Synergistic design: Detailing the benefits of a Green Infrastructure approach in a Western Australian Landscape

Simon Kilbane[1], Richard Weller[2], Richard Hobbs[3]
[1]*School of Architecture, Landscape and Visual Arts, University of Western Australia;* [2]*School of Design, University of Pennsylvania;* [3]*School of Plant Biology , University of Western Australia*

Introduction

The National Green Network (NGN) (Kilbane 2013) is a continental-scale Green Infrastructure (GI) research project that spans the Australian continent (Fig. 1). The research intent is to create an ecologically robust and interconnected protected area network design to enhance the resilience of the nation's landscape, biota and peoples. It prescribes a framework of ecological corridors and vegetated linkages as a structure for ecological connectivity and to meet protected area policy targets defined by the Convention on Biological Diversity (CBD, United Nations Environment Program 2010) and the National Reserve System (NRS, Commonwealth of Australia & National Reserve System Task Group 2009). The NGN was conceived through a design based approach which included ecological modelling, ground truthing and detailed design stages. The ground-truth stage conducted within a 25 x 25km study area at York in south-western Australia. This location was chosen as an exemplar of the complexity needed to be addressed to create a robust system and to test the pragmatics of implementing the design. This led to confirmation of the NGN as an over-arching framework that was then broadly adjusted by participants through a design charrette workshop. The creation of a final detailed NGN design is the focus of this paper. While the research method thus far created a flexible and ground-truthed design, to ensure accurate, measurable and visualised outcomes further work was required. Three different final design options were considered in terms of relative costs and benefits. The final preferred design outcome represents a 'middle ground', a synergistic design outcome that offers multiple ecological benefits and an array of ecosystem services.

Figure 9 | NGN as framework across the south-western Australia, showing the location of the York study area

Background

GI is described by Benedict & McMahon (2006) as 'the ecological framework for environmental, social, and economic health – in short, our natural life-support system'. Benefits of a GI approach include the ability to go beyond conservation planning and to explore the cultural as well as ecological benefits through designs that address climate and land-use change and increase ecological and cultural resilience. This mandates therefore that design flexibility should be exercised in order to reconcile goals with the existing land-uses and cultural values that landscapes hold. Such planning is also referred to as 'holistic landscape planning'(Hobbs 1993), the 'ecosystem approach' (Smith & Maltby 2003, United Nations 2010) and 'multi-functional' or 'integrated' approach (Bennett 2003, European Commission 2012, Van Der Windt & Swart 2008).

This research investigated the potential of this new Australian GI, the NGN, to shift from policy to practice; from continental to local scales; from conceptual model to precise and detailed designs. A 25 x 25 km site at York in south-western Australia established a study area within which to further assess the NGN potential. Located within one of the nation's only two recognised biodiversity hotspots (Myers et al. 2000) nominated for its high degree of biological endemism (Hopper & Gioia 2004) and threatening processes including land conversion and ecological fragmentation (Hobbs 1993), this landscape crystallises many of the problems facing the region. The soils are poor (Hopper 2009) and the removal of vegetation, in particular deep-rooted trees has resulted in saline groundwater intrusion exacerbating degradation and erosion. Faunal species are in decline or extinct through predatory carnivores such as the cat and fox and climate change is increasingly altering species' range, food resources, rainfall patterns and fire frequency. Most importantly the landscape is replete with existing land-uses. High value agricultural land and existing towns have created a highly fragmented landscape matrix containing less than 8.8% remnant vegetation and less than 0.1% as formal protected area (Western Australian Land Information Authority 2012).

While efforts to enhance landscape and ecological resilience through revegetation have been undertaken in the region this has not arrested the steady decline of this landscape and its' biota. In conjunction with revegetation, increasingly sustainable agricultural practices and halting vegetation clearing has meant an increase in vegetation cover, albeit to arrest the spread of salt and maintain arability (Smith 2008). Such revegetation generally utilises indigenous species that can also benefit resident biodiversity as food source, habitat and landscape linkages. However revegetation efforts occur in a piecemeal fashion, lacking a large-scale spatial framework to provide for meaningful ecological outcomes. Furthermore these landscapes are notoriously difficult if not impossible to restore to pre-European vegetation patterns, prompting a 'novel ecosystem' approach (Hobbs et al. 2009). Such an approach can enable addressing ecological connectivity, meet CBD and NRS targets and increase ecosystem health so as to provide robust ecosystem services (Millennium Ecosystem Assessment 2005).

The Design Charrette

An evaluation of the NGN was made by stakeholders within the York study area to test the veracity of the original NGN design. A design charrette, defined as 'a time-limited, multiparty design event organized to generate a collaboratively produced plan for a sustainable community'

(Condon 2008) gave the opportunity for participants to 'ground-truth' the NGN design. This resulted in spatial adjustments to the NGN based upon their own local knowledge and expertise and refined the design from broad conceptual corridors and linkages derived from an ecological modelling process (McRae & Kavanagh 2011) to more precise and feasible designs (Fig. 2). The reconfiguration and realignment of the NGN by charrette participants did not reach a final resolved design (i.e. one that could be implemented). It did however confirm the potential of the NGN as a broad spatial framework which could then be adjusted and refined through local input. It was also noticeable how participants in the charette seemed willing to ensure that their local area would meet the overarching aims of the NGN, ensuring a broader focus to the exercise. Two 'rules of adjustment' to which the design was altered emerged from the charrette. First 'Form': the re-alignment of the NGN to landscape elements such as remnant vegetation, roads and cadastre. Second, 'Function': an exploration of multi-functionality and potential for novel ecosystem approaches to revegetation and ecological restoration.

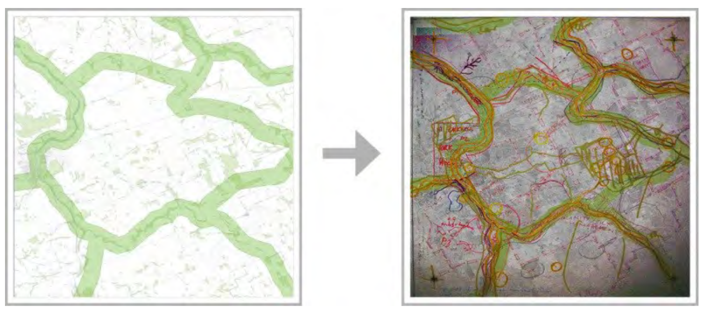

Figure 10 | Original NGN and adjusted design charrette outcome

Research Objective

The research accepted that no design can operate in isolation of real landscapes: pragmatic and place-specific designs are required. In seeking a response to the complexities and challenges previously outlined, the NGN design seeks to be a flexible entity, ably reconciling differences and bridging the gap between idea and practice through aligning this ideal model to real landscapes. This is a design that operates as a flexible framework and point-of-departure for iterative design and not as a final model, as is common in conservation planning. Therefore further to the iterative design process involving local stakeholders, the NGN required detailed designs and (at least) a rudimentary cost/benefit analysis. This was achieved by translating the charette results into an accurate, quantifiable and detailed plan for the York study area. This plan would not only 'join the dots' but also explore the potential for synergistic benefits and trade-offs between multiple land-uses. The design explores species assemblage and structure via restoration efforts to achieve multi-functional and 'synergistic' benefits, those that simultaneously maximise both ecological and cultural outcomes. Finally, designs aimed to be visual. The final design would be costed and benefits and impacts summarised with visualisations of the proposal.

Design Process (Method)

Detailed design occurred in three stages. First the 'digitisation' of the charrette design and the correction of inaccuracies. Second the trimming and adjustment of the 'form' through realignment to rural cadastre, landform and remnant vegetation. Third the exploration of ‘function’ (and multi-functionality) offered via the synergistic possibilities of ecological restoration. Calculations were then made by:

1. accounting for the area impacted under the proposal and potential income loss;
2. calculating vegetation already in existence; costs attributed restoration/revegetation efforts such as ripping of land, planting and new fence lines;
3. calculating the carbon sequestration potential ($) via the national carbon farming initiative (Australian Government 2012) and costing the relative ecosystem service benefits of mitigating salinity and soil erosion protection, increasing property values, tourism opportunities and so on.

Digitisation of the original charrette outcome

In order to create accurate and measurable designs that could be recognised for their potential benefits a translation of imprecise drawings to the digital was made (Fig. 3). To remain without bias this occurred through precise redrafting of the charrette informed by the revision of notes, recorded discussions and adherence to the rules of adjustment established at the charrette. Consequently, drawing inaccuracies were rectified where in conflict with the charrette intent.

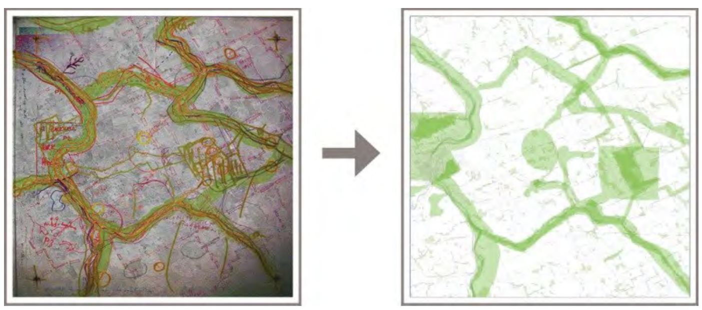

Figure 11 | A digitised version was created from the design charrette outcome

Refining the NGN Form

The second step concerned the fine scale re-alignment to landscape elements (such as remnant vegetation, roads and cadastre) to create a network hierarchy of corridors, stepping stone linkages and new core areas. The existing land cadastre was used as the basic building block for the detailed design with affected land parcels chosen and, if necessary, trimmed to align to landscape elements. As this new form wherever possible enveloped remnant vegetation patches and accepted the rural cadastre, a reduced number of land-holders are affected. This resulted in an overall reduction of the land (and therefore cost) required for ecological restoration from 10594 ha to 8039 ha as well as a reduction in fencing to just 30 linear kilometres. This resulted in a more pragmatic design (Fig 4) that closely reflects the charrette intent. The final form also created a hierarchy of connectivity linkages of varying widths and contiguousness as promoted by the charrette.

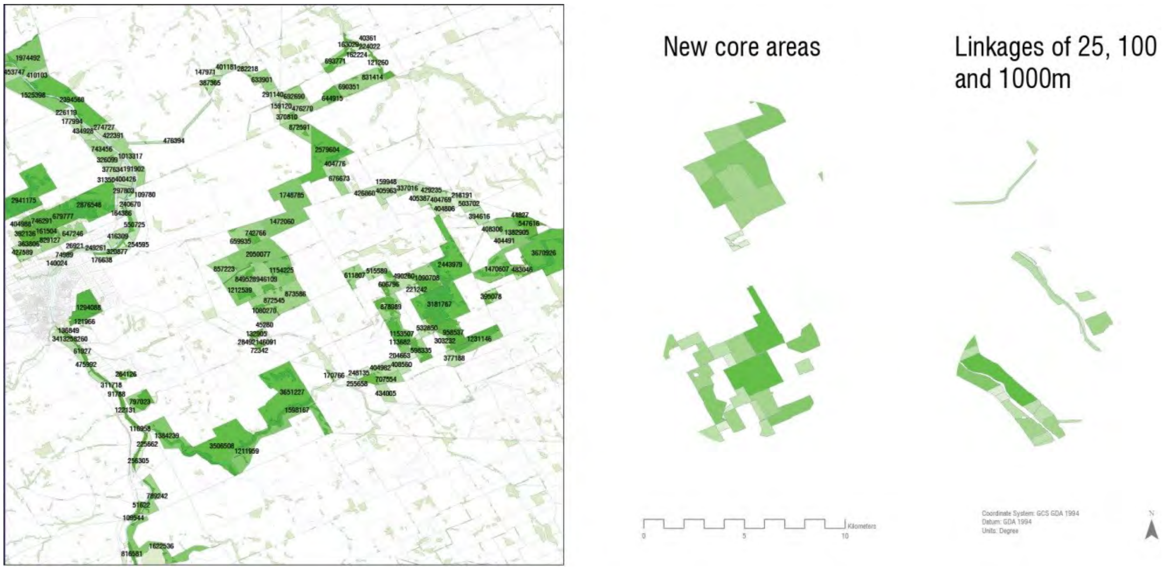

Figure 12 | Final detailed design. Inset: Detail of affected parcels of land reduced in number and trimmed.

Defining the NGN Function

While the form of the linkages was finalised; their function still required resolution. This third step explored a range of functions via ecological restoration approaches. This included high standard ‘ecological’ restoration, ‘cultural’ and alternative ‘synergistic’ opportunities. These created a range of ‘functions’ and highlighted future ecological trajectories and cultural benefits.

1. ECOLOGICAL FUNCTION. The first was a restoration approach that maximised the number and diversity of endemic species with a structure and high fidelity to pre-European ecological state. Cultural benefits, including CO2 sequestration were secondary. The cost to establish this scenario was estimated at $10,000/ha.

2. CULTURAL FUNCTION. The second scenario was revegetation as agro-forestry. Native and exotic tree species (*Eucalyptus, Pinus* spp.) ‘minimum stem’ count was assigned to maximise carbon sequestration potential. Function was considered economic, but some secondary ecological benefits would inevitably entail. The cost to establish this scenario was estimated at $3000/ha.

3. SYNERGISTIC (multi)FUNCTION. The third scenario was a synergistic middle-ground. The design provides for the minimum planting to sustain CO_2 credits yet also maintains biodiversity benefits through augmenting the overall endemic species numbers and diversity, through the selection of species that could benefit the wider landscape and biota yet could also provide cash-cropping e.g. Oil Mallee (*Eucalyptus* spp.) and Sandalwood (*Santalum* spp.). The final structure is a novel ecosystem characterised by greater structural and species diversity than ‘Cultural’ yet less than ‘Ecological’ scenarios. The cost to establish this scenario was estimated at $6000/ha.

Final Calculations

Results aimed to be spatially accurate, measurable and visual. Final costs and benefits (Table 1) of the refined design reflect land cost, change in rural income and the cost of revegetation. Benefits of the system were also calculated including the carbon sequestration capacity of the proposed system and reflect benefits such as securing biodiversity, increasing property values, long-term landscape health and the creation of large scale recreational and aesthetic amenity. These figures were drawn from industry practice and literature following extensive calculations.

Table 2 | Cost benefit summary of three scenarios

	TOTAL COST	TOTAL BENEFIT/Year	BALANCE (Over 20 years)
Scenario 1 'Ecological'	$80,875,340	$4,030,405	- $267,240
Scenario 2 'Cultural'	$24,602,340	$3,901,096	+ $53,419,580
Scenario 3 'Synergistic'	$48,719,340	$5,209,770	+ $55,476,060

Final Visualisations

As spatially accurate plans with encoded geo-spatial information, exploration is possible at the desktop with freely available Google Earth files, *in situ* via Augmented Reality (AR) with smart phone or GPS and/or by Computer Generated Image (CGI) in hard copy or on screen or website (Fig. 5).

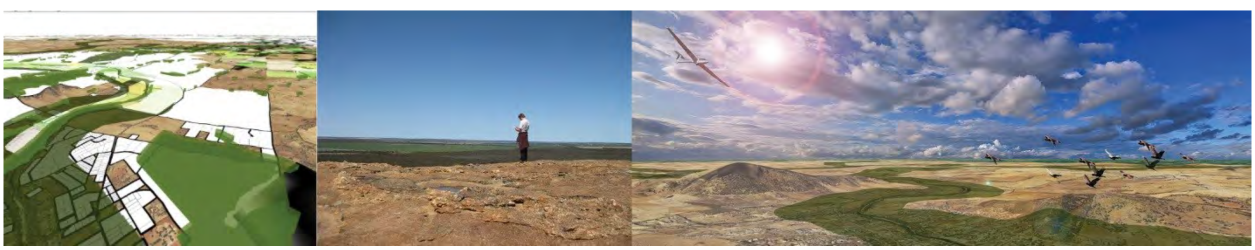

Figure 13 | Examples of the visualisation of the NGN: Google Earth; on-site with AR; and CGI.

Discussion and Conclusion: Assessing the Research Benefits

This paper has presented the results of research towards creating a new green infrastructure within a 25 x 25km study site in rural Western Australia. A Landscape Architectural projective design approach established a pragmatic and final detailed design. This design demonstrates that accurate, measurable and visual designs are required to shift from the theoretical to the practical. Through establishing a blueprint to recreate ecological connectivity linkages across fragmented landscapes, to meet biodiversity policy targets and provide robust ecosystem services, the design is reconciled with existing land-use. Research interpreted 'rules of adjustment', drawn from a design charrette with local stakeholders, then finalised the NGN 'form and function' design through detailed design resolution. This created spatially accurate, measurable and visually explicit final designs. A broad cost/benefit analysis of three scenarios, dependent upon the fidelity to ecological restoration, highlighted the benefits of an interconnected network of protected areas and confirmed the potential of this approach.

The final design expresses more than just habitat restoration for the long-term survival of the Australian biota. A spectrum of design intervention possibilities created landscape linkages of differing geometries and structural compositions. In this research a design approach with exploration via scenarios enabled the exploration of potential benefits beyond pure conservation objectives. These include the establishment of recreational greenways and cultural corridors that can be related to indigenous culture; agro-forestry to sequester carbon; and, a plan for degraded rural landscapes to deal with erosion, salinity and water security. These final multi-functional NGN designs break down the nature/culture binary and create hybrids of ecological and cultural functions, a new landscape characterised by novel ecosystems with measurable benefits for ecology and culture. The 'synergistic' scenario – the one that provided a balance of ecological and cultural benefits – proved not only to be the cheapest, but the outcome most likely to be implemented due to its broader appeal and suite of benefits.

The research created a plan that confirms the need for a flexible and holistic approach. Consideration must be made of the realities of working landscapes and their composite parts, be they ecological or cultural, when creating robust landscape designs. Factoring in of all variables and opportunities into a design process means that complementary or 'synergistic' potential benefits can be realised. GI as an ideological framework and organiser of landscape can help achieve this aim. GI can extend beyond greenways and ecological network approaches to offer a holistic spatial planning solution, exploring synergistic ecological and cultural benefits and help to create more resilient landscapes.

This paper argues that a broad spectrum of landscape possibilities such as those uncovered by the research will help to establish greater ecological and cultural resilience in complex landscapes and offer holistic 'win-win' approach to landscape planning. Engagement with real landscapes, land-uses and the limits and constraints that they impose allowed for iterative and adaptive designs which can only be described as 'synergistic'. Flexible, accurate, measurable and visual: these final designs express more than just habitat restoration to protect the Australian biota against climate change. Rather these synergistic designs negotiate a new path towards holistic landscape planning. The exploration and visualisation of scenarios – accompanied by visualisation, measurement and quantification of both ecological and of cultural benefits – means that the real work of restoration can now begin.

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