Improving the efficiency of biodiversity investment | Final report

By Natalie Stoeckl, Taha Chaiechi, Marina Farr, Michelle Esparon, Silva Larson, Diane Jarvis, Adriana Chacon and Lai Thi Tran

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JAMES COOK UNIVERSITY AUSTRALIA

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For further information contact Natalie Stoeckl: natalie.stoeckl@jcu.edu.au

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Charles Darwin University, Darwin Northern Territory, 0909, Australia.

Contents

Abstract

The overarching aim of this project was to provide information that would help improve the efficiency of biodiversity investments in northern Australia. We collected social and financial data from land managers across northern Australia, combined it with publically available biophysical data and analysed it using several different techniques. Controlling for a range of factors (e.g. size of property, rainfall), we found little evidence of a trade-off between biodiversity and agriculture, suggesting that conservation need not occur at the expense of agriculture in this region. We have also established that there are significant co-benefits (to agriculture) from programs that mitigate threats to biodiversity by controlling weeds. These programs represent more efficient investments than those which do not generate co-benefits. Our analysis also indicated that programs which promote on-farm diversification, improve land management practices and/or promote conservation-friendly attitudes could generate improvements in biodiversity without imposing costs on the agricultural industry, and that those who seek to promote biodiversity using financial rewards or penalties could increase the effectiveness of their programs by also using social rewards and penalties.

Principal focus, and why this is of significance

> *Our aim was to provide information that could be used to promote the efficiency of biodiversity investments in northern Australia. Most land in this region is privately managed for agriculture, so our principal focus became one of learning more about the costs of on-farm conservation.*

Scarce resources – particularly for biodiversity conservation[1]– means that it is essential to work out how to achieve environmental outcomes at minimum cost (Margules & Pressey 2000; Pannell 2008; Doole *et al.* 2014). Throughout the world, and especially in the UK, Finland, Poland, the US and Australia, much biodiversity, and many high-priority conservation areas are on privately owned or managed land (Hanley *et al.* 2012; Figgis *et al.* 2005; Pressey *et al.* 2000). The story is no different in northern Australia, where low intensity pastoralism comprises 75% of the area (Woinarski *et al.* 2013). Our principal focus thus became one of learning more about the costs and benefits of on-farm conservation in this region.

On-farm conservation is often achieved by developing on-farm 'programs' designed to encourage land managers to undertake conservation-related activities. Examples include the US Conservation Reserve Program (Claassen *et al.* 2008), the UK Environmentally Sensitive Areas (ESA) program (Dobbs and Pretty 2008), the Victorian Bush Tender Program (Stoneham *et al.* 2003), the New South Wales Environmental Services Scheme, and the Queensland Nature Assist program (Fitzsimons & Westcott 2004). Simplistically, these programs require land managers to pursue both market and non-market objectives, which are not always complementary and may thus impose costs on land managers. This may require government or other conservation organisations to compensate land-owners, which requires one to be able to assess trade-offs (McCarthy & Possingham 2012) to determine the amount of compensation required.

Programs that pay farmers for providing environmental services are a common means of providing such compensation, but these schemes do not always create genuine 'additionality' (Engel *et al.* 2008, Claassen *et al.* 2013). Formally, additionality is the environmental impact that occurs above and beyond that which would have occurred in the absence of the program (Lobley & Potter 1998). Lack

1 Australia is one of the bottom 40 countries in the world for spending on biodiversity conservation (Waldron *et al.* 2013)

of additionality can occur for a variety of reasons. For example, entry conditions and requirements for conservation programs are often set low to maximise participation; but this means that land holders may not need to 'do' much. They may, for example, be able to offer to 'protect' unproductive land (which they would not have used anyway) whilst continuing with grazing or other non-conservation focused activities elsewhere (Moon & Cocklin 2011). There may be some conservation minded farmers, who would have adopted the conservation practices anyway (Morris & Potter 1995; Pagiola 2008; Moon & Cocklin 2011), but now receive payment for doing it. As such there are cases where on-farm conservation programs create few genuine environmental outcomes, but still cost the government or others money (Engel *et al.* 2008; Garcia-Amado *et al.* 2001; Segerson 2013). In the US, Claassen *et al.* (2013) estimate that between 54% and 83% of on-farm conservation practices create genuinely 'additional' environmental impacts, but estimates are much lower in the UK: Armsworth *et al.* (2012) estimate that only $0.12 to $0.46 per dollar of public funds invested in Payments for Environmental Services (PES) schemes can be considered to be an actual compensation for loss of farm income, the remainder is 'pure subsidy'.

We agree with Armsworth *et al.* (2012), who emphasise that subsidies may help prevent land abandonment, the ecological outcomes of which are not well understood (Evans *et al.* 2006; Hanley *et al.* 2008; Amar *et al.* 2011), but which could potentially be quite detrimental. Some PES schemes are not actually intended to achieve additional environmental outcomes, but to reward stewardship. It must be stressed that care should be taken not to conclude that such subsidies are 'bad' or 'wasteful'. If the primary goal is to create genuine environmental improvements at least cost, then it is essential to understand the 'true' costs of doing so. Hence the importance of this research project.

Distinctiveness of issue to this landscape

> *As a signatory to the Convention on Biological Diversity, Australia has an international obligation to protect the biodiversity of Australian ecosystems. But there is also a strong desire to encourage economic growth in northern Australia – particularly within the Agricultural sector. This makes it all the more important to find ways of meeting international obligations, 'efficiently'.*

Historically, harsh climatic conditions, and the significant temporal and geographic scarcity of water has inhibited both European settlement and economic growth in northern Australia (Bennett 2005; Jackson *et al.* 2008). This means that the north has much lower population densities than elsewhere and that the economic structure of northern communities differs, sometimes substantially, from that of southern communities (Stoeckl & Stanley 2007). It also means that the region contains some of the most intact ecosystems in the world (Woinarski *et al.* 2007) – some of which, as a signatory to the Convention on Biological Diversity, Australia has international obligations to protect,

In terms of land-use, low intensity pastoralism dominates the north (Woinarski *et al.* 2013) and the industry generates significant income. In 2010-2011, for example, the gross value of the northern Australian agricultural production at the farm gate was AUS$5.2 billion (ABARES 2013; ABS 2012). Although accounting for less land area, other types of agriculture also make a significant financial contribution to the region: 90% of Australia's mango and banana crop and millions of tonnes of sugar are grown in the north each year (ABARES 2013; Commonwealth of Australia, 2014).

The area has been earmarked as having significant agricultural development opportunities (Commonwealth of Australia, 2014). Although the intention is to do this without compromising the natural environment, there is potential for conflict between development and conservation (Dale *et al.* 2014; Petheram *et al.* 2013; Stoeckl *et al.* 2013). It is therefore vitally important to find ways of meeting international obligations to protect biodiversity without imposing undue costs upon the agricultural industry.

Knowledge status and constraints

Estimating conservation costs in agricultural settings is particularly difficult because the complexity of the relationship between agricultural and 'natural' systems means that some conservation-related activities generate co-benefits for agriculture while some conservation-activities impose costs (suggesting the existence of a trade-off). To the best of our knowledge, no one has ever attempted to assess the 'true' cost of undertaking biodiversity activities on farms in Australia – likely to be at least partially because of significant data constraints.

Agriculture is both a consumer and a provider of ecosystem services (Power 2010), the implication being that agricultural and natural systems are inextricably and dynamically linked. For example, agriculture relies upon (or 'uses') genetic biodiversity, good soil and rainfall; in turn, it 'produces' things such as food and may also generate environmental impacts – both good and bad (TEEB 2010). Taking an economic production-function perspective, we can thus think of agriculture as a system where various natural and man-made 'inputs' (e.g. land, water, labour and machinery) are combined to generate (or, in economic jargon, to 'produce') various 'outputs' – some of these outputs can be sold in the market place (e.g. cattle, crops), and some cannot (e.g. aquatic or terrestrial biodiversity) - Figure 1. But the amount that is 'produced', does not just depend on how many 'inputs' are used. It also depends, interactively, on numerous intervening influences relating to:

- the external environment (e.g. prices, exchange rates, government policiesreliability of transport and communication networks, availability of social capital, pest and weed incursions)
- land management (e.g. agricultural and conservation practices)
- the attitudes, expectations and priorities of land managers.

Estimating conservation costs in systems such as these is thus extremely difficult because one needs to control for all these intervening influences and because the complex interrelationships mean that some conservation-related activities generate co-benefits for agriculture while some conservation activities impose costs.

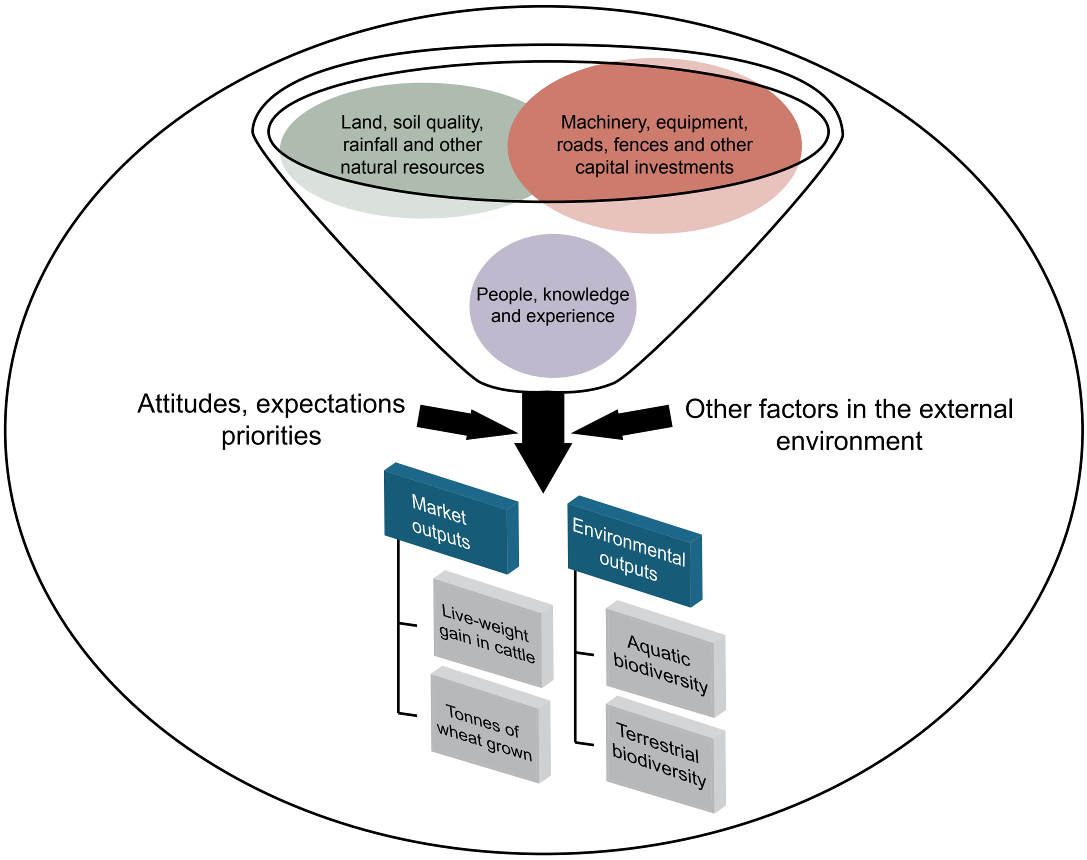

Figure 1: Agriculture and Conservation as a complex multiple 'input'/multiple 'output' production system influenced by external factors as well as by the attitudes, expectations and priorities of land managers

There is a substantial body of literature concerned with the nature of the relationship between agriculture and various ecosystem services that highlights "the possibility of symbiosis [co-benefits] between agriculture and the environment" (Harvey & Whitby 1988; see also Mahmoud & Shively 2004; Norton *et al.* 2009; Acharya 2006). But most of this has been undertaken from a biophysical perspective (Hodge 2008), with costs given comparatively little prominence. Literature that looks for co-benefits or trade-offs between agricultural production and biodiversity conservation using quantitative methods remains relatively sparse although this is an expanding area of research.

Arguably the biggest challenge facing applied researchers in this field relates both to data and to methods (Armsworth, 2014). Economists, particularly those working in agriculture and health, have developed numerous sophisticated methods for analysing complex production systems (Farrell 1957; Coelli *et al.* 2005). But most of these techniques are very data hungry. Those wishing to use them to assess on-farm conservation programs thus require both economic and ecological/biodiversity data for large numbers of individual farms – ideally over long periods of time (see, for example Peerlings & Polman 2004; Fleming *et al.* 2010; Sauer & Wossnik 2012). Although the Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES) has been conducting regular farm surveys since 1989/90, these surveys do not collect related motivational/attitudinal information or information relating to biodiversity or the natural environment. To maintain confidentiality, the locations of participating farms are not released so this data cannot be linked to particular points in space or to other relevant biophysical data (e.g. relating to rainfall or soil-type).

The research team have established that an integrated analysis has never been done in Australia and internationally only one group of researchers (Armsworth *et al.* 2012) have used biophysical data in their analysis of agricultural/natural systems – (they used an indicator of bird diversity in conjunction with data collected by themselves on 44 properties in the UK). Other international studies have instead been forced to use financial proxies such as the revenue which farmers have obtain from providing environmental services (Peerlings & Polman 2004; Sauer & Wossink 2012) or the proportion of property that was 'rough grass-land' (Fleming *et al*. 2010). No one has been able to assess costs, while controlling for a variety of biophysical and social factors (such as soil type, rainfall, farmer attitudes). Our understanding of the true costs of biodiversity almost anywhere in the world, and in northern Australia in particular, can thus best be described as minimal.

Methodological approaches

We developed questionnaires and collected social and financial data from more than 130 properties across the north. We were able to identify numerous public databases which contained geographically referenced biophysical data, and used Geographical Information Systems (GIS) to 'match' this to the social and financial data. We analysed the combined data set using a variety of different economic methods: by estimating production (revenue) functions, cost functions, efficiency scores, and determinants of life satisfaction.

One cannot simply work out how much it costs to undertake a conservation related activity and allocate all of those costs to 'conservation'. For example, grass cover helps prevent soil erosion and provides good habitat for some animals, but it is also good for cattle. So conservation activities that promote grass cover generate 'co-benefits' for the agricultural industry. Ignoring those 'co-benefits' and trying to estimate conservation costs by simply looking at expenditure, will mean that the 'true' cost of these activities are over estimated. At the risk of over simplifying things, it is almost as if the 'true' costs of these types of conservation programs should be estimated by working out how much is spent on them, and then subtracting all the good things (co-benefits) for agriculture. Similarly, if conservation programs impose costs on farmers (instead of creating co-benefits), then we need to add in those extra costs to actual expenditures when estimating 'true' costs[2].

The challenge therefore, is to determine if co-benefits or trade-offs exist. Neither cost-benefit nor cost-effectiveness analysis are particularly well suited to this type of analysis (Mallawaarachchi & Green 2012); whole-of enterprise type approaches are, instead, recommended. After collecting and collating data from a wide variety of sources, we then analysed it using several different approaches (Figure 2) – essentially looking for multiple lines of evidence. Further details are given on the following page.

2 Naidoo *et al.* (2006) use the phrase 'opportunity costs' when referring to this issue. Formally, they define opportunity costs as the change in market production that results from conservation programs, activities or actions. Although the word 'cost' is used, they note that it is possible for the costs to be either positive or negative, representing, respectively, situations in which conservation generates trade-offs or co-benefits in agriculture.

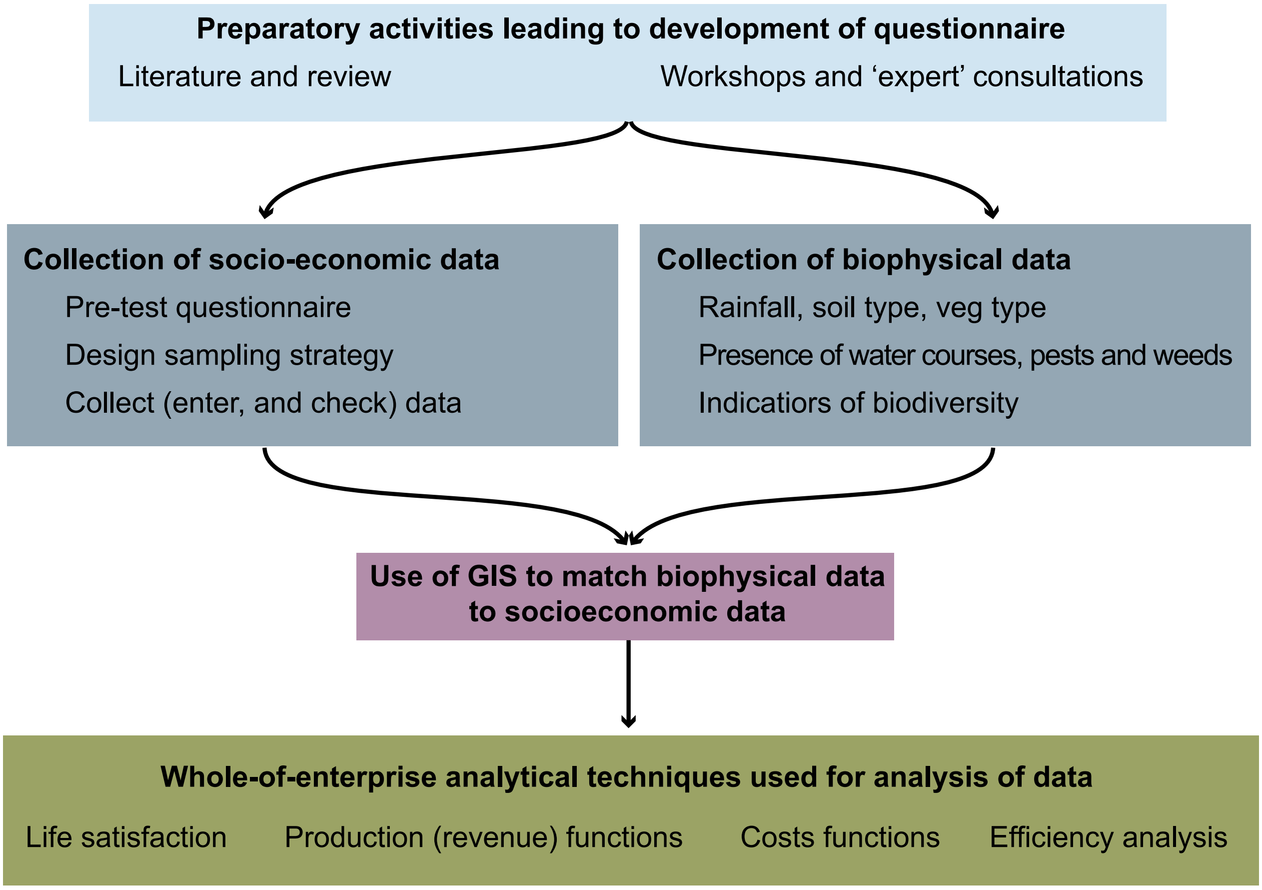

Figure 2: Summary of methodological approaches used in the project

First, we used a combination of desktop reviews, expert workshops[3], and targeted interviews with scientists, government agency staff, and land managers to identify a set of variables that could be used as proxies for (a) various 'inputs' and 'outputs' associated with agricultural production and biodiversity conservation in northern Australian agriculture; and (b) intervening influences (Figure 1). We were able to identify numerous public databases which contained geographically referenced biophysical data – some of which could be thought of as describing environmental 'inputs' (e.g. soil type, rainfall), and some of which could be thought of as being biodiversity 'outputs' (i.e. indicators of biodiversity and/or of threats to biodiversity) (see Appendix). We developed questionnaires (piloted with peers, in workshops and with agricultural producers) to collect social and financial data from land managers.

We chose to focus data collection efforts in two regions: the Daly River Catchment in the northern Territory (since it has both pastoralists and more intensive agriculturalists) and northern Queensland (QLD) – which also has grazing and intensive agriculture (see Figure 3). Properties were identified using a cadastral database. We excluded properties that did not list agriculture as a primary land use.

3 Participants included graziers, representatives from QLD Government; Cape York Sustainable Futures; Kowanyama land and Natural resource management office; Groundwater Flow Systems in Mountainous Terrain; Wet Tropics Management Authority (WTMA); Northern QLD Land Management; Tablelands re-vegetation unit; several northern QLD regional councils; the Daly River Management Advisory Committee; the Daly River Aboriginal Advisory Group; and Agforce. Comments and input were also elicited from economic, social and biophysical scientists.

This left us with 253 unique properties in the Daly River catchment, but the Queensland cadastral database contained almost 78,000 records. To further refine our sample for Queensland we discarded properties south of Rockhampton (although we needed to go down as far south as this to ensure that our sample included a reasonable number of free-hold properties since most northern properties are leasehold). We then ordered the remaining properties by size and randomly selected 100 properties from each decile for inclusion in our survey (to ensure a cross-section of sizes, thus enabling us to look for, and if necessary control for, economies of scale). After screening for duplicates, we were left with 570 properties within Queensland – approximately evenly distributed across the deciles. In April 2013 we mailed out a copy of the questionnaire to our selection of properties with two rounds of follow-up survey. Mail-out responses (n=111, with an estimated response rate of 13.5%) were supplemented with face-to-face interviews conducted in the Gilbert River Catchment, in north West Queensland (n=26).

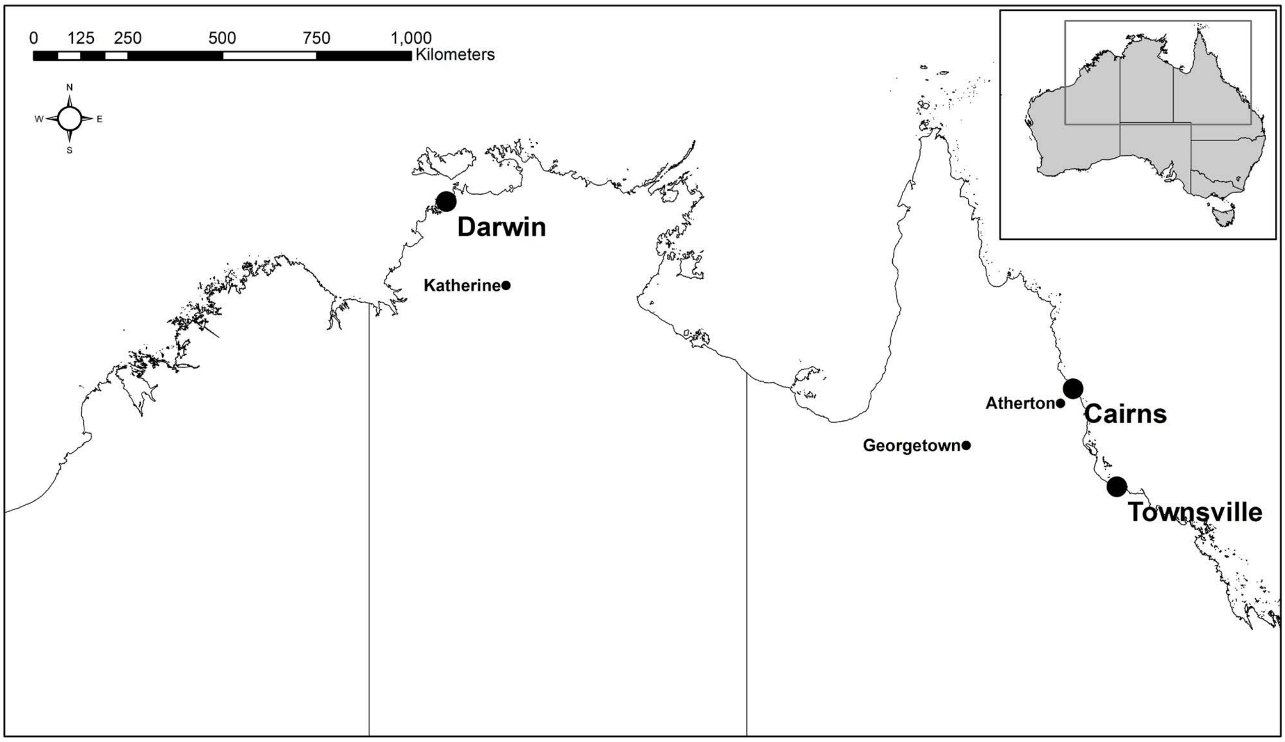

Figure 3: Northern Australia and key towns (Katherine, Georgetown, Atherton) in and around our study area

We used Geographical Information System (GIS) software to 'match' the biophysical data to the social and financial data collected via survey (see, for example Figure 4 which shows soil types across our study region), and four different whole- of-enterprise approaches to analyse it, as detailed below.

1. We used the Life satisfaction (LS) method to identify the most/least significant determinants of the overall quality of life for land managers (Chacon *et al*. in review). We used both ordinary and ordinal regression, testing numerous determinants, but were, in particular, looking for evidence of a statistically significant link between our indicators of biodiversity (or threats to biodiversity) and life satisfaction after controlling for other intervening factors.

2. We used ordinary least squares (OLS) regression to estimate a Cobb-Douglas production function, formally, setting out to identify and quantify, the key determinants of the value of on-farm-production (Tran *et al*. in review). We were, in particular, looking for evidence of a statistically significant link between our indicators of biodiversity (or threats to biodiversity) and on-farm production after controlling for other intervening factors. We extended the analysis by using estimated parameters to determine the effect of drought on production for an 'average' property, and the likely effect, on agricultural production across the north, should climate change mean more frequent, or more extensive droughts.
3. We used various regression techniques to examine costs. Here too, we were looking for evidence of a statistically significant link between our indicators of biodiversity (or threats to biodiversity) and costs after controlling for other intervening factors.
4. We used Output-Oriented Data Envelopment Analysis (DEA) to identify properties that were particularly 'efficient' at turning 'inputs' into (a) market outputs; (b) non-market outputs; and (c) a combination of market and non-market outputs (Stoeckl *et al.*, 2005). The inputs (i.e. controlling factors) that we used in this analysis were: rainfall during previous 12 months; the size/area of the property; the value of machinery and equipment on the property; and the total cost of all other inputs. Simplistically, the DEA analysis grouped properties that had similar amounts of inputs (i.e. land area, rainfall, capital equipment, other inputs). It then compared the output of each of those 'similar' farms, identifying properties which didn't produce as much as expected and producing an 'efficiency score' for each property. We used various different regression techniques to look for statistically significant relationships between those efficiency scores and other factors, to see which ones played a key role in determining 'efficiency'.

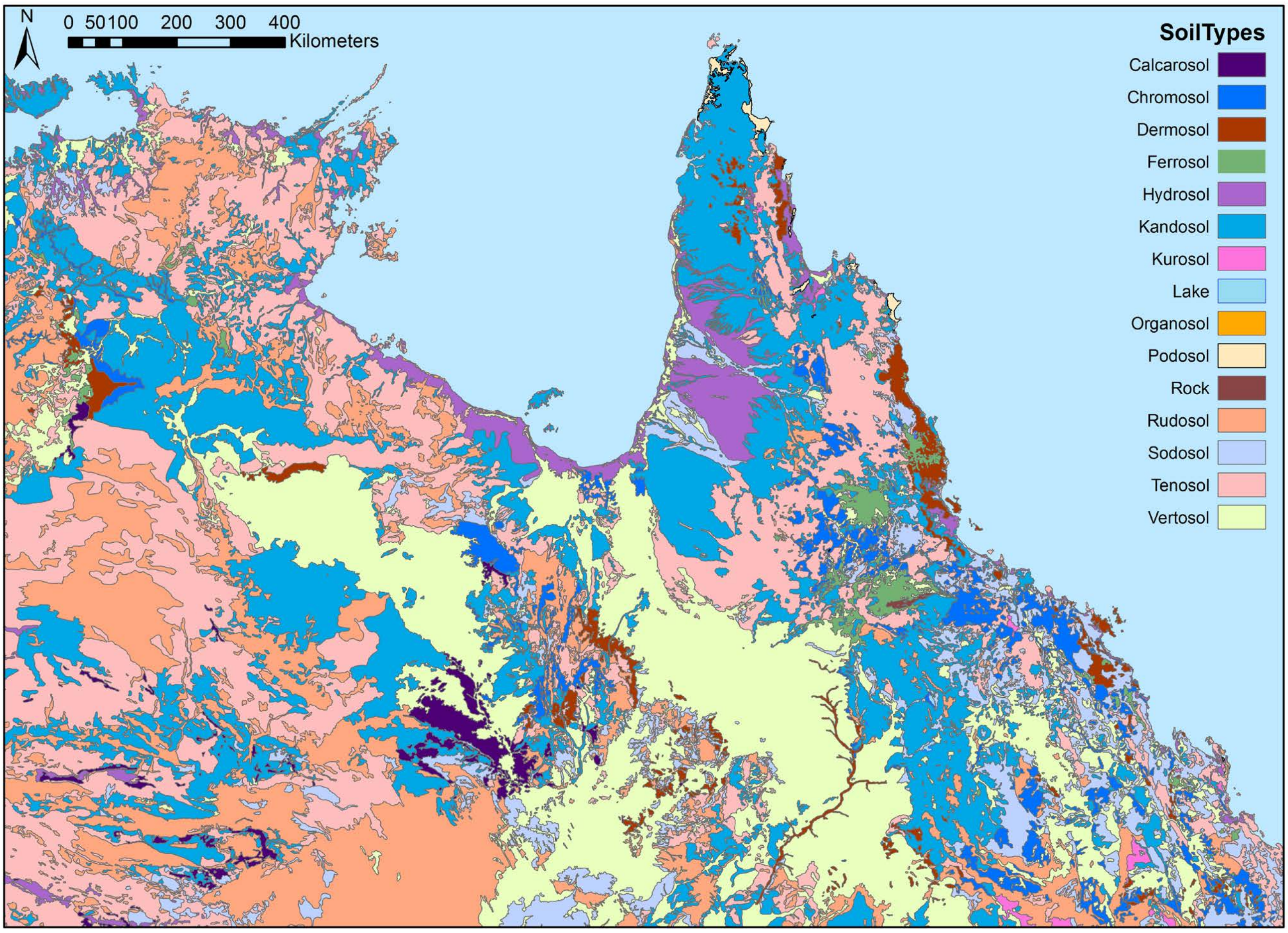

Figure 4: Soil types across our study region

Lessons learnt for this landscape

In line with researchers elsewhere in the world (Diener & Biswas-Diener 2011; Achor 2010; Esparon *et al.* 2014), we found that for our sample of land managers, the single most important contributor to overall Quality of life (QOL) was relationships with family and friends (Chacon *et al.*, in review). Contrary to expectations, we did not find a statistically significant relationship between profits and life satisfaction. This could at least partially reflect the fact that in this study we looked at the relationship between profits/farm-income and life satisfaction, rather than that which is normally investigated (household income and life satisfaction). But results did not change when we only considered those who both managed and owned their property. As such, the most likely explanation seems to be that for this group of respondents, money is a means to an end, not an end in itself (Diener & Seligman 2004). Such an interpretation is consistent with previous research which suggests that money/production is less important to the overall quality of life of northern Australian residents than social, environmental and aesthetic values (Larson *et al.* 2013; Larson *et al.* 2014; Stoeckl *et al.* 2014, Esparon *et al.* 2014). In accordance with other researchers (Welsch & Kühling 2009; Falk & Balling 2010), we also found evidence to suggest that the environment is important to overall quality of life (e.g. more rainforest associated with higher overall LS), but without further research, are unable to determine how/why this is so.

After controlling for a range of different external factors, we could find little to no evidence of a statistically significant link between any of our indicators of biodiversity (see Appendix) and agricultural production – using the traditional Cobb-Douglas production function approach (Tran *et al.*, in review), cost function analysis or the more innovative DEA approach (Stoeckl *et al.*, 2015). The single exception to this related to a potential trade-off between agricultural production and turtle diversity – although we note that this relationship does not imply causation.

First, as expected, we found that costs were higher for larger properties, for those with more machinery and equipment, more labour and/or with more debt. Superficial inspections of the cost data suggested that costs also differed across properties with different land-management practices, but after controlling for factors such as property size, labour and focus (livestock or other), we could find no evidence of a statistically significant link between production costs and our indicators of biodiversity.

Second, and also as expected, we found that the farms which produced most had more land, more labour, more capital and more fertile soils. But both our 'traditional' Cobb-Douglas production function analysis and our more innovative DEA analysis also clearly indicated that weeds have a significant, detrimental effect on production (our Cobb-Douglas analysis indicates that having one more 'listed' weed on the property could reduce output by up to 25% - Tran *et al.* in review). This is in accordance with the findings of other researchers (Holt 2011; Walker *et al.* 2005; Sinden *et al.* 2005) and ABS 2008) and affirms that programs which control threats to biodiversity (specifically, weeds) generate co-benefits for agriculture.

We also found that drought almost halves output (Tran *et al.* in review) – estimates which are comparable to other studies (Homewood & Lewis 1987; Madden & Horidge 2005; Peck & Adams 2010). We were able to use estimates from our model to infer that if climate change (a) increased the frequency of drought (from the existing situation of approximately 1 in 10 years to a bad case scenario of 1 in 2 years), and (b) doubled the number of properties affected each time it occurred (from the existing 11% to 22%), then this could reduce 'average' agricultural output in the north by as much as 16.5% per annum.

Third, our DEA analysis revealed that, after controlling for various extraneous factors (e.g. size of property, soil type and rainfall), land management practices, attitudes and the diversification of on-farm revenue streams did not have a noticeable impact on the 'bottom line' (i.e. on-farm production or finances). But these things did seem to impact the environment: having weed and stocking plans, or stock water points, having a positive attitude towards conservation, prioritising 'lifestyle' and not being dependent upon livestock for more than 70% of farm revenues, were all things that, on occasion, appeared to be 'good' for the environment, but didn't impose 'costs' on land managers by reducing productivity. The observation about properties with a livestock focus, lends some support to the findings of Woinarski *et al.* (2013) who compared biodiversity outcomes across conservation only and pastoral only properties in the NT, concluding that species were less abundant on pastoral properties. Our findings about the importance of attitudes also support those of previous researchers who have highlighted the importance of landholder attitudes and motivations for NRM outcomes (Greiner & Gregg 2011; Marshall *et al.* 2011).

National implications of lessons learnt

Our study area is representative of the ecological, cultural, and socioeconomic values in northern Australia (Pusey 2011; Kennard 2011), and these characteristics are shared by other areas in northern Australia. This suggests that our research findings are relevant elsewhere; perhaps not only in northern Australia, but maybe also in other rural/remote parts of Australia where agriculture is undertaken in relatively intact landscapes.

LESSON ONE: There doesn't seem to be a trade-off between biodiversity and agriculture in this part of Australia.

We used many different 'tools' to analyse our data, looking for evidence of a trade-off between biodiversity and agriculture (after controlling for things like soil type, rainfall, etc.). We found little. In this part of Australia (at least at this point in time), it is quite possible that protecting the environment doesn't mean we have to hurt the agricultural industry – we just need to be a clever about how we do it (see lessons two to four below for ideas).

LESSON TWO: Social factors are vitally important to NRM policy.

Our life satisfaction analysis clearly indicated that the single most important factor influencing the quality of life of land managers is having good relationships with family/friends, and our DEA analysis highlighted the importance of social factors (e.g. land manager attitudes and priorities) for biodiversity outputs. A general assumption that underpins (economic) advice given about market based policy instruments is that people 'value' money, but do not 'value' the environment. Simplistically, market based policy instruments thus seek to attach financial rewards or penalties to activities that impact the environment, reasoning that by undertaking activities that make them wealthy, people will (incidentally) be enticed into undertaking activities that are also beneficial to the natural environment. Our research suggests that in agricultural settings such as these, social rewards and penalties may prove to be an even more powerful means of influencing behaviour than financial rewards and penalties. In other words, biodiversity investments which promote the social benefits of conservation may have greater uptake and achieve more genuine 'additionality' than those which promote only the environmental or financial benefits; and it may be worth considering the idea of developing policies that explicitly generate social rewards and penalties for activities that impact the environment.

LESSON THREE: Investments in conservation-focused activities which help to control threats to biodiversity (e.g. weeds and pests) are likely to also benefit those in the agricultural industry

We found strong evidence to suggest that things which threaten biodiversity (weeds and drought) also have a negative impact on farm productivity. So controlling weeds will benefit both the environment and agriculture. As such the 'true' cost of controlling weeds and pests is less than that indicated by simplistic (e.g. expenditure) assessments, and investments in (properly managed) programs that control pests and weeds may thus be relatively more 'efficient' than programs that do not generate co-benefits elsewhere.

LESSON FOUR: Investments which seek to promote on-farm diversification, improve land management practices and promote conservation-friendly attitudes amongst land mangers could generate improvements in biodiversity without imposing costs on the agricultural industry. These investments do not necessarily generate co-benefits for agriculture, but they do not impose costs. As such, they could help promote biodiversity without creating a financial burden for the agricultural sector.

Problems addressing the focus and how to overcome

It is, at the best of times, difficult to convince people to complete surveys – particularly if asking for confidential data on costs and revenues. Such questions are all the more intrusive when asked of those who are in significant financial stress – a problem which arose because much of our study area was impacted by drought (one, which at the time of writing this chapter, is on-going). It is all the more difficult to convince people to complete another survey, when they are regularly asked to complete surveys for the ABS and for ABARES, and for other researchers. We attempted to at least partially address the problem of 'too many surveys' by collaborating with others NERP researchers who were collecting data from land managers across the north (Vanessa Adams in the Daly region; with Jorge Alvarez-Romero in the Gilbert), but could not control for the drought. Understandably, our response rates were lower than we would have hoped, and the relatively small sample size thus provided analytical challenges. We met this challenge, by using multiple different methods (all suited to small samples) – thus providing multiple lines of evidence. We note that the only other research that we know of that has blended financial and biophysical data, asking similar research questions (Armsworth 2012) did so with a sample of just 44. We do, however, note that it could be important to replicate this study with a larger sample – ideally incorporating a wider variety of land tenures/uses (we collected some data from conservation and Indigenous-managed properties, but this sub-sample was too small to allow us to make comparisons with the other properties).

Our other significant challenge related to the identification of appropriate indicators for biodiversity. Recognising that none were perfect, we tried many, but note that future investigations could benefit by having access to better indicators of (threats to) biodiversity.

Towards implementation

The Australian Government makes numerous substantive investments in programs that seek to improve the state of, or management of the nation's natural resources. These include investments in the National Landcare Programme (which includes the Environmental Stewardship program), the Reef 2050 Plan, The Green Army Programme, Working on Country, and the Land Sector Package (National Landcare Programme 2013; Australian Government Department of the Environment 2014d).

Our research suggests that these programs are not at odds with the agricultural industry; indeed some may be beneficial – particularly those which seek to control weeds and pests, and promote soil productivity. Our key concern is that simplistic estimates of their 'costs' which consider only expenditures and which do not take these co-benefits into consideration could lead one to overstate their 'true' cost, and thus underinvest.

As demonstrated here and elsewhere, however, it is extremely difficult to estimate the 'true' cost of conservation programs, particularly at large scale (e.g. Australia wide): neither the data nor current methods are yet up to the job. Until substantive improvements are made in that research realm, we tentatively suggest that one could subtract the potential benefits that reduced weeds and pests (or improved soils) might accrue to the agricultural industry from expenditures on these programs to generate a (back-of-the-envelope) estimate of their 'true' cost when making investment decisions.

We note that some current programs compensate land holders for undertaking various conservation-related activities (Australian Government Department of Agriculture, 2014a,b,c), but the literature suggests that not all of that money is likely to create genuine additionality (Engel *et al.* 2008, Claassen *et al.* 2013; Lobley & Potter, 1998). There may be good reasons for making such payments anyway (generating employment, keeping people on their land), but we note that market-based policies are not the only tool at the governments disposal, and our research highlights their potential worth. In particular, our research suggests that one may be able to improve the effectiveness of, and potential uptake of, conservation programs by using social rewards (and sanctions) and by promoting the social benefits of the programs (in addition to financial and environmental benefits). Indeed, even simple things like social events can be used as 'an effective mechanism to break cycles of unsustainable behaviour' (Tucker *et al.* 2009, p. IX). In addition, self-regulation has proven to be a useful tool in many situations, (Langevoort 2002; Krawiec 2003; Estlund 2010) including programs with environmental goals (Coglianese & Nash 2001; Lenox & Nash 2003; Short & Toffel 2010; Stoeckl 2003). As such lending further support to programs such as Landcare Australia, could be an effective way of raising the social profile, and hence adoption, or environmental programs, perhaps generating significant benefits at relatively low cost.

Finally we note that our finding about the potential benefit of agricultural diversification to the environment (which does not appear to impose a financial cost), suggests that those keen to promote development in the north, could do so at least environmental cost, if seeking to capitalise on economies of *scope* instead of simply economies of scale.

Looking ahead – future needs

As a signatory to the Convention on Biological Diversity, Australia has an international obligation to protect the biodiversity of Australian ecosystems. But there is also a strong desire to encourage economic growth in northern Australia – particularly within the Agricultural sector. This makes it vitally important to find ways of meeting international obligations, 'efficiently'.

As demonstrated here, assessing the 'efficiency' of biodiversity/conservation investments in agricultural settings is extremely difficult and, to quote Armsworth (2014): "Inclusion of costs in conservation planning depends on limited data and hopeful assumptions". There are two substantive difficulties when attempting to do this for on-farm conservation programs. First it is very difficult to assess costs. This is because, as demonstrated here, some conservation-related activities generate co-benefits while others create trade-offs. Simplistic assessments of the 'cost' of investments that generate co-benefits (e.g. expenditures on programs that control weeds) may lead one to underinvest in those programs.

Likewise, simplistic assessments of investments that create trade-offs may lead one to overinvest in those programs. Second, it is difficult to assess benefit (Claassen & Duquette 2014). The ultimate aim is to focus on *additionality* – i.e. the environmental benefits that occur which exceed those that would have occurred in the absence of the program. Simplistic assessments of 'benefits' (e.g. counting the number of farmers who agree to sign up for a program) that fail to consider the counterfactual, can lead to over-investment in programs. To make the estimation task even more challenging, conservation costs and benefits are dynamically inter-related, and thus, in an ideal world, should not be assessed separately.

The research described in this report has done much to improve our understanding of some costs of conservation-related activities, but this is a non-trivial problem and there remains much work to do. We thus encourage further collection of data, and further development of methods (some of which have been demonstrated here) to facilitate more accurate assessments of both the 'true' cost and the 'true' benefit of NRM based programs. This could provide substantially improved information to those who must make decisions about how best to prioritise conservation expenditures.

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Appendix

Summary of biophysical variables used in this study

TYPE OF DATA	*SOURCE*
Data describing the characteristics of property	
Soil types (proportion of the property comprising a certain soil, including: Chromosol, Dermosol, Ferrosol, Hydrosol, Kandosol, Rudosol, Sodosol, Vertosol, Tenosol)	CSIRO Digital Atlas of Australian Soils, http:// www.asris.csiro.au/themes/ Atlas.html
Vegetation cover (proportion of the property comprising a certain vegetation type, including: Forest and woodlands, Mangroves, Grasslands, Rainforests, Shrub lands, Cleared vegetation, Naturally bare, Unclassified unmodified native vegetation, Unknown, Water)	Department of the Environment, http:// www.environment.gov.au/ metadataexplorer/ full_metadata.jsp? docId=%7b245434BF-95D1-4C3E-8104-EC4B2988782D%7d
Perennial or non-perennial water course (present or absent within property boundaries)	https://staging.data.qld.gov.au/dataset/ vegetation-management-act-series/resource/ 06cda7dd-0608-4916-b109-6fd15be50110
Annual rainfall (mm); derived from records from hundreds of rain stations across the north, using data from rain station closest to each property	Bureau of Meteorology website http://www.bom.gov.au/
Photosynthesising or other vegetative cover (proportion of the property comprising either photosynthesising vegetation, non-photosynthesizing vegetation or bare soils)	MODIS NBAR Fractional Cover dataset developed by the Environmental Earth Observation Group, CSIRO Land and Water, obtained from https://www.auscover.org.au/xwiki/bin/view/ Product+pages/ Fractional+Cover+MODIS+CLW
Proxies of Threats to biodiversity	
Numbers and names of pests identified within the boundaries of the properties	http://spatial.ala.org.au/#
Numbers of 'Weeds of National Significance' or 'Weeds of State Significance' (QLD) within the boundaries of the properties	http://spatial.ala.org.au/#
Number of listed threatened ecological communities, number of listed threatened species, number of critical habitats, number of invasive species (weeds & animals) at specific locations	The Department of the Environment of the Australian Government Protected Matters database available at http://www.environment.gov.au/webgis-framework/apps/pmst/pmst.jsf

Human Influence Index(HII) weighted average score was calculated for the area within each property boundary. The HII is based on population density, human land use, infrastructure and human access.	Developed by the Wildlife Conservation Society (WCS), Center for International Earth Science Information Network (CIESIN), Columbia University; available at: http://sedac.ciesin.columbia.edu/data/set/wildareas-v2-human-influence-index-geographic/data-download
Proxies for biodiversity	
Number of National Heritage places, number of significant wetlands, number of reserves, number of regional forestry agreements, number of places on the Register of the National Estate, number of listed migratory species at specific locations	The Department of the Environment of the Australian Government Protected Matters database available at http://www.environment.gov.au/webgis-framework/apps/pmst/pmst.jsf
Numbers of species, number of endemic species, number of occurrences of species, number of Australian iconic species each identified within the boundaries of the properties	http://spatial.ala.org.au/#
Indicators of aquatic biodiversity, for the following biodiversity surrogates: freshwater fish, turtles, waterbirds and river types. Species distribution models were used to map the present-day distribution of each species. Aquatic ecosystem mapping and classification was used to map the distribution of hydro-ecologically relevant river types. Shannon's index of diversity (Shannon, 1948) was used to summarise spatial variation in each biodiversity surrogate based on their respective distribution datasets.	Kennard (2010)
Species richness data, for each of amphibians, birds, mammals and reptiles, utilising the weighted averages of the number of different types of each of the four species found within the property boundaries.	Sourced from Dr April Reside, ARC Centre of Excellence for Coral Reef Studies. Data originally accessed from the Australian Atlas of Living Australia (ALA: http://www.ala.org.au/), the Centre for Tropical Biodiversity and Climate Change (CTBCC: https://plone.jcu.edu.au/researchatjcu/research/ctbcc) species data base (Williams et al. 2010), and from the Queensland Museum (http://www.qm.qld.gov.au/).

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Email: nerp.northern@cdu.edu.au
Phone: 08 8946 6761

NERPNorthern

@NERPNorthern

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