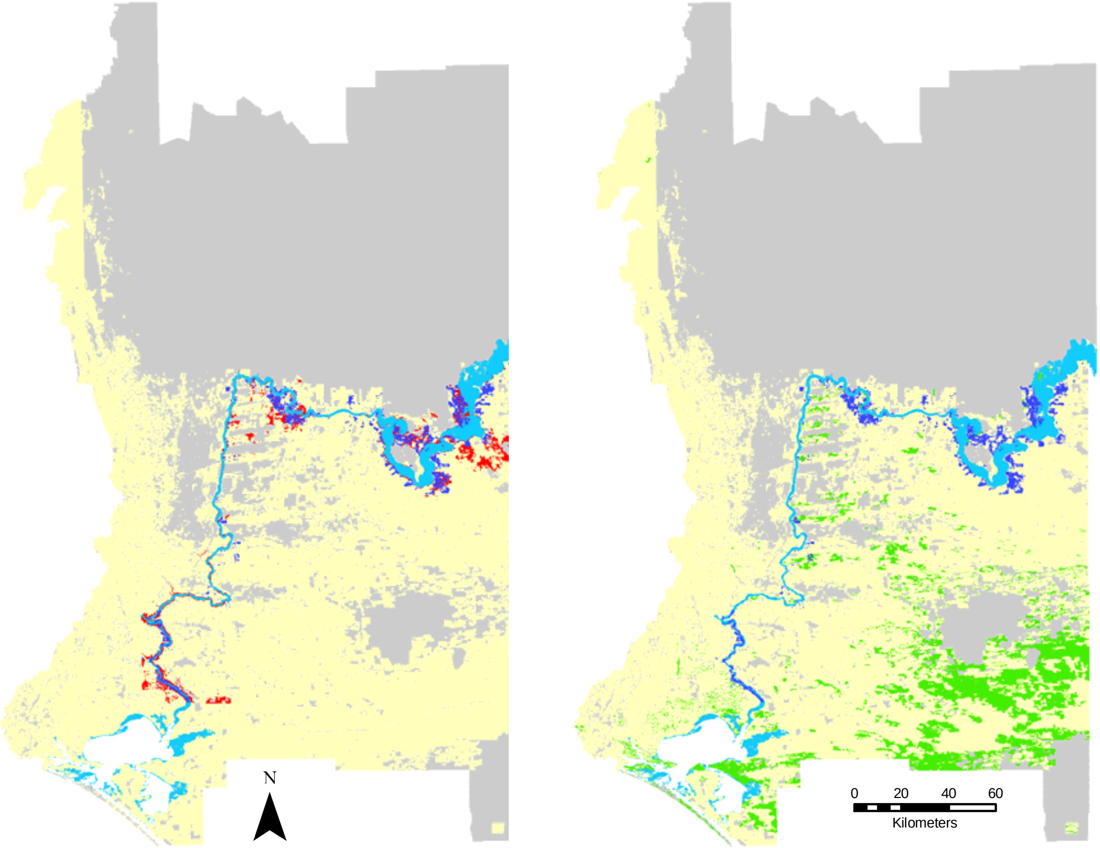
Table 4 – Model parameters used in economic analysis of biomass (Note: t = green tonnes of biomass)

Model Parameter	Units	Values
Establishment cost	$/ha	740
Time frame	Years	100
Discount rate	%	7
Maintenance costs	$/ha/yr	10
Harvest cost	$/t	12
Transport cost	$/t/km	0.046
Fertiliser costs	$/ha	40
Biomass price	$/t	30, 35, 40, 47
Biomass productivity	t	From Hobbs (unpublished data)
Opportunity costs	$	From Bryan *et al*. (2005b)

The natural resource management impacts of both biomass production and carbon trading are calculated in similar ways. Salinity impacts are quantified using the SIMPACT model (Bryan *et al*. 2005b, Wang *et al*. 2005). SIMPACT was used to spatially define areas where groundwater recharge impacts upon the salinity of the River Murray through the hydrogeological process of saline groundwater intrusion. Revegetation of dryland areas with deep-rooted perennial species such as those used in biomass production and carbon trading are assumed to eliminate groundwater recharge and resulting river salinity. Salinity benefits of revegetation are measured in units of Electrical Conductivity (EC). To calculate the salinity benefits, the biomass and carbon layers are overlaid with the salinity benefit layer in a GIS. Total salinity benefits are summed for all cells where biomass and carbon production are estimated to be economically viable (i.e. NPV > $0, Figure 2).

Wind erosion benefits of biomass and carbon production are calculated in a similar way. A spatial database of wind erosion potential was acquired from the South Australian Department of Water, Land, and Biodiversity Conservation. The seven classes of wind erosion potential were aggregated into 2 classes of low and high wind erosion potential. Areas originally classed as Low to Moderate were reassigned a class of Low and areas of Moderately High to Extreme were reassigned to High (Figure 2). To calculate the wind erosion benefits, the biomass and carbon layers are overlaid with the new wind erosion potential layer in a GIS. An indicator of total wind erosion benefits of biomass and carbon production was calculated simply by summing the area of High wind erosion potential for all cells where biomass and carbon production are estimated to be economically viable (i.e. NPV > $0).

Figure 2 – Areas of salinity benefit (red) and of high wind erosion potential (green)
For context, floodplain areas are represented as light blue and irrigated areas dark blue



6.2 Results

The results of the four models are presented in Table 5, Figure 3, and Figure 4. At a price of $30/tonne, biomass production is viable for an area of 95,496 ha located largely in the eastern scarp of the Mt. Lofty Ranges and in areas of minimal use along the River Murray. At $35/tonne, the viable area of biomass production jumps 10-fold to 975,646 ha. Viable areas at $30/tonne are located throughout the western part of the SA MDB. The areas to the east of the SA MDB however, are largely not viable at $30/tonne. These areas become viable at a price of $40/tonne and only some of the cereal growing areas to the east remain unviable. At $47/tonne biomass production is economically viable for most of the SA MDB study area. Ward and Trengove (2005) found that at a factory gate price of $47/tonne an Integrated Tree Processing plant still has a 15% internal rate of return on investment.

Table 5 - Indicators of the economic viability and natural resource management impacts of biomass production in the SA MDB calculated for all areas with an NPV > 0 over 100 year time period.

BIOMASS		Factory Gate Price ($/green tonne biomass)			
		30	**35**	**40**	**47**
Economic value	Total NPV of viable areas ($)	13,981,987	273,960,765	1,160,098,074	2,851,798,007
	EAE of viable areas ($/ha)	10.26	19.67	41.91	81.31
	Avg., (min, max)	(0.0-52.00)	(0.0-113.89)	(0.0-185.77)	(0.0-287.00)
Biomass	Viable tonnage per year (tonnes)	1,191,857	10,065,430	18,080,243	22,178,304
	Viable area of production (ha)	95,496	975,649	1,940,041	2,457,814
Salinity	Total salt reduced (EC)	1.61	2.65	3.06	3.23
Wind erosion	Total area of stabilised soils with high wind erosion potential (ha)	1084	27,754	210,464	283,263

In summary, at any of the prices assessed in this study there is likely to be enough viable area for biomass production to supply the 100,000 tonnes per year required by a single 5MW plant. As the price increases from $30/tonne to $47/tonne, the area, tonnage and profitability of biomass production increases significantly. NPV ranges from between 13.9 million at a factory gate price for biomass $30/tonne to $2.8 billion at $47/tonne. The average EAE ranges from between $10.26/ha/yr to $81.31/ha/yr for biomass prices of $30/tonne and $40/tonne respectively.

At the $30/tonne factory gate price approximately 1.61 EC salinity reduction benefits will be realised. In addition, there will be marginal salinity improvements up to 3.23 EC with the additional revegetation expected to occur with an increased factory gate price of $47 /tonne. Wind erosion reduction in high priority areas can be achieved with increased biomass plantings, which are in turn a function of biomass factory gate price. Hectares of high priority range from 1,084 ha ($30/ tonne) to 283,263 ha ($47/ tonne).

The analysis has been based on plant specifications with a generating capacity of 5MW or 40,000 MWh, which requires 100,000 tonnes of biomass feedstock per annum. Assuming the existence of sufficient regional generating capacity and network distribution infrastructure, the biomass tonnage predicted at a price of $30/tonne *can potentially* generate 50 MW or 13% of the combined demand (381 MW) predicted for 2008/09 for the Riverland and Murraylands ETSA regions (ETSA 2005). At a price of $35/tonne, the biomass tonnage *can potentially* produce 500 MW or 131% of the regional demand forecast for the same period. At a price of $47/tonne the feedstock capacity could potentially exist to generate 1100 MW or 8,800 GWh which would represent 84% of the total electricity supplied for South Australia (10,469 GWh) in 2005/06 (ETSA 2005). Assuming there is sufficient regional capacity, replacing coal fired electricity generation with biomass is equivalent to offsetting approximately 550,000 tonnes of CO_2 /year to 12 million tonnes of CO_2 /year or taking 104,000 – 2 million cars off the road respectively.

Figure 3 - Net equal annual equivalent returns per hectare per year from biomass production for the SA MDB under differing factory gate prices per green tonne of biomass. Net equal annual returns are an estimate of the annual returns per hectare expected from biomass over and above those from existing agriculture expressed in today’s dollars.

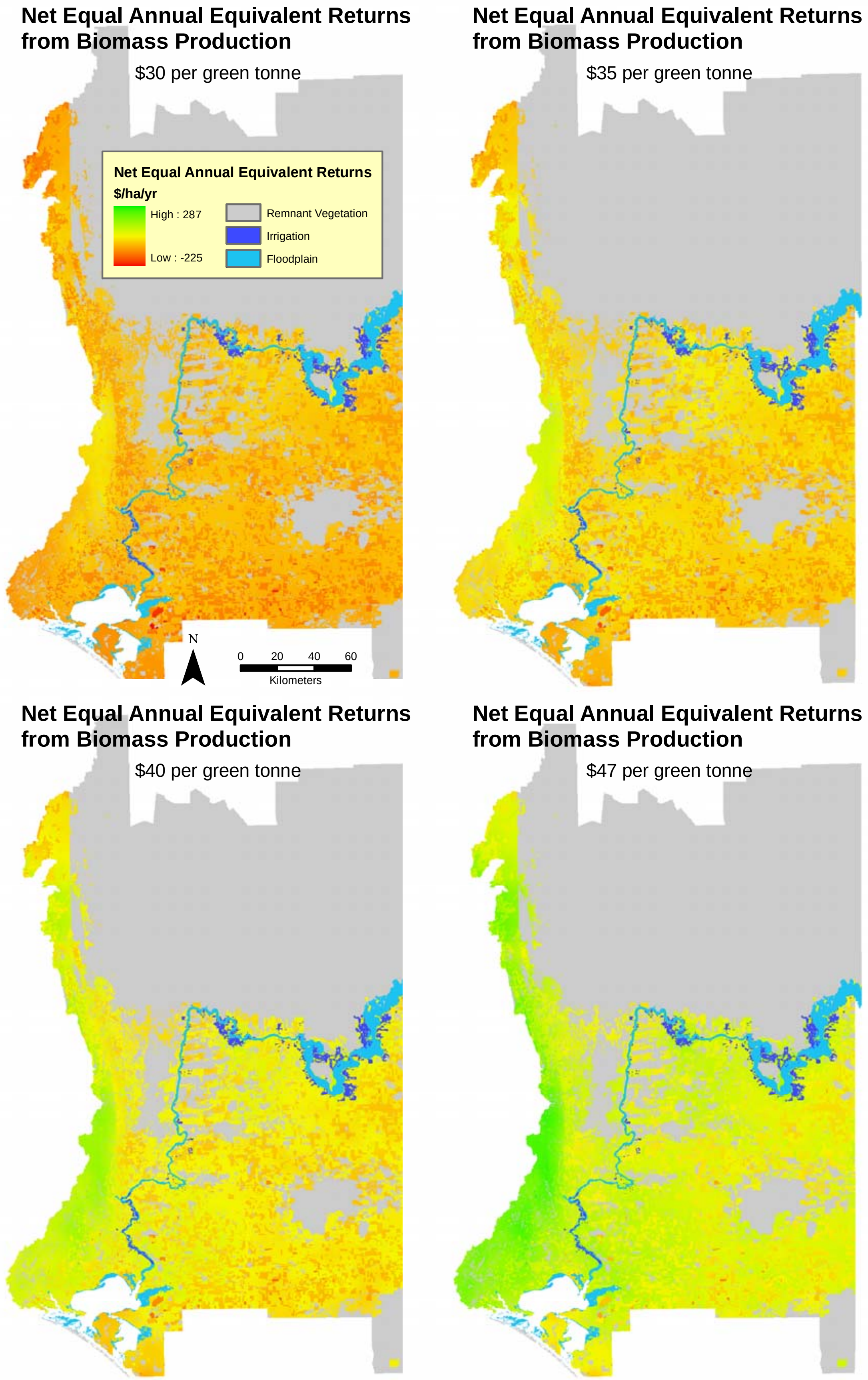
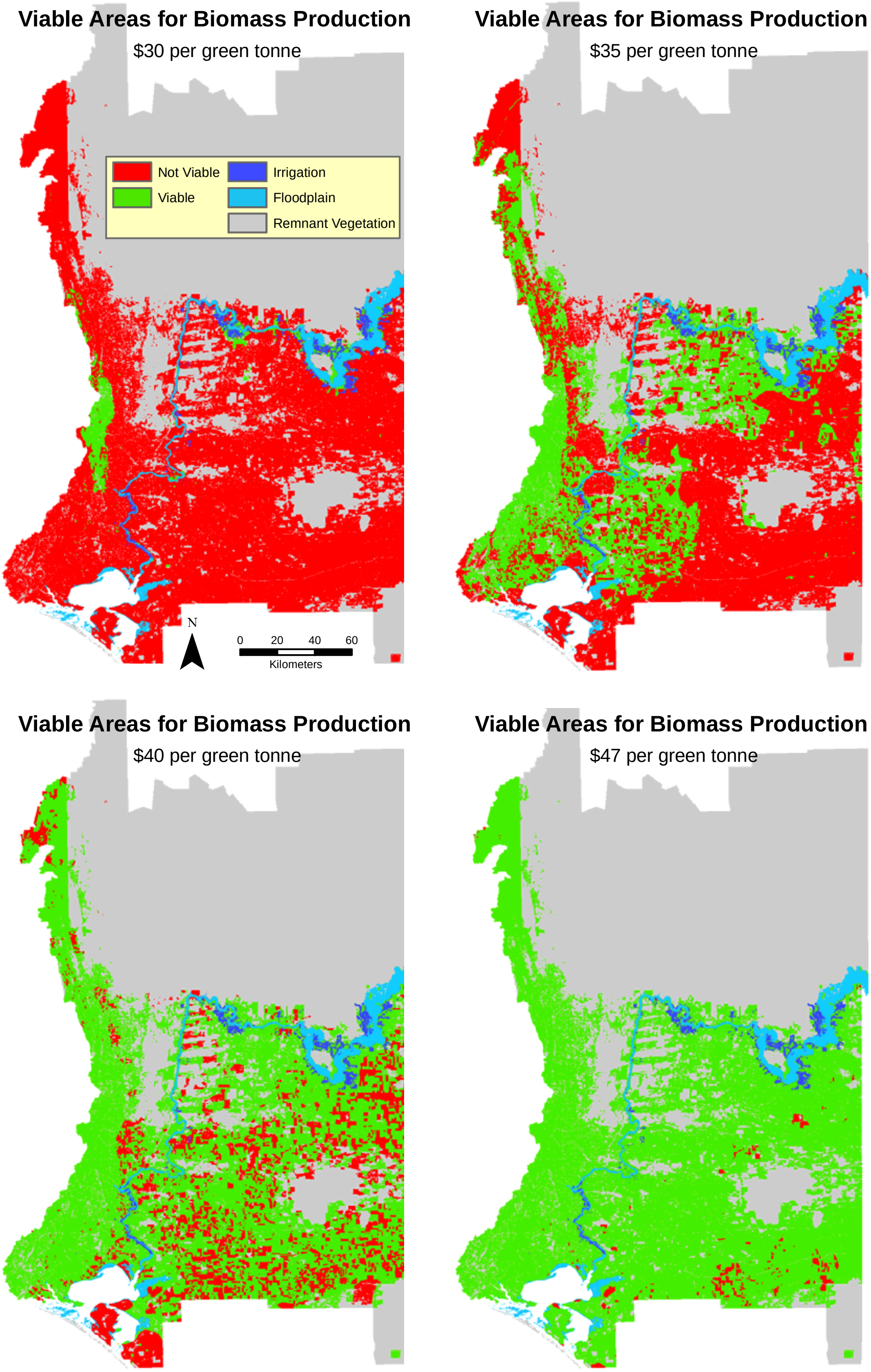


Figure 4 - Economically viable area of biomass production for the SA MDB under differing factory gate prices per green tonne of biomass.

Note that viable areas are those which have an NPV of biomass production > 0 over 100 years.



7 Analysis of carbon trading

The revegetation of cleared landscapes sequesters carbon from the atmosphere. Depending on the species planted and the locations, revegetation for carbon trading may also have local benefits for natural resource management. Revegetation for carbon trading may enhance biodiversity, mitigate salinity and wind erosion, as well as sequester carbon.

At the time of writing (27.11.05) carbon is trading at €21.60 (A$ 35 at a rate of €1 = AUD1.62) per tonne on the European market[6]. In this study we quantify the economic viability of revegetation for carbon trading in the SA MDB. We assess two types of revegetation – the plantation of sugar gum (*Eucalyptus cladocalyx*) and the plantation of a suite of local native mallee tree and shrub species. Both types of revegetation can have benefits for wind erosion and salinity but only the revegetation of local native species is considered to have any significant benefits for biodiversity. The sensitivity of the model is tested under four different prices for carbon (€10 or A$16.20, €20 or A$32.40, €30 or A$48.60, and €40 or A$64.80).

7.1 Methods

Economic models are built in GIS using layers describing carbon productivity, opportunity costs of foregone agricultural production, and annual maintenance and transaction costs (including costs of carbon accounting and monitoring). The economic measures of Net Present Value (NPV) and Equal Annual Equivalent (EAE) are calculated to quantify the costs and returns to carbon using discounting to account for time preference. Four analyses of the profitability of carbon production at carbon prices of €/t 10, 20, 30 and 40 are calculated for the SA MDB. The model parameter values are listed in Table 6 over a 100 year time period. Results are presented in terms of the areas, locations and tonnages of carbon sequestered at sites where revegetation for carbon trading is economically viable (i.e. where the NPV > 0 when all costs including opportunity costs of foregone agriculture are considered).

Table 6 – Model parameters used in economic analysis of biomass (Note: t = tonnes of carbon, the carbon price is converted to AUD using a rate of €1 = AUD1.62, establishment costs are an upfront once off cost and are an estimate of the cost of direct seeding).

Model Parameter	Units	Values
Establishment cost	$/ha	500
Time frame	Years	100
Discount rate	%	7
Maintenance costs	$/ha/yr	10
Transaction costs	$/ha/yr	10
Carbon price	€/t	10, 20, 30, and 40
Carbon productivity	t	From Hobbs (unpublished data)
Opportunity costs	$	From Bryan *et al*. (2005b)

The same economic model parameters are used to estimate the profitability of revegetation of local native mallee species as are used in the sugar gum model above. The models estimate profitability at a carbon price of €/t 10, 20, 30 and 40. However, the carbon productivity of sugar gum (*Eucalyptus cladocalyx*) and the suite of local native mallee species are modelled separately.

Benefits of carbon production for wind erosion and salinity are calculated in the same way as for biomass production. Specifically, these are calculated by overlaying economically viable areas of carbon production with areas of salinity and wind erosion benefit. In addition, the

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[6] Carbon prices have ranged from between €8.47 (1/12/2004) to €29.10 (11/7/2005). On the 11/01/2006 carbon is trading at €27.10 at http://www.pointcarbon.com/

production of the suite of local native mallee species have biodiversity benefits. These are simply calculated as the viable area of carbon production.

7.1.1 Carbon productivity - sugar gum monoculture

The sugar gum (*Eucalyptus cladocalyx*) species was selected as a high productivity species suitable for the low rainfall environments of the SA MDB. The carbon productivity estimates of sugar gum were based on observations of an unknown provenance of *Eucalyptus cladocalyx* planted in 1910 at Leighton with 497mm average annual rainfall (Boardman 1992). The species were observed at 81.4 years of age with a stand density of 546 trees per hectare. They displayed a mean stemwood accumulation rate of 3.78 m^3/ha/year and a wood basic density (dry) of 0.749 t/m^3. This and other observations of old age stands (66–88 years old) suggest the time to peak standing biomass is greater than 100 years. Hobbs (unpublished data, 2005) has estimated the stemwood productivity as a function of historic annual rainfall in the South Australian Murray-Darling Basin. The average annual rate of stemwood biomass growth was multiplied by 100 years and spatially extrapolated using relationships with the BiosEquil model (Raupach *et al*. 2001) to create a GIS layer of stemwood productivity for Sugar Gum in the SA MDB.

A simplified approximation of total standing carbon at 100 years (t/ha @ 546 trees/ha) can be calculated as:

> Carbon = stemwood production at 100 years * green biomass per stemwood volume * carbon per green biomass

We included a multiplier of 1.2 to capture the accumulation of below ground carbon. Another multiplier factor of 2 was used to estimate the productivity of more realistic planting densities of approximately 1,100 individual tree stems per hectare.

Therefore, at 100 years:

> Carbon = [stem_e_cla100] * 1.56 * 0.34 * 1.2 * 2

Even with these multipliers the carbon productivity estimates used here can be considered to be conservative.

7.1.2 Carbon productivity - local native mallee species

The carbon productivity of a local native mallee community was also modelled as the revegetation of native communities is an essential component to reaching regional resource condition targets for biodiversity. Carbon trading provides an economic incentive for large scale revegetation for achieving the multiple natural resource management objectives of salinity, wind erosion and biodiversity. The carbon productivity of a typical community of local native species in the SA MDB was estimated by combining the productivities of individual species. These are listed in Table 7. A planting rate of 1000 plants per hectare was used. Estimates are based on growth observations of some reasonably productive local native species common to dryland areas of SA MDB.

Table 7 - Species included in carbon productivity estimation for a typical local native mallee community in the SA MDB.

Mallee species	Non-mallee species
Eucalyptus brachycalyx	*Acacia ligulata*
Eucalyptus cyanophylla	*Acacia pycnantha*
Eucalyptus dumosa	*Callitris gracilis*
Eucalyptus incrassata	
Eucalyptus oleosa	
Eucalyptus porosa	
Eucalyptus socialis	

Measurements are from sites 8.5 to 15 years old (average 11.2 years) from SA MDB region (Loxton and Murray Bridge sites). Long term accumulation rates (100 years) are likely to be consistent with this early productivity rate due to the relatively slow growth rate of mallee species and native pine (*Callitris* sp.). Two representative *Acacias* have also been included in the selection as they are commonly used in revegetation projects. Much higher sequestration rates would be possible in the early years (and maybe longer term) by the use of higher planting rates than modelled here. The initial carbon productivity (+15%) of the site in the first 10-15 years by direct seeding. In the same way as the sugar gum model, we use a multiplier of 1.2 to capture below ground carbon accumulation. Again we consider the carbon productivity estimates to be conservative.

7.2 Results

7.2.1 Sugar Gum

The results indicate that the economic viability of sugar gum plantation for carbon trading is highly sensitive to the price of carbon (Table 8, Figure 5, Figure 6). At €10/tonne (A$16.20/tonne), sugar gum plantation for carbon trading is viable on only 587 hectares of land. As the carbon price reaches €20/tonne (A$32.40), sugar gum plantation for carbon trading is economically viable for over 417,000 ha, mostly located in the higher productivity areas of the eastern scarp of the Mt. Lofty Ranges. At €30/tonne (A$48.60/tonne), sugar gum plantation for carbon trading is generally viable over much of the study area, especially on the sheep grazing land, except perhaps in the lowest productivity areas to the east just south of the River Murray. At €40/tonne (A$64.80), sugar gum plantation for carbon trading is generally viable almost everywhere in the SA MDB.

Table 8 – Indicators of the economic viability and natural resource management impacts of sugar gum plantation for carbon trading in the SA MDB calculated for all areas with an NPV > 0 over 100 year time period.

SUGAR GUM		Carbon Price (€/tonne)			
		10	**20**	**30**	**40**
Economic value	Total NPV of viable areas ($)	46,121	117,650,792	849,401,309	2,151,410,887
	EAE of viable areas ($/ha) Avg., (min, max)	5.5 (0.0-12.63)	19.77 (0.0-95.97)	34.78 (0.0-179.31)	66.77 (0.0-262.64)
	Viable area of carbon production (ha)	587	417,076	1,711,693	2,260,266
Carbon sequestration	Viable total carbon production (tonnes/yr)	2,200	1,365,672	3,871,250	4,813,772
Salinity	Salinity reduction (EC)	0.0	0.97	2.57	3.09
Wind erosion	Total area of stabilised soils with high wind erosion potential (ha)	45.2	10,781	205,335	257,612

Sugar gum revegetation for carbon trading results in NPV ranges from between $46,121 at carbon price of €10/tonne (A$16.20) to $2.1 billion at a carbon price of €40/tonne (A$64.80). The average EAE ranges from between $5.50/ha/yr to $66.77/ha/yr for carbon prices of €10/tonne and €40/tonne respectively. At a carbon price of €20 (A$32.40) /tonne approximately 0.97 EC salinity reduction benefits will have been realised through revegetation of local native mallee species. Based on current hydrological modelling, there will be marginal salinity improvements to 3.09 EC with the additional revegetation expected to occur at an increased carbon price of €40 /tonne. The level of revegetation at carbon prices greater than €20 (A$32.40) per tonne will mitigate wind erosion on 10,781 ha and up to 257,612 ha at €40 /tonne. The carbon sequestered in economically viable areas in the

SA MDB ranges from between 2,200 to 4,813,772 tonnes/yr (Table 8). This is the equivalent of taking between 405 and 870,000 cars off the road annually.

Figure 5 - Net equal annual equivalent returns per hectare per year from carbon production under sugar gum plantation for the SA MDB under differing prices per tonne of carbon. Net equal annual returns are an estimate of the annual returns per hectare expected from carbon trading over and above those from existing agriculture expressed in today's dollars.

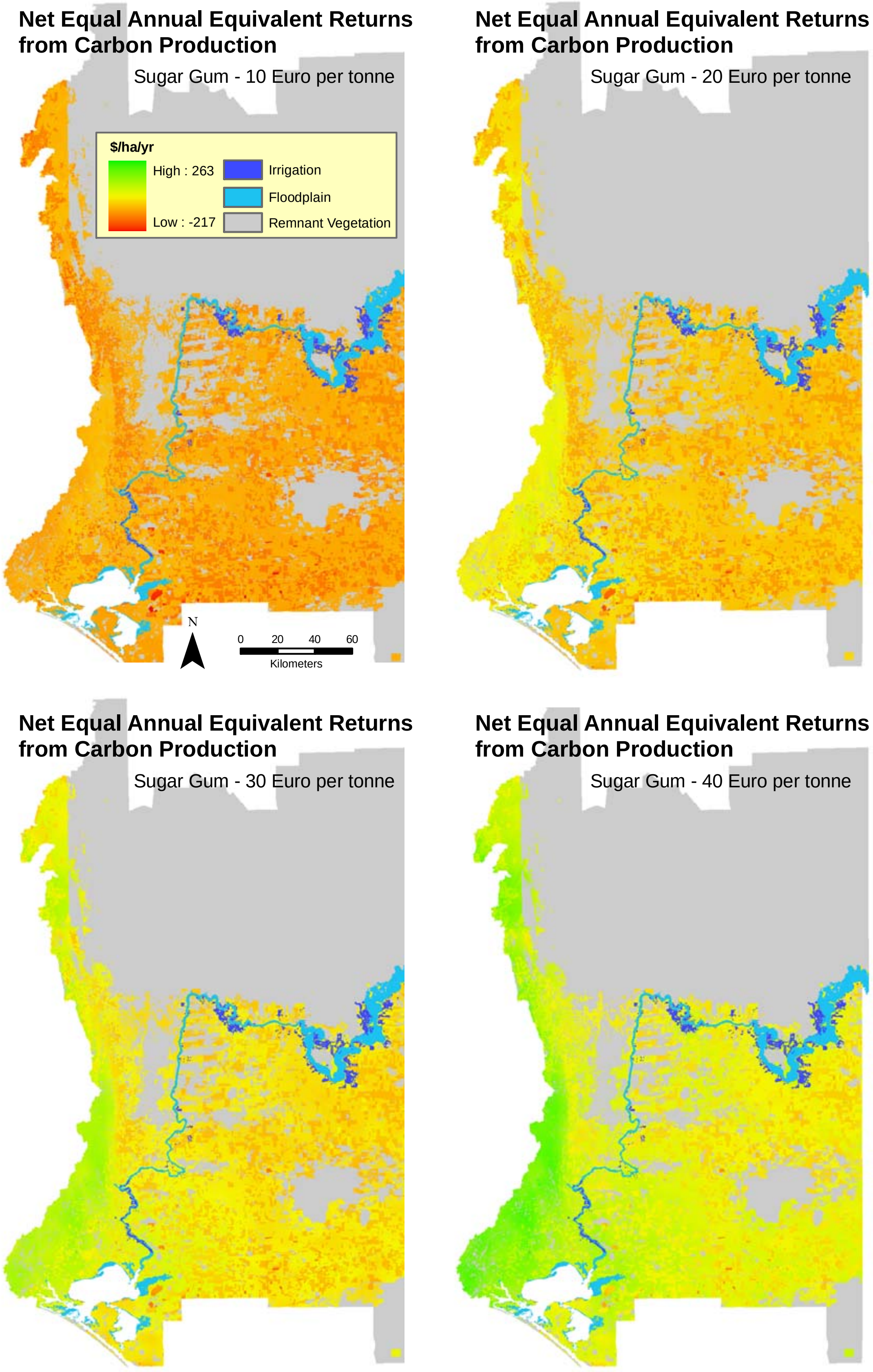
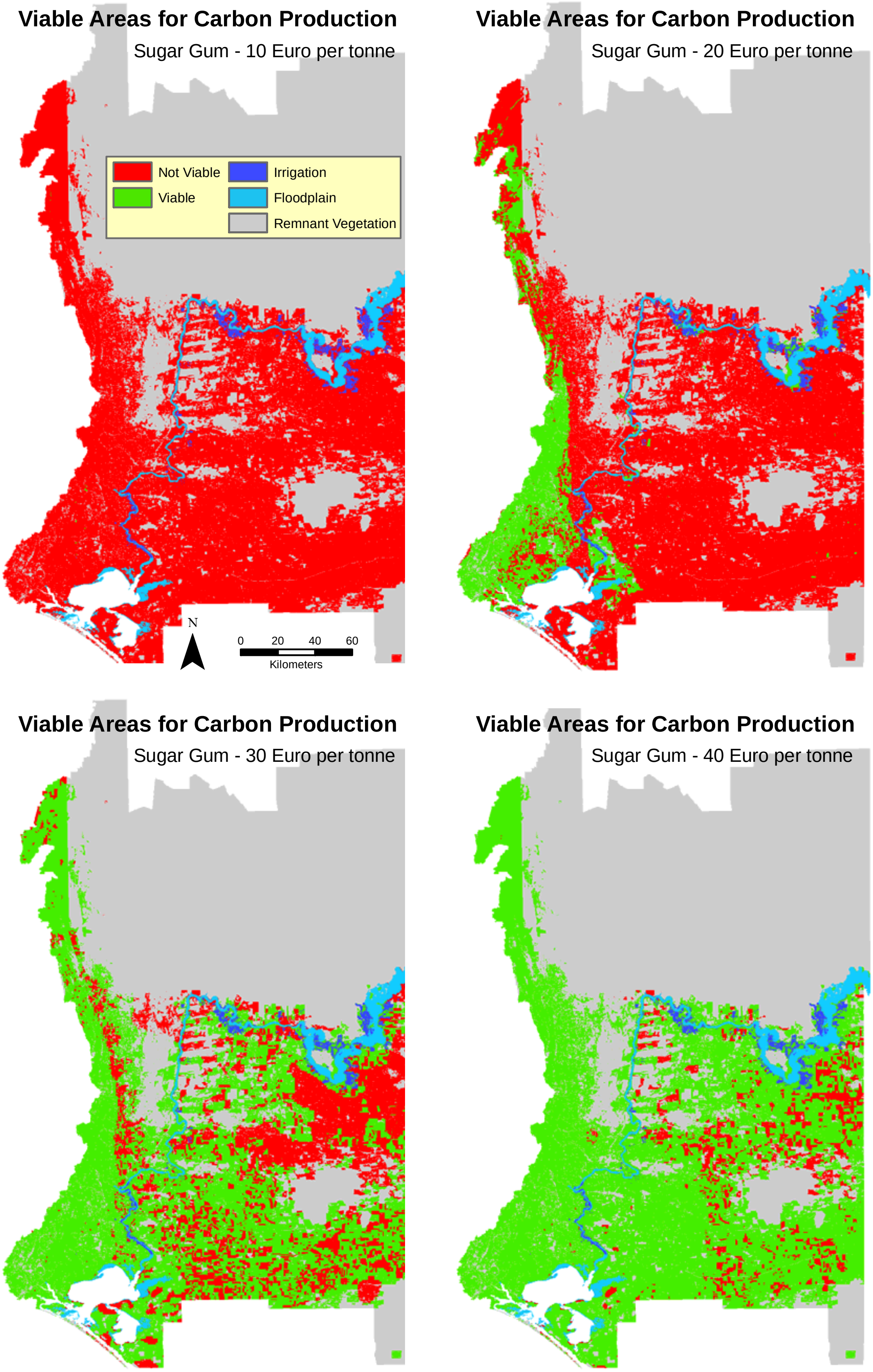


Figure 6 - Economically viable area of sugar gum plantation for carbon trading in the SA MDB under differing prices per tonne of carbon.

Note that viable areas are those which have an NPV of carbon production > 0 over 100 years.



7.2.2 Local Native Mallee Species

The results indicate that the productivity of local native mallee community species is lower than that of sugar gum plantation and the economic viability is concomitantly less (Table 9, Figure 7, Figure 8). No areas are viable at a price of €10/tonne. An area of 115,793 ha is economically viable for revegetation of local native mallee species at a price of €20/tonne located in the most productive areas along the eastern scarp of the Mt. Lofty Ranges. Although the returns are lower overall, the economically viable areas for revegetation of mallee communities show similar geographic patterns to that of sugar gum plantations. In the same way as for sugar gum, the economic viability of revegetation with local native mallee species increases and becomes generally viable at carbon prices of €30/tonne and €40/tonne.

Table 9 - Indicators of the economic viability and natural resource management impacts of local native mallee species for carbon trading in the SA MDB calculated for all areas with an NPV > 0 over 100 year time period.

MALLEE COMMUNITY		Carbon Price (€/tonne)			
		10	**20**	**30**	**40**
Economic value	Total NPV of viable areas ($)	0	12,466,048	337,643,473	1,113,873,635
	EAE of viable areas ($/ha) Avg., (min, max)	0.0 (0.0-0.0)	7.54 (0.0-64.28)	30.77 (0.0-132.13	41.13 (0.0-199.98)
Carbon sequestration	Viable total carbon production (tonnes/yr)	0	356,616	1,849,795	3,578,201
Biodiversity	Total area of revegetation for biodiversity (ha)	0	115,793	768,933	1,897,763
Salinity	Total salinity reduction (EC)	0.0	0.03	1.64	2.77
Wind erosion	Total area of stabilised soils with high wind erosion potential (ha)	0	2,051	32,258	230,431

Mixed species mallee revegetation for carbon trading results in NPV ranges from between $0.0 at carbon price of €10/tonne (A$16.20) to $1.1 billion at a carbon price of €40/tonne (A$64.80). The average EAE ranges from between $0.0/ha/yr to $41.13/ha/yr for carbon prices of €10/tonne and €40/tonne respectively. At a carbon price of €20 (A$32.40) /tonne approximately 0.03 EC salinity reduction benefits will have been realised through revegetation of local native mallee species. Based on current hydrological modelling, there will be marginal salinity improvements to 2.77 EC with the additional revegetation expected to occur at an increased carbon price of €40 /tonne. The level of revegetation at carbon prices greater than €20 (A$32.40) per tonne will mitigate wind erosion on 2,051 ha and up to 230,431 ha at €40 /tonne (Table 9). The carbon sequestered in economically viable areas in the SA MDB ranges from between zero to 3,578,201 tonnes/yr. This is the equivalent of taking up to 660,000 cars off the road annually.

At a carbon price of €20 (A$32.40) per tonne, approximately 115,000 ha of land is estimated to be more profitable under revegetation than current agricultural practices. Current databases indicate there are 3,075,050 ha of remnant revegetation in the SA MDB. An additional 115,000 ha represents an increase of 3.7%, well in excess of the 1% revegetation increase articulated in the resource condition targets. At a carbon price of €40 /tonne the increase of 1,897,763 ha in revegetation represents a 61% increase in the extent of native vegetation in the SA MDB. We have not assessed how the additional plantings of mixed mallee communities will contribute to the enhanced 15% representativeness targets suggested by Bryan *et al*. (2005b).

Figure 7 - Net equal annual equivalent returns per hectare per year from carbon production under revegetation of a suite of local native mallee species for the SA MDB under differing prices per tonne of carbon. Net equal annual returns are an estimate of the annual returns per hectare expected from carbon trading over and above those from existing agriculture expressed in today’s dollars.

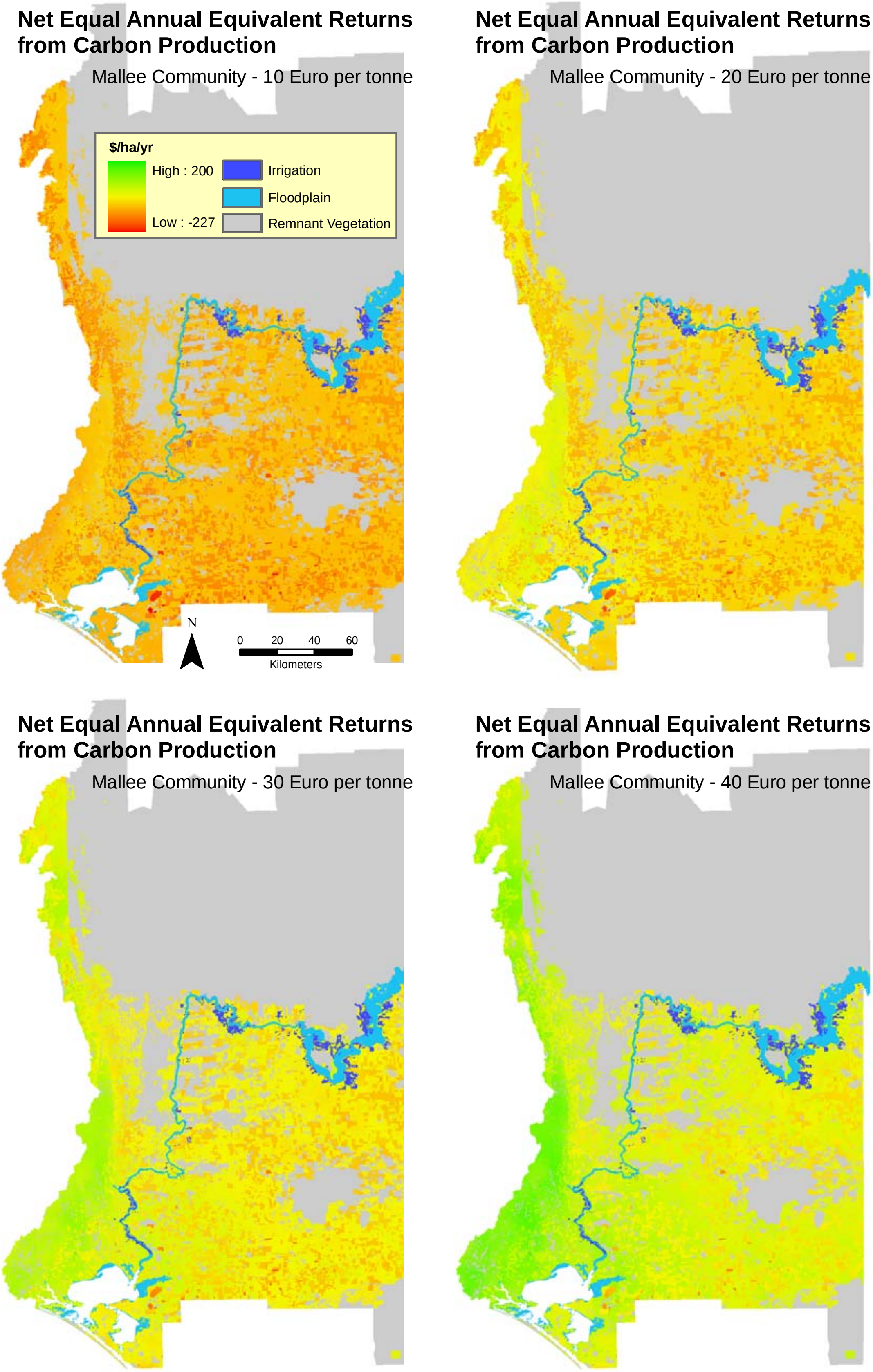
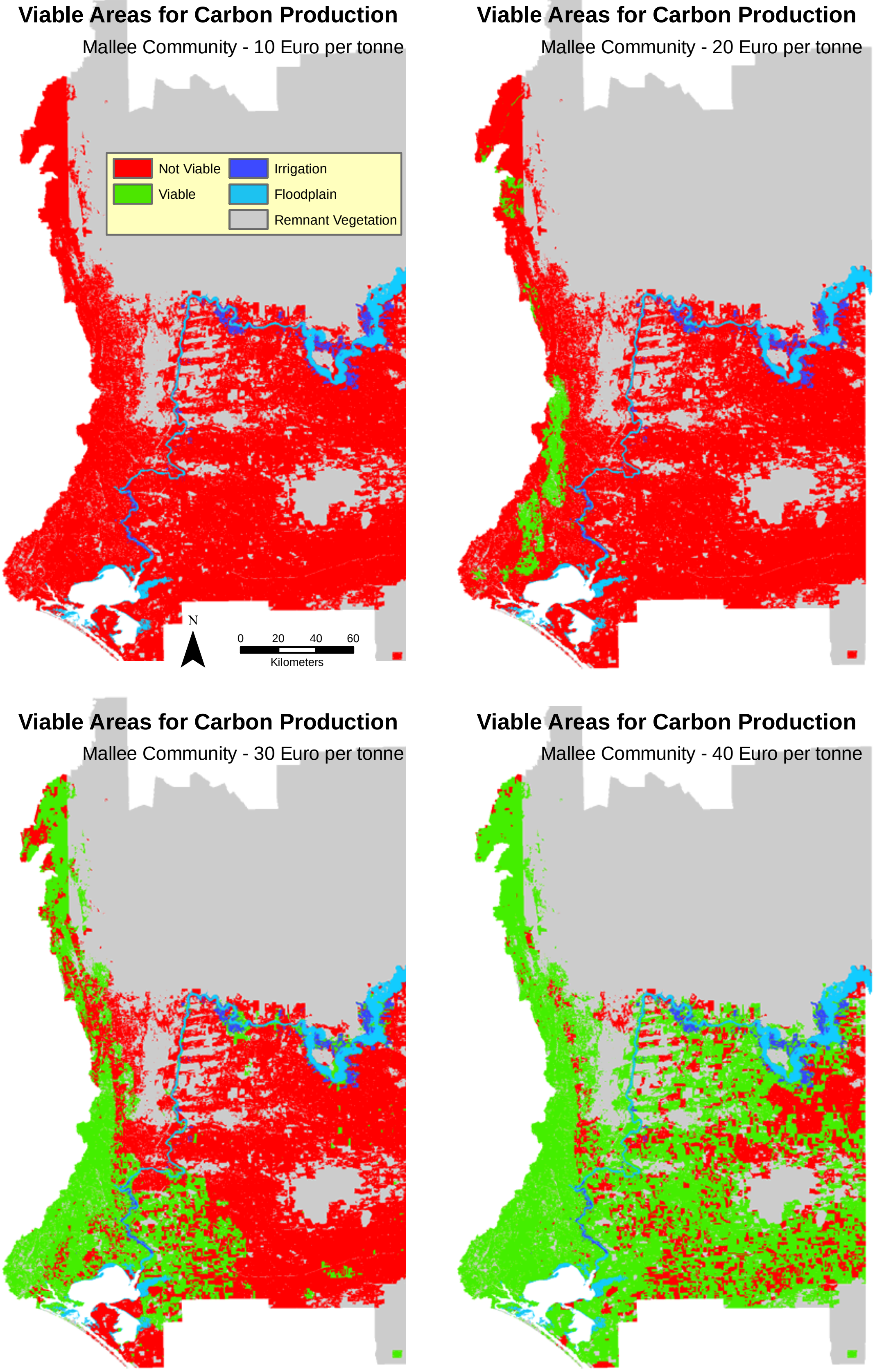


Figure 8 - Economically viable area of revegetation of a suite of local native mallee species for carbon trading in the SA MDB under differing prices per tonne of carbon.

Note that viable areas are those which have an NPV of carbon production > 0 over 100 years.



Viable Areas for Carbon Production
Mallee Community - 10 Euro per tonne

Viable Areas for Carbon Production
Mallee Community - 20 Euro per tonne

Viable Areas for Carbon Production
Mallee Community - 30 Euro per tonne

Viable Areas for Carbon Production
Mallee Community - 40 Euro per tonne

8 Conclusion

The spatial scale of natural resource management actions such as the revegetation of deep-rooted perennials required to meet resource condition targets in the South Australian Murray-Darling Basin is very extensive (Bryan *et al*. 2005b). The high cost of these actions makes direct purchase and undertaking by government infeasible. In this study we review three categories of market-based instruments for their potential to encourage cost effective revegetation at the scale required in the SA MDB. We conclude that price based instruments, implemented as tenders, can provide initial stimulus for revegetation and marginally enhance the cost effectiveness of public funds for natural resource management. However, the incremental improvements in cost savings are not sufficient to compensate the level of revegetation efforts required to meet prescribed resource condition targets nor is the long term efficacy of revegetation efforts and management guaranteed. The review indicates that the estimated gains from trade realised from a quantity based instruments, implemented as cap and trade schemes, are not sufficient to compensate incurred individual costs and they are unlikely to provide substantial incentive for large scale revegetation efforts. The analysis indicates that commercially viable alternative farming systems and associated market creation and barrier removal are necessary precursors for the long term adoption of environmentally beneficial revegetation at a sufficient scale to meet resource condition targets. Effectively, alternative and profitable farming systems are required that can provide joint benefits for salinity, wind erosion, and biodiversity.

We identified two potential commercially viable alternative farming systems to offset the substantial private costs of long term adoption of revegetation practices. One option identified biomass production suitable for integration with, or replacement of, existing on-farm activities. Access to newly created markets can supplement or replace income on farms where revegetation has been undertaken. A second option identified was carbon production suitable for trade in the existing global market.

Spatio-temporal economic models were developed in this study to estimate the profitability of biomass and carbon production. We have quantified the natural resource management benefits for salinity, wind erosion and biodiversity associated with economically viable areas of biomass and carbon production.

We have found that conservatively, revegetation of deep-rooted perennials for both biomass production and carbon trading are likely to be at least as profitable as existing agriculture, particularly sheep grazing in spatially optimised locations. At higher prices, both activities are likely to be substantially more profitable than existing agriculture over much of the SA MDB.

Biomass production may make a minor contribution (<3.23 EC) to salinity targets and may contribute to the stabilisation of substantial areas of high wind erosion potential. Biomass processing can potentially offset between 550,000 and 12 million tonnes/yr of CO_2 emissions from coal-fired electricity generation (this is the equivalent of taking between 104,000 and 2.2 million cars off the road). Biomass production does not however, contribute to biodiversity targets.

Sugar gum production for carbon trading is expected to produce similarly small salinity benefits (<3.09 EC). The wind erosion benefits include between 10,781 ha and 257,612 ha of high wind erosion potential stabilised. The carbon sequestered in economically viable areas in the SA MDB ranges from between 2,200 to 4.8 million tonnes/yr. This is the equivalent of taking between 405 and 870,000 cars off the road annually. Sugar gum plantations are not considered to provide biodiversity benefits.

Production of local native mallee species for carbon trading is again expected to produce similarly small salinity benefits (<2.77 EC). Revegetation of mallee species may stabilise between 2,051 and 230,000 ha of high wind erosion potential soils. The volume of carbon sequestration is up to 3.6 million tonnes/yr (this is equivalent to taking 660,000 cars off the road annually). Importantly, at a carbon price of €20 (A$32.40) per tonne, approximately 115,000 ha of land is estimated to be revegetated for biodiversity. This represents an increase in the area of vegetation of 3.7%, well in excess of the 1% resource condition target. At higher carbon prices (€40/tonne), the area of vegetation in the SA MDB may be increased by up to 61%.

Our results demonstrate that both biomass and carbon production are potentially economically viable alternative farming systems and can make substantial contributions to both regional economies and regional resource condition targets. However, for large scale adoption of these alternative farming systems three actions need to occur:

Firstly, a biomass processing industry needs to be developed in the region, coordinated with revegetation establishment on private landholdings. This could involve co-investment by government and energy companies in the development of a processing plant. Bryan *et al*. (2005b) and Ward and Trengove (2004) also suggest other impediments to adoption of biomass production such as robust contractual arrangements, capital constraints, and maintenance of farm cash flow also need to be addressed.

Secondly, institutional barriers to trade in the European carbon market need to be removed (or an Australian Market expanded). This would require substantial development of a reliable carbon accounting and auditing tool, a system of enforceable and tradeable property rights, and legislative alignment with carbon markets.

Thirdly, widespread uptake of these alternative farming systems by private individuals is required. We recognise that the actual level of adoption is partially contingent on a number of complex, interacting factors. These include individual attributes and behaviours, cultural norms, traditions and conventions, social institutions, the ease and predictability of land use change, and the effectiveness of communicating the economic benefits of new farming systems relative to current agricultural production (Rural Solutions SA 2005). These are aspects of current and ongoing research.

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