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Challenges for valuing ecosystem services from an Indigenous estate in northern Australia

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ABSTRACT

Recent Australian government policy for developing northern Australia applies a standard financial approach that disregards the importance of Ecosystem Services (ES), and the significance of associated socio-cultural benefits of ES for the wellbeing of Indigenous people who constitute the majority of the regional rural population. First, we assess available ES valuation methods for estimating non-market and market values of ES from an Indigenous estate, Fish River Station (FRS), representative of 'typical' regional savannas. Second, we estimate the direct (fire and weed management) and indirect (foregone income from pastoral enterprise) costs associated with maintaining those services. For valuation of ES, we applied a conventional Basic Value Transfer technique using global databases including available regional studies—providing valuations of USD 286 and 84 M y^{-1}, respectively. However, constituent studies used in these valuations had limited relevance to both the ecosystems and socio-cultural contexts of our study. For evaluating Indigenous socio-ecological benefits of ES, estimated conservatively at USD 2.21 M y^{-1}, we applied a local wellbeing valuation technique. The minimum costs required to maintain ES flows were estimated as USD 5.6 ha^{-1} y^{-1}. Our study illustrates that, to better inform regional development policy, significant challenges remain for appropriate valuation of ES from north Australian savannas, including recognition of socio-cultural services and wellbeing benefits incorporating Indigenous values.

1. Introduction

The importance of natural ecosystems in human wellbeing and their significance for decision-making for development is well recognized in recent global initiatives, namely the Millennium Ecosystem Assessment (MA, 2005), the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES, 2015), The Economics of Ecosystems and Biodiversity (TEEB, 2010a), and by several eminent researchers (Daly, 1996, 2005, 2013; Costanza et al., 1997, 2014; de Groot et al., 2012). It is widely acknowledged that cost-effective valuation methods need to be developed and employed for assessing current and future ecosystem services (ES) (Costanza et al., 2014). Such methods need to include the socio-cultural benefits of ES for human wellbeing (TEEB, 2010b).

This paper assesses available ES valuation methods, and estimates the costs of maintaining ES flows, based on a case study focusing on an Indigenous (Aboriginal) property in northern Australia – a region where Indigenous people have managed the vast fire-prone savanna ecosystems for thousands of years and, today, maintain very substantial interests in land and constitute the majority of the rural population especially in remoter areas (Taylor, 2006; Russell-Smith and Whitehead, 2015). Australian savannas are known for their bio-diverse and cultural landscapes, providing a suite of services that support the cultural, spiritual and socio-economic livelihoods of Indigenous communities (Altman, 2006; Altman et al., 2011; Russell-Smith et al., 2013, 2015; Sangha et al., 2011, 2015a,b). However, since most of these services cannot be readily measured according to current market indices, they are rarely (if ever) taken into account in development planning as evident from their absence in a recent northern development plan advanced by the Australian Government (2015). At the present time a key challenge is to incorporate the non-market values of ES from Indigenous estates into current financial accounting systems to appropriately inform development policies for northern Australia.

The Australian Government's (2014, 2015) policy proposal for 'developing the north' focuses on developing agricultural, mining

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and non-renewable energy enterprises and associated infrastructure. The proposal applies a typical financial approach, with little recognition of the vital roles of natural systems and Indigenous values in supporting people's livelihoods and local economies. Given this political and environmental context, in this paper we provide an assessment of (a) market and non-market values of ES and related valuation approaches, and (b) the costs of maintaining ES, as applied to an Indigenous (Aboriginal)–owned property, Fish River Station (FRS), in the Top End of the Northern Territory (Fig. 1). We use a standard Basic Value Transfer (BVT) approach to apply global and available regional ES estimates for deriving the value principally of biophysical services, and local trade-off analyses using welfare costs to derive the value of associated socio-cultural services. Additionally, we estimate the costs required to maintain the flow of cultural and natural values from FRS, as a basis for informing regional development policy agendas. Our study illustrates the key challenges for assessing the non-market values of ES and the appropriateness of valuation methods, which remain for appropriately recognising and valuing ES in north Australian savanna management contexts.

2. Background

Our case study is illustrative generally of Indigenous-owned or managed lands occupying ~20% of Australia's 1.18 M km^2 northern savannas—a region characterised by savanna vegetation comprising scattered trees over understorey grasses, relatively infertile soils, and markedly seasonal summer rainfall (October–April) with long-term mean annual rainfall of at least 600 mm y^{-1} (Fig. 1). At the time of the 2011 national census, the regional population comprised 750,000 people of which the majority live in towns and settlements, and 20% are Indigenous. Indigenous people typically comprise the majority (~90%) of the population in remote areas (Russell-Smith and Whitehead, 2015).

2.1. Description of Fish River Station

Fish River Station (FRS) is situated in the Daly River region of the Northern Territory (NT), covering approximately 180,000 ha which is representative of an average-sized property (~120,000 ha) in the region (Fig. 1). In 2010, FRS was purchased from a private organisation for it's natural and cultural heritage values by the Australian Government in partnership with conservation-based Non-Government Organisations. FRS is listed as a Category II Protected Area by the International Union for Conservation of Nature (IUCN) (Indigenous Land Corporation, 2012). Previously, it was managed as an under-developed pastoral beef cattle enterprise. The property supported an average carrying capacity of 2 head km^{-2} compared to 6 head km^{-2} usually recommended for the region. The current lease-holder, the Indigenous Land Corporation (ILC), has a statutory function to grant its interest in FRS to its Indigenous owners by 2017. The ILC and partners have been providing Indigenous employment opportunities and building peoples' capacity to manage FRS.

The Indigenous traditional owners of FRS – the Ngan'giwumirri (Labarganyin), Wagiman, Malak Malak and Kamu people – hold customary social, cultural and spiritual connections with the area. There are numerous named sacred sites and burial places, and other areas that are known, used and managed for their resources (ILC, 2012; NAILSMA, 2014). These include 22 'restricted works areas' (listed under the NT Aboriginal Sacred Sites Act 1989 by the Aboriginal Areas Protection Authority, 2011). Approximately 2000 Indigenous people resident in the Daly River catchment have direct or indirect cultural connections with the property.

Currently, ~100 people occasionally access FRS, mainly for cultural and ceremonial purposes, or for hunting, collecting bush food and medicines. However, these are not commercial activities. In the 1860s, with the onset of European settlement in the Daly region, Indigenous people lost independence and control over their land (Ritchie, 2009). Over time, dependency on tobacco and other items influenced people to move to regional centres. Later, with the establishment of local Christian missions, initially for a decade from 1899, and again in 1955 for two decades, Indigenous people developed greater dependencies on store foods and other supplies, and less dependency on traditional resources. Although most local Indigenous people now reside in regional community centres, legal recognition of Indigenous rights to land under Australian Government legislation from the 1970s has helped foster renewed connection with people's traditional estates.

Today, Indigenous people regularly visit FRS enable them to maintain their knowledge of the landscape, and other aspects of living on, and connecting with, 'country'—a term as used by Indigenous people in northern Australia to describe cultural connection to their traditional estates. These activities help strengthen their cultural obligations and build capabilities, as discussed below.

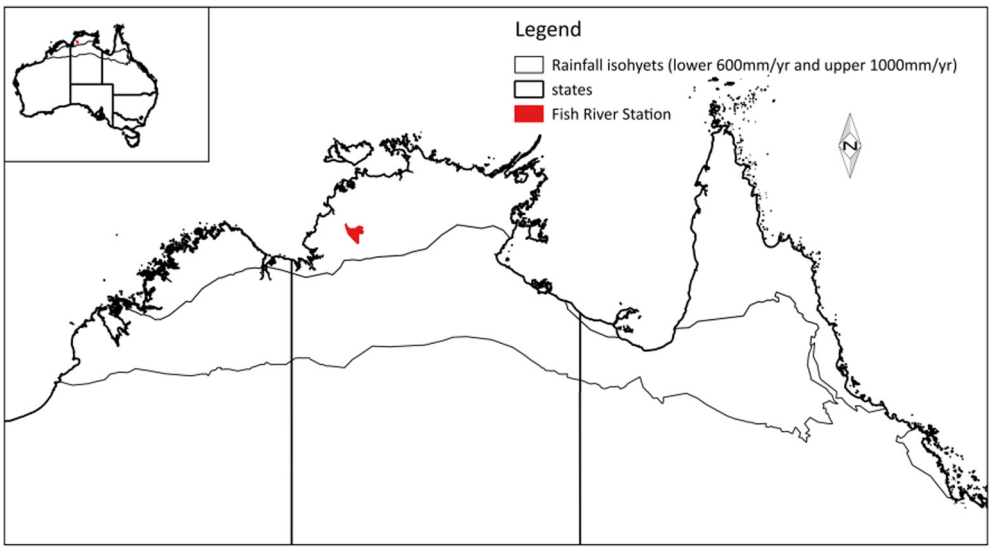

Fig. 1. Location of Fish River Station in relation to rainfall isohyets in northern Australia.

2.2. Ecosystem services derived from Fish River Station

As for much of northern Australia's savannas, the vegetation of FRS remains largely intact despite over 100 years of beef cattle pastoralism. The natural vegetation comprises eucalypt woodland, tussock grassland, and rich wetland/riparian and tropical rainforest ecosystems (Fig. 2). It is from these four ecosystem types that a number of *intangible* (non-marketable) and *tangible* (marketable) services/benefits are derived.

2.2.1. Intangible/non-marketable ecosystem services

FRS provides a range of socio-cultural and ecological services that, at present, are accorded no market value—bush food and medicine; biodiversity conservation; protection and regulation of water resources; traditional ecological knowledge; various cultural, sacred and identity values; and art and craft materials (Mahney et al., 2011; ILC, 2012, 2012–2013). These ES are integral to people's lives, and are particularly significant in maintaining traditional ecological knowledge, social relationships, cultural practices, and other activities that improve people's wellbeing (Altman et al., 2011; Indigenous Land Corporation, 2012–2013; Russell-Smith et al., 2009, 2015; Russell-Smith and Whitehead, 2015; Sangha and Russell-Smith, 2015; Sangha et al., 2015a; Whitehead et al., 2009). For example, FRS affords access to sacred and cultural sites, provisioning services of cultural significance. Those services contribute to peoples' cultural values (stories, songlines and ceremonies), which further impart benefits to the wellbeing of local people for cultural knowledge and identity. Moreover, these ES are important, not only for their values or benefits, but also because they enable people to develop and maintain their knowledge and capabilities, and in building self-esteem and freedom to lead lives as they want (Sangha et al., 2015b).

2.2.2. Tangible/marketable ecosystem services

Tangible ecosystem services include those with a current or potential market ($) value. Carbon (C), in the form of greenhouse gas (GHG) emissions abatement and sequestration, is currently marketed under Australia's present climate change mitigation initiative, the Emissions Reduction Fund (ERF; http://www.environment.gov.au/climate-change/emissions-reduction-fund).

Mitigation of CO_2-e emissions through improved fire management under the ERF can provide for direct monetary benefits, either through contractual arrangements with the Australian Government or third parties. Additional market-based opportunities involving biosequestration of carbon in non-living (e.g. coarse woody debris) and living (tree) biomass pools are under advanced development (Russell-Smith et al., 2015). The ERF has led to a rapid development of a regional carbon economy, although it has been in effect in Australia only since December 2012.

3. Methods

Well-known valuation methods were used to measure the market and non-market values of ES from FRS in monetary units, and to estimate the costs required to maintain the flow of those services, as described below:

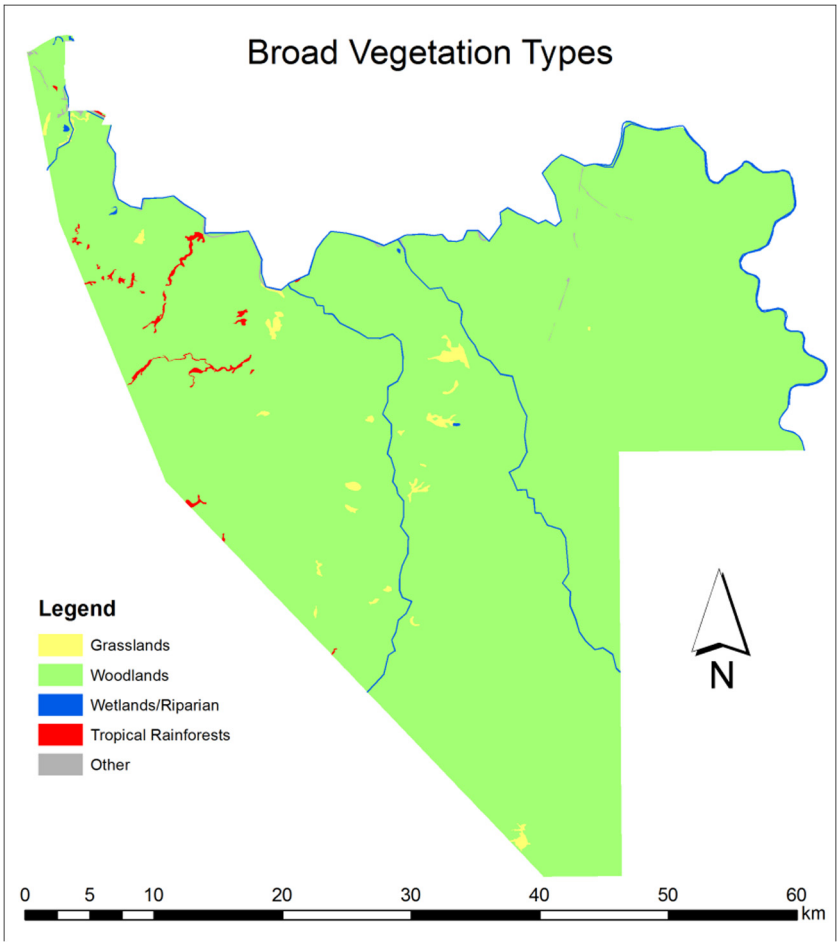

Fig. 2. Main ecosystems on Fish River Station (note: 'other' represents 150 ha of cleared land).

3.1. Valuation of ecosystem services

3.1.1. Value of intangible/non-marketable ecosystem services in monetary units

The value of various intangible ES from FRS was collectively assessed by applying various indirect methods, namely BVT, and deriving substitute values using Government Indigenous welfare expenditures. Monetary values for any ES are expressed here in USD unless stated otherwise (the currency conversion rate 1 AUD = 0.78 USD, as on 19/06/2015, was used).

3.1.1.1. Basic value transfer or BVT method. The non-market value of various intangible ES was assessed as a 'bundle'. Applying the BVT method, we used valuation data from a global study conducted by de Groot et al. (2012), for which Van der Ploeg and de Groot (2010) developed a TEEB database of 1310 studies. The adjusted (using average inflation rates over 2012–2015) median values (USD) ha^{-1} $year^{-1}$ for woodland (1,571), grassland (2,785), tropical forest (2,431) and inland wetland/riparian systems (17,608) were applied in this study. The details of the type and number of ES values, the number of studies and methods used are provided in Table 1(a).

We also applied values specifically for a north Australian context using the same TEEB database (de Groot et al., 2012), derived from regional studies conducted by Blackwell (2006) and Curtis (2004). Derived values from these studies were USD 469, 233, 2177 and 1088 ha^{-1} $year^{-1}$ for woodlands, grasslands, tropical forests and wetlands ecosystem services, respectively (Table 1(b)). Those values were also adjusted using average inflation rates over 2004/06-2015. Step-wise calculations are explained in Appendix 1.

These global and regional Australian ES valuations focus mainly on biophysical services (e.g. air, water and climate regulation; soil formation; prevention of soil erosion and flooding; genetic resources), except for recreation and eco-tourism services in some studies (Table 1 a, b). These valuations do not account for the range of socio-cultural benefits that Indigenous people derive from their country (TEEB, 2010b; McVittie and Hussain, 2013).

3.1.1.2. Government Indigenous welfare expenditures. We assume that local Indigenous people, having security and access to FRS, benefit in terms of building their capabilities and enhancing their wellbeing. For this, we apply a Capability Approach, proposed by the Economics Nobel Laureate, Professor Amartya Sen, in the 1990s. He argued that 'development' is about enabling people to lead healthy and creative lives while providing them with an appropriate environment (Sen, 1999). The availability of various ES at FRS contributes to utilizing and building Indigenous people's capabilities (Table 2).

Here, we focus on the socio-cultural services of 'country', and estimate the monetary value of their benefits for contributing to Indigenous wellbeing (see TEEB, 2010b). 'Country' offers a range of services fulfilling various social, economic and cultural needs of local people (e.g. maintaining ceremonial and kinship connections, practising Indigenous ecological knowledge). Those services, essential for people's existence, are beyond current market measures, and for the most part, differ from values of the wider non-Indigenous public. Fig. 3 highlights how some of these country-related benefits are important for building and enhancing peoples' capabilities as well as wellbeing.

To derive a value for these suites of 'country' services in terms of their benefits for people, we considered their substitute or equivalent value from the established costs of Government welfare services, plus opportunity costs associated with Indigenous people visiting FRS in lieu of employment. We applied substitute values for current Government welfare expenditure on four welfare-relevant services that are delivered by peoples' engagement with 'country': a safe and supportive environment, economic participation, healthy lives, and early childhood development (SCRGSP, 2014). The Australian Government spends USD 33,890 $person^{-1}$ y^{-1} (SCRGSP, 2014) on Indigenous welfare service sectors (i.e. a safe and supportive environment, economic participation, healthy lives, early childhood development—Table 1b). We used only 50% of that expenditure as a substitute to evaluate ES, given that Indigenous welfare expenditure per capita is more than double the figure for non-Indigenous people in recognition of their special needs and circumstances (USD 16,302; SCRGSP 2014). In 2014, 80 Indigenous people visited FRS for up to a week each. To estimate the value of ES derived from 'country' benefits, we included the value of associated welfare benefits, plus associated employment opportunity costs (@USD 500 $person^{-1}$ y^{-1}), for 80 people (Table 1b). We acknowledge that it is difficult to estimate a total value of such socio-cultural services of country especially when they constitute the essence of peoples' living (Sangha et al., 2015b). Thus, our wellbeing valuation provides only a sub-set of the total non-market value of socio-cultural ES available from FRS.

Additionally, engagement of Indigenous rangers in the management of FRS currently offers five full-time equivalent jobs, with each ranger earning USD 58,500 y^{-1}; derived as the average value of economic opportunity provided through the Australian Government's 'Working on Country' program (Social Ventures Australia, 2016). Thus, a total direct economic benefit of USD 292,500 y^{-1} is realised for five rangers, which directly saves the costs of government welfare payments if the rangers were unemployed.

3.1.2. Value of tangible/marketable ecosystem services

The monetary value for greenhouse gas abatement achieved through enhanced savanna fire management was derived from the annual average number of Australian Carbon Credit Units (ACCUs) accruing to FRS over the period 2011–2014 (Indigenous Land Corporation, 2015a). The significant role better fire management plays in mitigating greenhouse gases is recognized by the Australian Government under the Savanna Burning Methodology (SBM) for ERF projects.

As well as emissions abatement, we also considered the additional potential for carbon bio-sequestration in non-living and living biomass pools, calculated using methods described in Russell-Smith et al. (2015). An average price of AUD 13.95 per ACCU was applied, based on the Australian Government carbon auction, 16–17 April, 2015 (http://www.cleanenergyregulator.gov.au/ERF/Auctions-results/April-2015).

3.2. Cost of maintaining the flow of ES

3.2.1. Trade-off analysis of fire, weed and pest management expenditure to estimate the maintenance costs for ES flows

An understanding of annual management costs to maintain ecological processes and functions is especially pertinent in the case of FRS given that the property was purchased for both its biodiversity and cultural values. Operational costs associated with the management of fire, weeds and pests were derived from actual FRS data ILC (2015b). In addition, there are ongoing costs associated with maintaining adequate infrastructure (e.g. roadworks, water points and fencing, ongoing vehicle and equipment costs), and administration. Based on FRS costs for 2014–2015, we also included an estimate of USD 8,000 y^{-1} for participation of traditional owners at cultural knowledge camps. In the absence of available capital infrastructure costs, we assumed that a conservative average of USD 25,000 y^{-1} is required for building roads, shed, fences etc.

However, above weed and pest management costs are not sufficient to control all the weeds and pests that occur on FRS; there are 22 known weed and five major pest species that need to be managed (BushBlitz report (Fish River Station), 2012). These management costs are considered more fully in Discussion.

Table 1
TEEB valuation for global-median and regional relevant ES values, and wellbeing valuation approaches as applied in this study.

Ecosystem type	Total ES values derived from total No. of global studies, and relevant Australian studies	Type and range (USD ha^{-1} y^{-1}) of ES values	Methods used in global and Australian studies
Part A: ES valuation approach applied by de Groot et al. (2012) and used in our study to derive median global values of ES (as described in Methods) using TEEB database (van der Ploeg and de Groot 2010)			
Woodlands (TEEB database includes tropical woodlands, heath land, scrub and other woodlands)	46 ES values (23 used in TEEB) from Africa, South America, Southern Europe and Asia; 11 global studies. One Australian study by Blackwell (2006) on rangeland values was applicable for our study while another by Blamey et al. (2000) valuing remnant vegetation per household was not	Common ES included raw materials, food, air, climate and water regulation, etc., and Australian studies included gene pool and medical values. ES values range: USD 0.10–3312 ha^{-1} y^{-1}; median value = USD 1522 ha^{-1} y^{-1} (2012; where 1 USD = 1 International $)	DC, DMP, RC, AC, TC, CV etc.; CV by Blamey et al. (2000)
Grasslands (TEEB: tropical and temperate grasslands, rangelands, steppe, etc.)	40 ES values (21 used in TEEB) from Asia, South Africa, Botswana, China and USA; 19 global studies. None relevant studies from Australia	Common ES included food, raw materials, air quality, water, climate regulation, nutrient cycling, recreation etc. Australian studies applied TEV. ES values range: USD 0.10–2954 ha^{-1} y^{-1}; median value = USD (2012) 2698 ha^{-1} y^{-1}	DC, RC, AC, TC, CV, TEV, BT, HP etc.; TEV/BT used by Blackwell (2006)
Inland wetlands/riparian areas (TEEB: floodplains, swamps and marshes, and other wetlands)	266 ES values (87 used in TEEB) from Canada, Brazil, South Africa, Europe, US, and several countries from Asia, Oceania, South America; 33 global studies. Three Australian studies – Blackwell (2006), Mallawaarachchi et al. (2001) & Gerrans (1994) – the first was applicable in our study while two latter studies were not, as Mallawaarachchi et al. (2001) estimated WTP for improvements from the status quo (increasing the area of tea tree woodlands and wetlands), not for the ES itself; and Gerrans (1994) estimated only the aesthetic value of Jandakot wetlands, WA	Food, raw materials, aesthetic, cultural, gene pool, nutrient cycling, recreation etc. Australian studies included biodiversity protection, recreation, TEV, aesthetic value, etc. ES values range: USD 0.005–248,909 ha^{-1} y^{-1} (and other values up to USD 27 M y^{-1} for a specific case study area); median value = USD (2012) 16,534 ha^{-1} y^{-1}	DC, RC, AC, TC, CV, TEV, BT, HP, PES etc.; CV (Gerrans 1994; Mallawaarachchi et al. 2001) and TEV/BT (Blackwell 2006)
Tropical Rainforests (TEEB: tropical-rain and – dry forests)	237 ES values (140 used in TEEB) from Australia, China, Mexico, Brazil, India, South America, USA and various Asian countries; 61 global studies. One Australian study – Curtis (2004) was applicable to our study; another by Mallawaarachchi et al. (2001), focussed on community values of improved tea tree woodlands (not the ES itself) and estimated per household values, was not applicable	Timber, food, raw materials, air, water and climate regulation, recreation, medical, gene pool, erosion and bio control etc. Australian studies – water, air and climate regulation, erosion prevention, biodiversity protection etc. ES values range: USD 0.11–1536 ha^{-1} y^{-1} (other values were up to USD 1.559 B y^{-1} for a specific case study area); median value = USD (2012) 2355 ha^{-1} y^{-1}	DC, RC, AC, TC, CV, TEV, BT, HP, PES etc.; DMP and MCA by Curtis (2004) and CV by Mallawaarachchi et al. (2001)

Part B: Our study estimating – i. regional ES values using relevant Australian studies from TEEB database, and ii. local ES values for socio-cultural benefits

Ecosystem types	Blackwell (2006)	Curtis (2004)	Regional ES value calculations
Woodlands (regional Australian studies in TEEB included rangelands)	TEV for a bundle of ES was AUD 417 ha^{-1} y^{-1}, calculated using values from Costanza et al. (1997) applying BVT method (ES values for rangelands were used for woodlands in our study)	NA	We applied adjusted values (using World Bank GDP deflation (inflation) rates and Purchasing Power Parity of AUD, to derive 2015 estimates) i.e. USD 469 ha^{-1} y^{-1} from values suggested by Blackwell (2006) for Australian rangelands
Grasslands	NA	NA	We derived grassland's adjusted values (i.e. USD 233 ha^{-1} y^{-1}) as 50% of the total rangeland ES values suggested by Blackwell (2006), using our best judgement and knowledge.
Inland wetlands/riparian areas (included inland wetlands)	TEV for a bundle of ES was AUD 35,208 ha^{-1} y^{-1} (swamps/floodplains), calculated using values from Costanza et al. (1997) applying BVT method	NA	We derived adjusted values i.e. USD 1088 ha^{-1} y^{-1}, as 50% of mean tropical rainforest values suggested by Blackwell (2006) and Curtis (2004), to derive conservative estimates

(*continued on next page*)

Table 1 (*continued*)

Ecosystem type	Total ES values derived from total No. of global studies, and relevant Australian studies	Type and range (USD ha^{-1} y^{-1}) of ES values	Methods used in global and Australian studies
Tropical Rainforests (included wet tropical rainforests)	TEV for a bundle of ES was AUD 3608 ha^{-1} y^{-1}, calculated using values from Costanza et al. (1997) applying BVT method	Total value of ES from the rainforests of Wet Tropics World Heritage Area was AUD 210–236 ha^{-1} y^{-1}; calculated applying surrogate for the market value of land, multiple criteria analysis and expert opinion from a Delphi panel of experts	We applied adjusted mean ES values (i.e. 2177 ha^{-1} y^{-1}); suggested by Curtis (2004) and Blackwell (2006)
Country – Property scale value of socio-cultural benefits estimated from trading off welfare expenditure currently afforded by the Australian Government	Not included, except for the recreational/eco-tourism values that were considered in the original studies referred to by Costanza et al. (1997)	Not considered, except for the recreational and aesthetic values of the Wet Tropics World Heritage Area	Local-scale value of ES for socio-cultural benefits • Trading off additional welfare expenditure per Indigenous person (USD y^{-1}) compared that to a non-Indigenous person, on four domains of wellbeing: to provide safe and supportive environment, enhance economic participation, healthy lives and early childhood development (details in Methods section) • Trading off travel expenses for 80 people to visit FRS (USD $person^{-1}$ y^{-1}) and to conduct management activities to maintain cultural values • Saved costs of welfare payments by employing five rangers (USD y^{-1})

*AC – Avoided Cost, BT – Benefit Transfer, CV – Contingent Value, DC – Direct Cost, DMP – Direct Market Price, HP – Hedonic Price, MCA – Multiple Criteria Analysis, PES – Payment for Ecosystem Services, RC – Replacement Cost, TC – Travel Cost, TEV – Total Economic Value.

3.2.2. Land price

We also used land purchase price as a component of management costs for maintaining ES flows from FRS and its biodiversity conservation and cultural values, given that the property was purchased for those purposes along with longer-term employment opportunities for Indigenous people. The ILC and partners bought FRS for USD 10.53 M under an indefinite term, perpetual crown lease agreement. This value was adjusted using inflation rates up to 2015 for USD 11.80 M. Generally, the term for perpetual crown leases is 99 years; hence we discounted the purchase price over this time-period to reflect the annual costs of managing ES that flow from FRS.

3.2.3. Foregone beef enterprise

We include the value of benefits foregone from the pastoral beef enterprise as an ongoing significant management cost associated with the shift to cultural and biodiversity conservation land use. On FRS, a small beef enterprise operated prior to its purchase in 2010. The value of forgone beef enterprise was considered for 4000 cattle available for sale at the time of purchase (ILC, 2012), using average long-term (2001–2012) gross margin estimates for regional pastoral businesses (McLean et al., 2014). These estimates were spread over three years to reflect the average turnover rate for beef cattle since usually one third of a herd is sold in a year (Bray et al., 2015).

All monetary values were adjusted using inflation rate (World Bank and Reserve Bank of Australia), and converted to USD (2015), unless stated otherwise.

4. Results

The non-market and market values of ES derived from FRS for tangible and intangible benefits, and the baseline management costs required to maintain the flow of ES, are presented below.

4.1. Value of ecosystem services

The non-market value of ES from FRS at the ecosystem-scale ranged from USD 286 M y^{-1} based on applying the BVT method for global-scale values, to USD 84.4 M y^{-1} applying the BVT method for pertinent Australian regional-scale studies (Table 3). Additionally, the valuation of property-scale socio-cultural ES derived from the substitute valuation of welfare costs, employment benefits, and lost employment opportunity benefits, was estimated as USD 1.78 M y^{-1} (Table 3). Also at the property-scale, the potential market value of ES derived from the sale of carbon credits for emissions abatement and biosequestration was valued as USD 437 K y^{-1} (Table 3).

4.2. The costs required to maintain the flow of ES

Annualised costs associated with maintaining the flow of ES from FRS are summarised in Table 4. Associated costs include:

- Management expenditures for on-ground fire, weed, and pest management of USD 538,000 y^{-1}; repairs and maintenance of USD 213,000 y^{-1}; infrastructure development of USD 25,000 y^{-1}; and cultural camp costs of USD 8,000 y^{-1}
- Land purchase price—annualised over the 99 year term of the lease of USD 119,000
- Foregone beef enterprise of USD 104,921 y^{-1}

Total maintenance costs from the above equate to USD 5.6 ha^{-1} y^{-1}

Table 2
Importance of country in building capabilities of Indigenous people.

ES derived from Country/ homeland	Materials/items	Capability
Food/medicine	Bush food and medicine	Knowledge of native plants and animals, what, where, how, and when to eat – ultimately contributing to good health
Art & craft	Material objects, ochre, paint, etc	Knowledge and ability to use different plant/stone/earth materials, and to develop ideas for painting/dancing based upon rituals/ceremonies in relation to country – enabling people to lead creative lives
Songlines	Represent the invisible pathways on land, and the footprints of ancestors that describe the rules and responsibilities of a particular country	Knowledge of songlines enables people to take care of their country in a customary way – enabling people to pass-on their rituals and culture

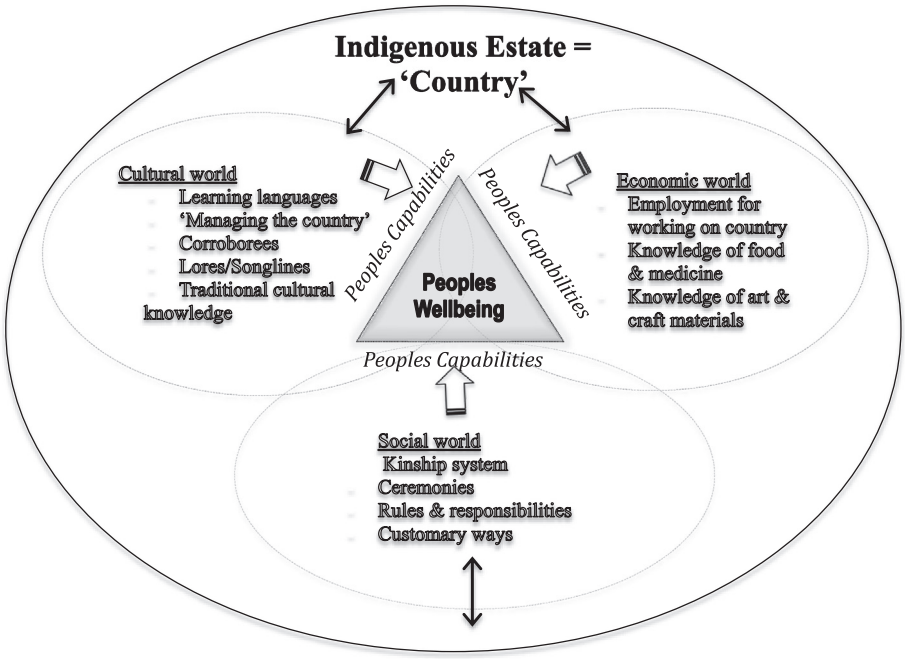

Fig. 3. An Indigenous estate, supporting cultural, social and economic worlds of people, contributes to build and enhance their capabilities and wellbeing through various traditional practices and learning processes (source: Sangha et al. (2015b)).

Table 3
Total value of non-marketable and marketable ES of FRS, applying different valuation methods.

Ecosystems-based values	Area (ha)	Unit value (USD ha^{-1} y^{-1})	Total Value (USD y^{-1})
4.1.1. Non-marketable ES:			
ia. Applying BVT using global-median values of each ecosystem from TEEB database (de Groot et al. 2012)			
Woodlands	175,600	1,571	275,867,600
Grasslands	1,260	2,785	3,509,100
Inland wetlands/riparian areas	290	17,068	4,949,720
Tropical Rainforests	700	2,431	1,701,700
Disturbed/clear land	150	0	0
Total value			**$286,028,120**
ib. Applying BVT using regional-relevant values from the Australian studies from TEEB database (de Groot et al. 2012)			
Woodlands	175,600	469	82,356,400
Grasslands	1,260	233	293,580
Inland wetlands/riparian areas	290	1088	315,520
Tropical rainforests	700	2177	1,523,900
Disturbed/clear land	150	0	0
Total value			**$84,489,400**
Property 'country' – scale values			
ii. Applying tradeoff of Indigenous welfare expenditure to assess the socio-cultural values of Indigenous estate: 50% tradeoff of			$1,444,747
Government expenditure for provision of cultural and social ES from FRS that can save expenditure on welfare services (safe and			$40,000
supportive environment, economic participation, healthy lives and early childhood development) for 80 people who regularly			$292,500
visit FRS Travel expenses for 80 people to visit FRS Saved costs of welfare payments for employing five rangers Total wellbeing			**1,777,247**
benefits from country			
4.1.2. Marketable ES:C credits (mitigation and sequestration)			**437,383**

Table 4
Minimum costs required for maintaining ES flows from FRS.

Minimum costs applying	Total Value (USD y^{-1})
i. Tradeoff of:On-ground fire, weed and pest management, repairs and maintenance costs, and salaries of workers	751,000
Ongoing annual infrastructure development costs (e.g. new roads, fences, sheds, etc.)	25,000
Cost of visits for cultural knowledge training camps to maintain cultural values	8,000
ii. Annualised land price	119,000
iii. Foregone benefits from beef enterprise	104,921
Total	**1,007,921**

5. Discussion

5.1. Market and non-market values of ES

For the purposes of informing sustainable development planning in northern Australia, this paper provides a valuation assessment of ES from a typical regional pastoral property now managed for its Indigenous cultural and biodiversity conservation values. We also assess the minimum costs associated with maintaining those services. This assessment highlights current challenges associated with valuing both biophysical and socio-cultural ES benefits in a regional context.

For assessing market and non-market values of ES, we applied (a) comparable ecosystem-based monetary values of ES from the TEEB database (de Groot et al., 2012), and property-scale assessments of (b) C benefits using market price and (c) socio-cultural benefits using substitute values for welfare expenditure (Table 3). Assessment of non-market values of ES from four ecosystems at FRS afforded values of USD 84 M y^{-1} or USD 286 M y^{-1}, depending upon application of regionally, or globally relevant TEEB values, respectively. With the exception of recreation or eco-tourism values, most non-marketable services included in the TEEB database essentially value biophysical ES (TEEB, 2010b; McVittie and Hussain 2013; Table 1a, b).

For carbon benefits, the undertaking of strategic fire management to reduce GHG emissions from wildfires, and associated carbon sequestration in both non-living and living biomass, provides a regional example of a tangible property-scale ES, readily measured through potential or earned income. The fire management activity offers significant economic opportunities for fire-prone regions of north Australia generally, and for Indigenous lands with limited pastoral potential especially (Russell-Smith et al., 2009, 2013; Russell-Smith and Whitehead 2015; Preece et al., 2016). FRS was the first property in northern Australia to formally implement 'savanna burning' as part of a nationally accredited program (Walton et al., 2014).

We assessed Indigenous socio-cultural benefits of ES from FRS at USD 1.78 M yr–^{1} mostly by applying a 50% discount for the substitute costs of government expenditure on welfare services. However, this valuation largely accounted for usage and visitation by just 80 people based on data for one year only, and for only some components of Indigenous wellbeing. Over time, substantial welfare benefits (exceeding USD $20 M y^{-1}) can be anticipated assuming that most local Indigenous people with cultural ties to FRS visit, use and enjoy imbued associated cultural benefits.

For estimating the baseline costs required to maintain the flow of ES, we applied a pragmatic approach to assess ongoing costs of management as USD 5.6 ha^{-1} y^{-1}. As FRS is managed for both cultural and biodiversity conservation values, we have assumed that the costs associated with ongoing management of this property are a useful indicator of the minimum cost of maintaining ES values into the future. We acknowledge that current on-ground weed and pest management costs are adequate only insofar as maintaining current threat levels. For example, attempts at targeted eradication of noxious weeds are recognised as requiring expenditures more than 25 times those currently applied at FRS; the Northern Territory Government spends USD 78–195 ha^{-1} y^{-1} to manage just one noxious weed, *Mimosa pigra* (DNRETAS 2010). However, our maintenance costs are broadly equivalent to the USD 4 ha^{-1} y^{-1} estimate required for protecting 80% of threatened species in Australia's premier savanna conservation reserve, the World Heritage-listed Kakadu National Park (Woinarski and Winderlich 2014). We thus consider this a useful maintenance benchmark figure for broader application in regional savanna conservation management and policy contexts.

5.2. Valuation approaches

In the absence of primary data for FRS, for convenience we relied principally on the widely applied BVT approach for valuation of ES at the ecosystem-scale. As illustrated in Table 1a,b, however, the application of values derived from available global or other regional assessments presents significant comparability issues (Richardson et al., 2015), and potentially impacts on the credibility of resultant valuations in policy contexts. We applied ecosystem-based values from the global TEEB database (Van der Ploeg and de Groot 2010; de Groot et al., 2012), which comprises 1310 ES estimates from >200 studies including only two pertinent studies from northern Australia, and none relevant to Australian Indigenous estate values (Table 1). We used median values for four broadly comparable ecosystem types from available global studies, and regionally derived mean values from the two Australian studies. As illustrated in Table 1a,b, however, the ecosystem types derived from the TEEB database do not readily equate with those at FRS; for example, the extensive savanna woodlands at FRS overlap only in part with the broader woodland category from the TEEB database, including one Australian study valuing 'rangelands' (Blackwell, 2006). Similarly, the species diverse wet tropics rainforest from north Queensland (Curtis, 2004) or tropical forests from coastal areas (Blackwell, 2006) are not directly comparable with the small patches of relatively species-poor monsoon forest in our study area. To address this we thus discounted the mean value from both those studies by 50%. Mismatches between the TEEB ecosystem classification with our savanna system classification has obvious valuation implications. Despite such inconsistencies a recent ES assessment conducted for Cape York Peninsula, north-east Australia, applied a similar BVT approach as applied here based on the same underlying database for valuing woodlands amongst 10 other ecosystems (Preece et al., 2016).

The widely applied BVT method, incorporates a number of different valuation techniques such as avoided costs, replacement costs, eco-tourism/travel costs, contingent valuation, benefit transfer and others (de Groot et al., 2012; Richardson et al., 2015). However, its application and appropriateness for any particular case study needs to be thoroughly qualified (Brander, 2004; Richardson et al., 2015; McVittie and Hussain, 2013). For example, ES valuation studies from OECD countries may not be transferable for valuation studies in developing countries where people may have different value systems and lower financial capacities. In such circumstances, ES values should be adjusted (e.g. using Purchasing Power Parity (PPP), Consumer Price Index (CPI), and Inflation Rates), to derive locally relevant present values. However, we argue that adjusted estimates might still be misleading if local people have different value perceptions of natural systems in a particular region in comparison to consumable items that are used for assessing PPP/CPI. Moreover, there can be diverse cultural percep-

tions of natural systems within a socio-natural landscape and such values are often missed in most BVT studies (Chan et al., 2012).

Apart from recreational and eco-tourism services, most BVT estimates largely fail to incorporate an appropriate estimate for socio-cultural services derived from natural systems (TEEB, 2010b; McVittie and Hussain, 2013). Such socio-cultural services are indispensable for supporting Indigenous livelihoods at FRS, and can differ markedly or essentially from values held by the wider society (TEEB, 2010b). For our assessment of socio-cultural benefits of ES, we derived substitute (or trade-off) values from Government Indigenous welfare expenditures, which indirectly deliver multiple benefits as well as enhance peoples' wellbeing. Generally, a trade-off analysis requires a holistic approach for understanding links between natural and social systems (Ruijs et al., 2013). It also involves a careful evaluation of associated socio-economic and political factors; an assessment of what to trade-off for ES is critically important in this kind of analysis (Elmqvist et al., 2011; Briner et al., 2013).

Our welfare-related substitute valuation applied government expenditure on attributes which are related to benefits that Indigenous people obtain from living on 'country'. A recent report found a 3.4 times return on government investment from a large (1.4 M ha) Indigenous estate managed for its cultural and biodiversity conservation benefits, 250 km north-east of FRS (Social Ventures Australia, 2016). That estate, formally recognised by the Australian Government as an Indigenous Protected Area, affords multiple economic and social benefits for a number of Indigenous communities, rangers and Indigenous landowners, including through the undertaking of a highly successful commercial savanna burning emissions abatement project. While acknowledging smaller estimates of socio-cultural ES from FRS, in line with the above report our assessment suggests the significant value of 'country'-related benefits for Indigenous people.

We acknowledge also that there remain substantial challenges for valuing the monetary contribution of socio-cultural services given their intangible and incommensurable nature (Milcu et al., 2013; TEEB, 2010a, b). To date, most ES studies including cultural services have provided monetary valuations only for recreation and eco-tourism (Table 5). However, we consider that it is essential to further explore and, where feasible, quantify the monetary value of socio-cultural ES, as applied incorporating a novel, wellbeing approach. Such valuations need to complement and enhance qualitative assessments to better inform development policies. In the northern Australian context, various qualitative studies have highlighted health, economic, socio-cultural and educational country-related benefits for Indigenous people (e.g. Burgess et al., 2009; Garnett et al., 2008; Grieves, 2007, 2009; Hunt, 2010; Russell-Smith, 2016; Sangha and Russell-Smith, 2015; Sangha et al., 2015a; Taylor, 2008; Weir et al., 2011). In the absence of monetization, such values typically are not considered in current development policy (e.g. Australian Government, 2015). This study addresses some of those gaps. However, further research is required to appropriately address the costs of land degradation and loss of ES from the current, widespread pastoral land use in the region to fully inform our northern development policies.

Estimating a holistic ES value for wellbeing benefits derived from 'country' (including Indigenous employment benefits) presents evident challenges. In northern Australia, Indigenous estates fundamentally represent the manifestation of peoples' spiritual and cultural values. These values are notoriously difficult to quan-

Table 5
A review of main ES studies that have included cultural services (listed in a chronological order for global and local Indigenous-Australian studies (underlined)).

Reference	Type of cultural ES	Monetary assessment of cultural ES (Yes/No)	Methods used
Costanza et al. (1997, 2014) (>100 global studies)	Recreation and eco-tourism	Yes; Recreation/Ecotourism	Willingness To Pay (WTP)/Contingent Valuation (CV)
Van der Ploeg and de Groot (2010) reported 216 studies on cultural ES (TEEB – global database)	Aesthetic, recreation and inspiration	Yes; mainly Recreation/ Ecotourism	WTP/CV/Travel Cost Method (TCM)/Direct Market Method
De Groot et al. (2012) (>200 global studies)	Aesthetic, recreation and inspiration	Yes; mainly Recreation/ Ecotourism	WTP/CV/TCM/Benefit Transfer (BT)
Chan et al. (2012)	Various kinds of cultural ES	No (Preferred qualitative values)	Deliberative decision making, narrative approach, structural decision making, paired comparisons etc
Milcu et al. (2013) reviewed 107 cultural ES studies	Mostly recreation and eco-tourism; <10 studies included cultural diversity or social relation, none on identity, ceremonial or language values of ecosystems	Yes; only 12 out of 107 studies assessed Recreation/Ecotourism	WTP/CV, and spatial valuation
Baulcomb et al. (2015)	Cultural ESs of coastal and marine environments	Discusses the importance and need of economic value, esp. for non-recreational ES	Suggests an augmented ES valuation framework for assessing the changes in cultural values due to different environmental management options
Infield et al. (2015)	Various kinds of cultural ES	No	Suggested wellbeing approach to cultural ES
Burgess et al. (2009)	Caring for Country: Health benefits	No	Medical check-ups and procedures that suggested improvements in health outcomes for Indigenous people living on country
Hunt (2010)	Looking after country: Socio-economic benefits	No	Subjective assessment of socio-economic benefits except for employment figures
Zander et al. (2010)	Recreational and cultural values (i.e. water holes) of three tropical rivers in northern Australia	Yes; Recreation	WTP (using urban population sample)
Birckhead et al. (2011)	Cultural services of water	No	Subjective wellbeing approach to cultural and economic values of water services
Oliver (2013)	Role of bush food and medicine in Indigenous health	No	Subjective assessment of health benefits

tify using current valuation techniques (Chan et al., 2012; MA, 2005; TEEB, 2010b). For example, there is no ready replacement or substitute value for the services provided by the 22 recorded sacred sites on FRS. Similarly, a spiritual experience involving connections with 'country' is not readily valued (Milcu et al., 2013). Some services, however, such as wild resources can be valued in monetary units applying substitute values; for example, subsistence values of USD 670–1871 yr^{-1} Indigenous $household^{-1}$ for fish, crocodile and turtle food resources in a study of three north Australian river systems (Jackson et al., 2014).

As recommended by others, we suggest that a hybrid approach for valuing ES is appropriate, incorporating: (a) assessment of monetary values for those values that directly or indirectly relate to monetary inputs/outputs; and (b) ranking and mapping others that cannot be readily monetised (Kumar and Kumar, 2008; MA, 2005; Milcu et al., 2013; Seppelt et al., 2011). In line with the first approach, the government welfare replacement value applied in this study offers significant estimates of socio-cultural benefits afforded by FRS. However, for the second approach, further research is required to conduct focus group meetings in participation with locals to evaluate and map other socio-cultural benefits of ES from FRS.

The foregoing discussion highlights the significant challenges remaining for developing effective ES valuation frameworks for north Australian savanna systems, including appropriate socio-cultural accounting addressing the interests of Indigenous residents. As illustrated by current uninformed regional development agendas, such frameworks are essential for promoting sustainable development policies and pathways advocated by Costanza et al. (1997, 2014), MA (2005), IPBES (2015), TEEB (2010a).

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Appendix A.

Step-wise calculations for Ecosystem Services (ES) value assessments.

i. Ecosystem Services median global values using TEEB database (Van der Ploeg and de Groot, 2010)
   1. TEEB database was analysed for woodland, grassland, inland wetland and tropical rainforest ES values, among the other ecosystems; and corresponding ES values from references 46, 40, 266, and 237 were applied.
   2. A wide range of ES values for each ecosystem type (e.g. USD 0.10-3312 ha-1 y-1 for woodland ES values or USD 0.005-248,909 ha-1 y-1 for inland wetlands) necessitated adoption of median values: USD 1522 ha-1 y-1 (2012) for woodland ES; 2698 ha-1 y-1 for grasslands; 16,534 ha-1 y-1 for inland wetlands and 2355 ha-1 y-1 for tropical rainforests (all values in 2012).
   3. These ES values were adjusted using World Bank GDP deflation rates (http://dx.doi.org/10.1016/j.ecoser.2017.04.013) for 2015 (international dollars ($1 USD in 2012) adjusted to USD in 2015).
   4. To calculate the aggregate values, the surface area of each ecosystem type was calculated and multiplied by respective ES values (i.e. area (ha) x value per ha/yr for each ecosystem).

ii. Regional Ecosystem Services values using relevant Australian studies from TEEB database
   1. Two relevant studies, Blackwell (2006) and Curtis (2004), were selected from the TEEB database.
   2. ES values in AUD (2005–Blackwell; 2002–Curtis) were adjusted for 2015 using standard inflation rate over that time period (1.3 and 1.4; RBA inflation calculator http://dx.doi.org/10.1016/j.ecoser.2017.04.013), and then converted to USD using World Bank exchange rate (2015). For example: Woodland ES value (2005) = AUD 417 ha-1 y-1; inflated to AUD 515 ha-1 y-1 by 2015, which was then adjusted for USD 469 using World Bank GDP deflator rate (inflation; 0.91) over 11 years.
   3. ES value for Tropical Rainforests was derived as mean value from Blackwell (2006) and Curtis (2004), and adjusted for 2015 values, as above. Details mentioned in Table 1, part B.

iii. Local scale Ecosystem Services values for socio-cultural benefits
   1. 50% of Indigenous welfare expenditure (=AUD 21,724/person/yr, for 2012; Indigenous Expenditure Report 2014) values were first adjusted using inflation rate of 1.06 for 2015 over three years (http://dx.doi.org/10.1016/j.ecoser.2017.04.013), and then converted to USD using World Bank exchange rate (0.78).
   2. Travel (USD 500/person/yr) and employment (USD 58,500/person/yr) values, along with C benefits, weed and pest management costs, infrastructure and the cultural training camps costs, were based on 2015 values.
   3. For C benefits, GHG emissions were calculated using standard Australian Government calculation procedures available at www.firenorth.org.au and http://savbat2.net.au. A total of 27,067 carbon credits (data from FRS), being the annual average 2011–2014, were used for calculating the monetary values using the Australian Government price of $13.95 for 1 carbon credit (=1 t.CO2-e). For details see Russell-Smith et al. (2015).

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