Using ecosystem services to underpin cost–benefit analysis: Is it a way to protect finite soil resources?

S. Greenhalgh a,⇑, O. Samarasinghe a, F. Curran-Cournane b, W. Wright a, P. Brown c

a Landcare Research NZ, Private Bag 92170, Auckland Mail Centre, Auckland 1142, New Zealand
b Auckland Council, Private Bag 92300, Victoria Street West, Auckland 1142, New Zealand
c Landcare Research NZ, P.O. Box 10 345 The Terrace, Wellington 6143, New Zealand

Article info
Article history:
Received 11 November 2016
Received in revised form 6 July 2017
Accepted 13 July 2017
Available online 27 July 2017

Keywords:
Versatile soils
Ecosystem services
Cost–benefit analysis
Policy
Urban development

Abstract
Urban encroachment onto versatile land is a global challenge, and as the pressure to develop this land mounts there are moves to assess the broader impacts of these decisions. One common decision support tool for policy decisions is cost–benefit analysis (CBA), and despite criticisms of the approach it enjoys widespread use. Using a case of urban development onto versatile rural land in New Zealand, two issues relating to the use of CBA are tackled – the monetisation of all values and what values to include – along with a discussion of irreversible decisions. To identify which costs and benefits to include in a CBA we provide a structured process using an ecosystem services framework early in a CBA to provide a comprehensive means to identify and justify the costs and benefits to include. Using members of the community to decide which ecosystem services are most important for a given context allows more robust deliberation of values and what to include in the CBA. To demonstrate the value of non-market values (e.g. regulatory services) we use soil characteristics. Our assessment demonstrates the challenges facing decision-makers and ongoing methodological shortfalls as CBA approaches are applied to non-substitutable resources and irreversible decisions.

1. Introduction

Since the 1970s the use of cost–benefit analysis (CBA) to inform decision-makers has increased, and in some places any decision must be supported by a formal CBA process (Hanley, 2001; Business Council of Australia, 2012; Murray, 2013; Australian Government, 2014). CBA, as defined by Kelman (1981), is simply systematic thinking about decision-making. It is a process for identifying, valuing, and comparing the costs and benefits of a project, policy, or decision (Bunce et al., 2013) and is used as an analytical tool around the world (Adler and Posner, 1999; Hanley, 2001; Shapiro, 2011; Australian Government, 2014; Turnpenny et al., 2014; New Zealand Treasury, 2015).

The primary objective of a CBA is to determine whether the benefits of a project, policy, or decision outweigh its costs, and by how much relative to other alternatives (Bunce et al., 2013). A CBA process forces the decision-maker to consider or identify all the related costs and benefits of a project, policy, or decision, including potential impacts on human lives and the environment (Bunce et al., 2013; Pearce et al., 2006; Hanley, 2001). Thus, CBA encourages consideration of cause and effect in relation to the project, policy, or decision (Murray, 2013).

There remains debate about the role of CBA, however. Kelman (1981) argues that the validity of CBA is based on moral philosophy, and others note that CBA has been developed based on the values of a small, not necessarily representative, sample of people, which may not be morally sound for all cultures and people (Henrich et al., 2010). It is criticised for producing morally unjustified outcomes, or for not producing morally relevant information, but Adler (1998) contends that CBA is a decision procedure, not a moral standard.

1.1. Monetisation of all values

In the early days of CBA the environment (or environmental values) was largely thought of as incommensurable, such that it could not be measured in monetary terms, and so the omission of environmental values within a CBA was not seen as a major deficiency (Pearce, 1998). Difficult-to-obtain data – especially for valuing environmental resources, human life, and other hard-to-measure goods – continues to be a problem for CBA (Adler and Posner, 1999; Baveye et al., 2016). How to incorporate different types of values has been a topic of debate. Some practitioners feel that...
CBA should be done with all costs and benefits expressed in a common measure, typically dollars (Kelman, 1981; Murray, 2013). The argument for using monetised values is that it makes it easier for decision-makers to monitor a project or policy than when qualitative information is used. Some authors argue that qualitative information on environmental values carries less weight and is likely to be ignored or excluded (Adler and Posner, 1999; Hanley, 2001; Gómez-Baggethun et al., 2010; Eppink et al., 2016). Attempting to reduce everything to monetary terms, however, means that much of the richness of the understanding of a project’s or decision’s effects could be lost (Murray, 2013).

Although some authors insist on the use of monetary values (Adler, 1998) to compare projects, policies, and decisions, others are opposed to putting a dollar value on things that are not normally bought and sold in markets, because these goods are intangible (Kelman, 1981; Prest and Turvey, 1965). Intangible items are “priceless”, and any market value we place on these goods tells us little about their social value (Ackerman and Heinerzling, 2004). It is difficult to measure the value of the intangible aspects of ecosystems because these values belong to the cognitive and emotional realm of human beings, and individuals may be unable, or may decline, to monetise these values (Spash, 2006). As a result, these items are likely to be undervalued in analysis. Also where ecosystems are approaching critical ecological thresholds and the services provided become non-substitutable and scarce then value (i.e. willingness to pay) increases making economic valuation less meaningful (Farley, 2008). There are also challenges where unequal societal wealth distribution leads to vastly different valuations resulting in an under-provision of services to those with lower incomes (Spash, 2008), as well as the ability to aggregate values on a single scale of measurement (Wegner and Pascual, 2011; Samarasinge et al., 2013).

While CBA practice tends to monetise all values, some CBA guides and authors (e.g. Adler and Posner, 1999; Hanley, 2001; Murray, 2013; Australian Government, 2014; New Zealand Treasury, 2015) acknowledge that not all costs and benefits are feasibly monetised, and these non-monetised costs and benefits are included in a CBA alongside the monetary values.

We agree that non-monetised costs and benefits are important and should be presented to decision-makers alongside the monetary CBA calculations (Prest and Turvey, 1965). However, the inclusion of environmental impacts in a CBA is complex. Efforts have been made to value and internalise economic impacts on the environment into decision-making (Krutilla, 1967; Gómez-Baggethun et al., 2010). However, it is often the case when considering environmental impacts in CBA that a complete list of costs can be collected but information on benefits is incomplete (Prest and Turvey, 1965; Ackerman and Heinerzling, 2004).

1.2. Irreversible decisions

Even when it is possible to obtain monetary values, there are various limitations to applying a CBA approach where costs and benefits accrue over very different time horizons (Wegner and Pascual, 2011; Baveye et al., 2016). Common practice is to discount future benefits to obtain a present value. Discounting, however, effectively renders the time beyond the discounting period invisible, and in doing so diminishes consideration of the welfare of future generations. Discounting is particularly challenging in the case of irreversible change and where there are intergenerational welfare implications (Sumaila and Walters, 2005). If we irreversibly lose an ecosystem service, then even if we invest the dollar-equivalent present value of the benefit that service provides in the future, we cannot use the invested money to recover that service in a later period (Ackerman and Heinerzling, 2004). Some even believe there is a case for the use of negative discounting when considering damage to natural capital for the gain of current generations at the expense of future generations (Goodin, 1982; Hall, 1990; Gowdy et al., 2010; Fisher and Hanemann, 2012), particularly when the value of the irreversibly lost ecosystem is likely to increase (Porter, 1982; Angelsen, 1991).

High-quality versatile soils fall into the category of ecosystems whose value is likely to increase. Given the relative scarcity of versatile land for agricultural production (particularly horticultural production) compared to the availability of land for housing, as well as increasing concerns over global food security, this is expected to lead to greater scarcity and food values in the future (Rosegrant and Cline, 2003). This means the value of agricultural land is likely to rise significantly, indicating the option value for agricultural land (Capozza and Helsley, 1990; Angelsen, 1991). Although option values are difficult to quantify, they should be acknowledged in urban development decisions.

1.3. Costs and benefits to include

There has been much debate in the literature about whether costs and benefits should be monetised, but there appears to be less attention paid to exactly what benefits or costs to include in an analysis. CBA guidance is often vague on this issue and does not provide a systematic method for selecting the most important costs and benefits (see, e.g., Asian Development Bank, 2013; Bunce et al., 2013; New Zealand Treasury, 2015). Arguably this is an important component in any analysis, because it identifies and provides a rationale for those values (either as a cost or a benefit) that are important to a decision, and where effort should be taken in collecting the relevant information. It is only at this point that any decision about whether to monetise all or some of the values should be made.

Given the time and cost of undertaking these types of analysis and the budget constraints of many agencies, focusing on the most relevant costs and benefits is also more efficient and prudent. Targeted prioritisation of key costs and benefits is important, particularly in environmental and ecological contexts, where key values are often intangible or difficult to value and therefore potentially overlooked. An ecosystem services framework (see Table 1) is a useful tool when identifying values provided by nature and ecosystems (Greenhalgh and Hart, 2015). Therefore, we propose using an ecosystem services framework in the early stages of CBA, where natural capital is affected, to identify key values relevant to the decision at hand.

The use of deliberative processes in CBA has been advocated to improve the validity of decisions and reduce reliance on potentially out-of-touch bureaucrats (Nou, 2008). Using a structured framework, such as an ecosystem services framework, becomes more helpful in deliberation, because without a guiding framework such processes are typically ad hoc and key values can be missed (Greenhalgh and Hart, 2015).

In this paper we use a case of urban development onto versatile rural land to tackle two critiques of and challenges to CBA – monetisation of all values and what values to include – and discuss another challenge – accounting for values related to irreversible decisions. In response to Wegner and Pascual’s (2011) call for more deliberative approaches, we also offer an option for incorporating more deliberative approaches into CBA practice. To identify which costs and benefits to include in a CBA, we provide a structured process through the use of an ecosystem services framework in the early stages of a CBA to provide a comprehensive way to identify and justify the costs and benefits to include. Using members of the community to decide which ecosystem services are most important for that context allows a more robust deliberation of values and what to include in the CBA. To demonstrate the value
of non-market values (i.e. regulatory services), we use soil characteristics to express the value of these services.

Our assessment also demonstrates the challenges facing decision-makers and the ongoing methodological shortfalls when CBA approaches are applied to irreversible decisions. For this assessment we accept that urban development will progress and we apply CBA to assist with the decision on where to develop. We do not explicitly use CBA to determine whether or not development should occur.

2. Methodological framework

The methodological approach followed in this assessment evaluated the use of an ecosystem services framework and community participation to identify the key set of costs and benefits to include in a CBA. Ecosystem services are defined as the benefits people obtain from nature (Table 1; MEA, 2005), and they are becoming a de facto standard when talking about soils (Baveye et al., 2016), which is an important consideration for this assessment. The ecosystem services framework is useful because it provides a comprehensive grouping of the potential impacts of a policy or project. The comprehensive nature of an ecosystem services framework has been tested in business- and government-focused assessments, as outlined in Greenhalgh and Hart (2015), confirming that this framework does provide a comprehensive assessment of the potential impacts of a decision. Most CBAs are likely to include provisioning services (easier to measure and monetise) but may overlook many of the regulating, cultural, and supporting services (e.g. Covce, 2006; Murray, 2013).

The use of community participation was an important component of our assessment to ensure that the wider concerns and opportunities around development were identified early in the assessment process. Inclusive involvement at the outset enabled stakeholders to deliberate on the potential effects of the policy/project, thus reducing the risk of criticism and appeal of the assessment.

The different steps in the ecosystem services framework (adapted from Ranganathan et al., 2008, and Hanson et al., 2012) that were used within a CBA are outlined in Fig. 1. The initial scope of the assessment was identified and then refined with community stakeholders at the start of a workshop to identify and prioritise relevant ecosystem services. The community stakeholders were drawn from local government, business/rural industry (industry group representatives, a property developer, a vegetable grower, a dairy farmer, and a lifestyle block owner), a non-government organisation, the community, and indigenous people from the assessment area. This group represents the range of people affected by the decision, reducing the probability of deliberations being driven by a single viewpoint.

The workshop was designed to systematically explore the extent to which each ecosystem service was either impacted by the development project, or the extent to which the project depended on each ecosystem service, including the substitutability of each service. A series of questions (see Table 2) were discussed by the stakeholder group for each ecosystem service (as outlined in Table 1). This prioritisation process enabled the relevant ecosystem services to be identified, classified as costs and/or benefits, and then quantified as part of the CBA. A mix of monetary and non-monetary values was used. We acknowledge that these questions are framed as static, one-shot choices. However, during discussions in the workshop the temporal and spatial aspects of these questions were raised and discussed by the participants. The reframing of these questions for future assessments to explicitly include a spatial and temporal dimension should be considered.

2.1. Assessment context

CBA is a central evaluation tool for New Zealand local government policy making (Murray, 2013), with the comparison of costs and benefits required under the Resource Management Act 1991 (usually as part of a Schedule 32 analysis) and the Local Government Act 2002 (LGA). The LGA requires an assessment of the costs and benefits of the options in terms of the current and future wellbeing of communities, and the views and preferences of the people who are likely to be affected by, or who have an interest in, the matter to be considered, along with indigenous cultural values (Knight, 2007). Local authorities determine the scope of each assessment, and what costs and benefits are to be considered and quantified (Knight, 2007; Murray, 2013).

Our assessment context is a local government policy decision over urban development onto highly versatile and productive agricultural land adjacent to New Zealand’s fastest-growing city, Auckland. This issue of competition for land is becoming increasingly important globally in areas with high population growth (Godfray et al., 2010a,b; Smith et al., 2010; Curran-Cournane et al., 2014). With the forecast global ratio of three urban dwellers...
to two rural dwellers by 2025, the urbanisation of agricultural land poses a significant challenge to meeting future food demand (Matuschke, 2009; Satterthwaite et al., 2010; Bai, 2013). This is further exacerbated by urban centres historically being located near highly productive agricultural land. As a result, urban expansion often disproportionately affects these versatile, highly productive lands (Satterthwaite et al., 2010; Bai, 2013).

It is no different in New Zealand, where there is growing concern about the use of high-class land (Land Use Capability [LUC] classes 1–3; Lynn et al., 2009) for rural and urban uses, with urbanisation disproportionately affecting most high-class and productive soils (Rutledge et al., 2010; Curran-Cournane et al., 2014). LUC classes range from 1 to 8, with LUC 1 land being the most versatile land for agricultural production.

2.2. Location description

The study area is Pukekohe, an agricultural area targeted for urban residential development just south of Auckland. Auckland’s population is anticipated to grow from 1.5 to 2.5 million in the next 30 years (Auckland Council, 2013). Development options were investigated for the proposed Auckland Plan (the Plan), including options to expand the Rural Urban Boundary. Pukekohe is one of the ‘greenfield areas of investigation’ identified in the Plan.

Vegetable growing is a significant source of economic activity and employment in Pukekohe (Curran-Cournane et al., 2014) due to the large amount of high-class versatile land in the area. Across New Zealand LUC 1 and 2 land represents approximately 5% of the total New Zealand land area, and LUC classes 1, 2, and 3 only represent 14% of the land mass (Rutledge et al., 2010). In the Auckland region, LUC class 1 land occupies less than 1%, and LUC 2 and 3 land occupies about 27% of the area (Curran-Cournane et al., 2014), with about 86% of the LUC 1 land limited to south Auckland, particularly in and around Pukekohe.

The Pukekohe area provides about one-third of New Zealand’s fresh vegetable production, with some fields having continuously grown vegetables for more than 100 years, often with more than one crop each year (Lowe, 2010). This highly efficient vegetable production system can be attributed to the area’s highly fertile and well-structured dark-brown granular soils, its unique and effectively frost-free temperate climate, the availability of irrigation water, the supply of labour, and its proximity to a multitude of freight options (Curran-Cournane et al., 2014).

Pukekohe is the only place in New Zealand where frost-susceptible crops can be grown reliably year-round (Hunt, 1959; Curran-Cournane et al., 2016). The lack of frosts allows potato crops to be planted earlier than in other regions of New Zealand, allowing for three crops of potatoes per year, and the region is the sole supplier of potatoes for 3 months of the year. Similarly, lettuce production in Pukekohe remains unaffected when the rest of

---

Note: These questions are adapted from WRI (2012), and Ranganathan et al. (2008).

Fig. 1. CBA stages with links to an ecosystem services framework (CBA steps from Buncle et al., 2013; the ecosystem services framework is depicted in red boxes).
New Zealand is affected by frosts (Curran-Cournane et al., 2014; Jivan, 2014). Therefore, without the production of these crops in Pukekohe they would not be available on the market without imports from overseas or indoor growing, and therefore higher costs (Ford, 2014). This land cannot be replaced or substituted by other land close to Auckland, and vegetable growers are concerned that urban development is going to affect future generations in the vegetable industry (Jivan, 2014; Curran-Cournane et al., 2016).

This assessment compares the costs and benefits of urban development on two areas adjacent to Pukekohe, called west (W) Pukekohe and north-east (NE) Pukekohe for our purposes (Fig. 2). Both areas have been considered as potential growth options. The decision being assessed is which site is preferable to develop given that one of the sites must be developed.

W Pukekohe covers approximately 290 ha, of which 45% is LUC 1, 48% is LUC 2, and 7% is LUC 3 land; although 69 ha is on peat soils, which are drained wetlands and less versatile. Currently the area is a mix of open pasture and horticultural land. NE Pukekohe is about 660 ha, with 50% of the area LUC 2 or LUC 3 land; although 69 ha is on peat soils, which are drained wetlands and less versatile. Currently the area is a mix of open pasture and horticultural land. NE Pukekohe drains to the same estuary, which discharges to the Manukau Harbour (Auckland Council, 2013). Stormwater from W Pukekohe and NE Pukekohe contains just one small ‘headwater’ creek, fed by a large, drained peat wetland covering nearly one-quarter of the area. In contrast, the topography of NE Pukekohe is heavily dissected by numerous streams and creeks (Tonkin and Taylor, 2013).

To ensure comparability between W and NE Pukekohe, we assumed the same number of hectares supplying the same number of new dwellings are developed in each area: 290 ha of land in W Pukekohe and 290 ha of the 660 ha of land in NE Pukekohe. In NE Pukekohe this consisted of 123 ha of dairy grazing, 67 ha of sheep and beef grazing land, and 47 ha of other pastoral land, with the remainder in native vegetation or lifestyle blocks with no current agricultural production value.

2.3. Applying the approach

Most CBAs of residential housing developments include the monetary costs and benefits that are easily measured, such as infrastructure costs (suburban roads, water and sewer lines, power supply and telephone cables, etc); basic community services (e.g. town centres, schools, emergency services, police, public transport); and social infrastructure such as recreation. The social costs commonly considered include congestion and the resulting loss in economic value; increases in greenhouse gas emissions and air pollution; mental health costs related (in some cases) to lack of social services and amenities; and lack of public transport services and subsequent higher car usage (Biddle et al., 2006).

Some of the less common environmental costs/benefits identified and discussed in the literature include pollution of land and groundwater basins due to waste disposal and landfill; pollution of coastal waters, rivers, and lakes due to urban development and higher stormwater run-off; depletion of freshwater stocks near major urban areas due to higher demand; carbon sequestration; pollination; air pollution due to fossil fuel emissions; and development pressure on agricultural land (Biddle et al., 2006; De Sousa, 2002; Dorsey, 2003). However, there appears to be no systematic approach for identifying which environmental costs and benefits, or ecosystem services, to include in an assessment.

The aim of the prioritisation workshop with community stakeholders was to address this deficiency and to identify those ecosystem services the community believe are important, would be affected by urban development, are necessary for successful urban development, or are necessary for the agricultural sector. The workshop used the questions in Table 2 to determine the ecosystem services considered by the group to be high, medium, or low priority (see Table 3).

Nine ecosystem services were prioritised (Table 3) – crops, livestock, wild foods, freshwater, air quality maintenance, water regulation, water purification and waste treatment, recreation and ecotourism, and ethical and spiritual values. The ‘education and inspiration’ and ‘habitat’ values were also given a high priority, but the stakeholder group felt these services would be addressed within the other cultural services that had been prioritised.

The prioritised ecosystem services formed the basis of the wider values included in the subsequent CBA analysis and where data collection effort was largely directed. The workshop provided a forum for stakeholders to discuss and deliberate on how urban development and agricultural production either depended on or impacted ecosystem services.

2.4. Data collection

Data collection covered the mainstream costs and benefits directly related to development (housing development and lost agricultural production) and the wider costs and benefits identified through ecosystem services prioritisation. Market or financial information for mainstream costs and benefits is readily available. The less commonly available information for the wider costs and benefits was collected in a survey and through analysing soil characteristics. No attempt was made to monetise all costs and benefits associated with the prioritised ecosystem services.
N/A Stakeholder did not believe there was a relevant relationship.

We also consider (approximately 69 ha of the 290 ha in the development area) assumed to affect construction on peat soils in W Pukekohe cost of development in NE Pukekohe, while unstable land was considered cost premiums considered. Slope was assumed to affect the prioritisation workshop.

### Table 3

<table>
<thead>
<tr>
<th>Ecosystem service</th>
<th>Dependence</th>
<th>Impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Provisioning service</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crops</td>
<td>N/A</td>
<td>High negative impact</td>
</tr>
<tr>
<td>Livestock</td>
<td>N/A</td>
<td>High negative impact</td>
</tr>
<tr>
<td>Capture fisheries</td>
<td>N/A</td>
<td>High negative impact</td>
</tr>
<tr>
<td>Aquaculture</td>
<td>N/A</td>
<td>High negative impact</td>
</tr>
<tr>
<td>Wild foods</td>
<td>N/A</td>
<td>High negative impact</td>
</tr>
<tr>
<td>Timber and other wood fibres</td>
<td>Medium</td>
<td>N/A</td>
</tr>
<tr>
<td>Fibres and resins</td>
<td>Medium</td>
<td>N/A</td>
</tr>
<tr>
<td>Animal skins</td>
<td>N/A</td>
<td>Medium negative impact</td>
</tr>
<tr>
<td>Ornamental resources</td>
<td>N/A</td>
<td>High positive impact</td>
</tr>
<tr>
<td>Biomass fuel</td>
<td>Uncertain</td>
<td>Uncertain</td>
</tr>
<tr>
<td>Freshwater</td>
<td>High</td>
<td>High negative impact</td>
</tr>
<tr>
<td>Genetic resources</td>
<td>N/A</td>
<td>Medium negative impact</td>
</tr>
<tr>
<td>Biochemicals, natural medicines</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Regulating services</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maintenance of air quality</td>
<td>High</td>
<td>High impact: maybe positive or negative</td>
</tr>
<tr>
<td>Global climate regulation</td>
<td>N/A</td>
<td>Medium negative impact</td>
</tr>
<tr>
<td>Regional/local climate regulation</td>
<td>Uncertain</td>
<td>High negative impact</td>
</tr>
<tr>
<td>Water regulation</td>
<td>High</td>
<td>High negative impact</td>
</tr>
<tr>
<td>Erosion control</td>
<td>Medium</td>
<td>High positive impact</td>
</tr>
<tr>
<td>Water purification and waste treatment</td>
<td>High</td>
<td>High impact: maybe positive or negative</td>
</tr>
<tr>
<td>Disease mitigation</td>
<td>Uncertain</td>
<td>High negative impact</td>
</tr>
<tr>
<td>Maintenance of soil quality</td>
<td>N/A</td>
<td>High negative impact</td>
</tr>
<tr>
<td>Pest mitigation</td>
<td>N/A</td>
<td>High impact: maybe positive or negative</td>
</tr>
<tr>
<td>Pollution</td>
<td>N/A</td>
<td>High negative impact</td>
</tr>
<tr>
<td>Natural hazard mitigation</td>
<td>Medium</td>
<td>High negative impact</td>
</tr>
<tr>
<td>Cultural services</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recreation and ecotourism</td>
<td>High</td>
<td>High negative impact</td>
</tr>
<tr>
<td>Ethical and spiritual values</td>
<td>High</td>
<td>High negative impact</td>
</tr>
<tr>
<td>Educational and inspirational services</td>
<td>N/A</td>
<td>High negative impact</td>
</tr>
<tr>
<td>Supporting services</td>
<td>High</td>
<td>High negative impact</td>
</tr>
<tr>
<td>Habitat</td>
<td>High</td>
<td>High negative impact</td>
</tr>
</tbody>
</table>

**N/A Stakeholder did not believe there was a relevant relationship.**

Ecosystem services in bold refer to those services considered most important in the prioritisation workshop.

### 2.4.1. Housing development information

The difference in the cost of housing development in the two areas was used to measure the cost or benefit of developing in one area over the other. House construction (including labour) and infrastructure development costs were taken from a published industry report (Wilson, 2015). These costs assumed each house is standard quality with an average floor area of 158 m² (Wilson, 2015; Page, 2013). Infrastructure costs included earth works, civil works (including water supply and roads), and landscaping, as well as professional fees and development fees (Page, 2013).

Slope and unstable land were the construction and development cost premiums considered. Slope was assumed to affect the cost of development in NE Pukekohe, while unstable land was assumed to affect construction on peat soils in W Pukekohe (approximately 69 ha of the 290 ha in the development area) (Page and Fung, 2011; Tonkin and Taylor, 2013). We also consider additional stormwater requirements for developing peat land in W Pukekohe using an annualised cost of rain-garden construction and maintenance for each dwelling (Kettle and Kumar, 2013; Table 5).

We assumed the same number of dwellings were constructed in each location at a density of 8.33 dwellings per hectare (inclusive of roads/footpaths/services etc found within urban areas). This density was calculated using the proposed development areas and number of dwellings given in Tonkin and Taylor (2013).

### 2.4.2. Crop and livestock information

If land is converted to housing it will no longer produce agricultural products. Therefore, the cost of development is the value of foregone agricultural production. In W Pukekohe, approximately 68 ha are in vegetables, 24 ha in fruit, and 39 ha in forest/lifestyle blocks, with the rest in pasture (50 ha under dairy grazing, 55 ha under sheep and beef grazing, and 54 ha of other pastoral land). All of NE Pukekohe is in pasture (c. 43% in dairy), except for 54 ha of forest/lifestyle blocks. W Pukekohe, being mostly LUC 1 and 2 land, is more versatile and able to produce a wider range of agricultural commodities than NE Pukekohe. We assume that the land under agricultural production is in its best use, acknowledging that this use will change over time in response to commodity prices. We also acknowledge that lifestyle blocks, if of big enough size, could potentially revert to more intensive agricultural production. This, however, was not a scenario considered, as it is uncommon.

Onions, potatoes, and green crops are typical crops grown in the W Pukekohe area (Aitken and Hewett, 2014). The production costs and net revenue data for these crops were derived from Agribusiness (2014). For pastoral farming the average production and revenue data were based on published data from the dairy and sheep and beef industries (DairyNZ, 2014; Beef + Lamb, 2014).

### 2.4.3. Wild foods, recreation, and ethical and spiritual values

Despite the extensive exploration of urban expansion in this area, no existing information was available for these services. To fill this data deficit, an online survey using Facebook was undertaken. The survey targeted people who live in or around Pukekohe and who take part in outdoor activities in the area. Respondents (330 in total) provided information on whether they or any family members (with whom they share a home) have visited the Pukekohe area 1) to participate in outdoor recreational activities, or 2) to collect/harvest wild foods, or 3) if they have places of cultural, historical, religious, or personal significance in the area. They were then asked to locate on Google Maps where they had undertaken each activity or the locations of significance to them. Additional questions on visit frequency and the trend in service quality for each location were asked. ‘Heat maps’ were generated for the most visited/most significant places (Figs. 3, 4, and 5).

Outdoor recreational activities were grouped into water-based recreation (swimming, kayaking/boating, fishing; Fig. 4), recreational activities that would be desired closer to residential areas (running/walking, mountain biking); and recreational activities more desirable further from residential areas (hunting, tramping, 4WD/motocross, and horseback riding). No land-based recreation activities were directly impacted by either development. However, there were four walking/running sites located nearer W Pukekohe and two walking/running, one mountain biking, three horse-riding, and one hunting site near NE Pukekohe. Given the proximity of the proposed development areas it is likely that new residents, regardless of development area, will utilise these sites. As long as there are walking/running tracks in the immediate vicinity of a proposed development area, it was assumed this should meet any demand for this type of recreation (which users are likely to prefer closer to their home).
Fig. 3. Wild foods heat map, Pukekohe area: red indicates highest activity; yellow is lower activity; green is lowest activity. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Fig. 4. Water-based recreation heat map, Pukekohe area: yellow indicates higher activity; green is lower activity.
The significant places were grouped into cultural, historical, religious, or personal significance (Fig. 5). Within the proposed development areas, only the historic Pukekohe East School in NE Pukekohe will be directly affected. The wild foods identified through the survey were mostly water-based or located near waterways (eel, pipi, watercress, game meat, scallops, whitebait, oysters, and other seafood; Fig. 3). Therefore, the quality and availability of these wild foods will be influenced by the water-related ecosystem services. The already degraded aquatic ecosystems in the area (Auckland Council, 2016) mean wild foods are no longer collected in the immediate vicinity or downstream of the development areas; any collection is in the less developed parts of the wider area.

2.4.4. Air quality, water regulation, and water purification

Air quality, water regulation, and water purification are strongly influenced by soil characteristics. Therefore, the impact on these services has been tied back to the soils in each of the proposed development areas.

In W Pukekohe two-thirds of the soils are Granular soils, with another 23% Organic soils (peat). In NE Pukekohe approximately 80% of the soils are Brown soils. In terms of air quality and sediment loss, W Pukekohe soils have low to very low structural vulnerability (based on Hewitt and Shepherd, 1997), compared with moderate to high in NE Pukekohe. This means W Pukekohe soils have a lower likelihood of creating dust pollution under good agricultural management practices.

Nitrogen (N), phosphorus (P), and microbial filtering services were used to compare the water purification and waste treatment services between the two areas (Hewitt et al., 2015). W Pukekohe soils have lower microbial filtering potential and are therefore a higher contamination risk than the soils in NE Pukekohe. The soils in W Pukekohe have the better N filtering potential of the two areas. Similarly, W Pukekohe has better P filtering potential (high) than NE Pukekohe (moderate). The actual pollutant loss, however, will vary by land use.

Water regulation services can be described according to the soil run-off and infiltration potential (Dominati et al., 2010; Hewitt et al., 2015). The soils in W Pukekohe tend to have moderate to high run-off potential, with the exception of the peat soils, which can absorb and attenuate water. However, the high water table in the area does reduce the extent to which these peat soils absorb water. The larger floodplain area in W Pukekohe does mitigate some of the high run-off potential, however, as does the flatter topography of the land. While the soils in NE Pukekohe mostly have low run-off potential, they are on steeper slopes, meaning their run-off will be higher than if the land were flatter.

3. Cost–benefit analysis

3.1. Summary of ongoing costs and benefits

Table 4 summarises the ecosystem services provided in NE Pukekohe and W Pukekohe in their current undeveloped state. The decision being made in the CBA is which of the two sites to develop, assuming development of a site is going to occur. If we were making a choice between development and no development, loss of these ecosystem services could be listed as costs or benefits of development at this stage. However, in our case these services are either costs or benefits depending on which site is developed.
Table 4: Ecosystem services provided by the two sites in current undeveloped state.

<table>
<thead>
<tr>
<th>Ecosystem service</th>
<th>W Pukekohe</th>
<th>NE Pukekohe</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Agricultural revenue</strong> ($/yr):</td>
<td>$1,770,108</td>
<td>$0</td>
<td>Milk and meat production is likely to be substitutable with other areas. However, production of frost-sensitive vegetable production has few substitute areas, either locally or within NZ. Despite both areas draining to the same tributary, there is expected to be higher negative downstream impact on water quality from the NE Pukekohe development (see water purification). The soils in W Pukekohe are more versatile than those in NE Pukekohe, implying a higher option value. The horticultural industry employs approximately 2.75 times more people than the pastoral industry in the Auckland area, providing approximately 1.1 times greater value added to the regional economy (Hughes, 2011).</td>
</tr>
<tr>
<td>• vegetable production</td>
<td>$84,645</td>
<td>$102,787</td>
<td></td>
</tr>
<tr>
<td>• milk production</td>
<td>$422,450</td>
<td>$1,043,195</td>
<td></td>
</tr>
<tr>
<td>• other pasture production</td>
<td>$41,553</td>
<td>$35,840</td>
<td></td>
</tr>
<tr>
<td>• fruit production</td>
<td>$1,185,240</td>
<td>$0</td>
<td></td>
</tr>
<tr>
<td><strong>Total agricultural revenue</strong></td>
<td>$3,503,996</td>
<td>$1,181,822</td>
<td></td>
</tr>
<tr>
<td><strong>Employment:</strong></td>
<td>Lose mostly horticultural workers</td>
<td>Lose mostly pastoral workers</td>
<td></td>
</tr>
<tr>
<td><strong>New services due to urbanisation</strong></td>
<td>Similar</td>
<td>Similar</td>
<td></td>
</tr>
<tr>
<td><strong>Freshwater</strong></td>
<td></td>
<td></td>
<td>Water for urban development is likely to come from the Waikato river for both areas.</td>
</tr>
<tr>
<td>• Agricultural use</td>
<td>Irrigation demand</td>
<td>Mostly rainfall</td>
<td></td>
</tr>
<tr>
<td>• Urban use</td>
<td>Similar</td>
<td>Similar</td>
<td></td>
</tr>
<tr>
<td><strong>Wild foods</strong></td>
<td>Similar</td>
<td>Similar</td>
<td></td>
</tr>
<tr>
<td><strong>Air quality maintenance:</strong></td>
<td></td>
<td></td>
<td>Assume the same level of additional air emissions from both developments. Horticulture is mostly in W Pukekohe on soils that are more resistant to structural change and creation of dust. NE Pukekohe is mostly in pastoral production with less soil disturbance. Therefore, assume little dust generated from current agricultural production activities. There will be some effects on air quality from agricultural chemical use related to horticultural production. W Pukekohe has higher risk of flooding and run-off during storm events.</td>
</tr>
<tr>
<td>Housing emissions</td>
<td>Similar</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Agriculture dust emissions</td>
<td>Low to very low (90%) structure vulnerability</td>
<td>Moderate (80%) to high (10%) structure vulnerability</td>
<td></td>
</tr>
<tr>
<td>• chemical emissions</td>
<td>Likely higher</td>
<td>Likely lower</td>
<td></td>
</tr>
<tr>
<td>Water regulation:</td>
<td></td>
<td></td>
<td>Expect impacts on water quality to be slightly greater in NE Pukekohe due to the greater number of tributaries in the development area and steeper slopes. The peat soils in W Pukekohe are also likely to act as a filter for some contaminants. In terms of nutrients, NE Pukekohe soils have lower nutrient filtering capacity and therefore are more likely to leach more nutrients than W Pukekohe. Soils in W Pukekohe have low microbial filtration potential and are likely to lose more microbes (e.g. E. coli) than NE Pukekohe. This will affect stream stream swimmability. Soils in W Pukekohe have better structural vulnerability and are less likely to erode when compared to NE Pukekohe. The soils in W Pukekohe have a greater ability to attenuate heavy metals (esp. peat soils) than NE Pukekohe, and therefore result in fewer heavy metals reaching waterways. In terms of development, the downstream benefits on water quality are likely to be greater from developing the NE Pukekohe area. Overall, the soils in W Pukekohe are probably better for horticultural production than NE Pukekohe, while the soils in NE Pukekohe are better for livestock production than W Pukekohe. Sites for land-based recreation were not found within either development area, but further afield. We assume that affects are the same for each area. In the estuary area downstream of both areas there is some kayaking/boating, swimming and fishing, but the area appears less popular than other areas (e.g. Clarks Beach, Port Waikato, Karitotahi). Water quality is a key determinant for continued water-based recreation. Historic Pukekohe East School is within the NE Pukekohe development area.</td>
</tr>
<tr>
<td>Soil run-off and infiltration potential</td>
<td>Moderately high to high run-off potential</td>
<td>Low run-off potential</td>
<td></td>
</tr>
<tr>
<td>Floodplain</td>
<td>Large floodplain area</td>
<td>Small floodplain area</td>
<td></td>
</tr>
<tr>
<td>Water purification:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Agricultural nutrient loss:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• nitrogen losses</td>
<td>Moderate to high N filtering index (i.e. low N loss risk)</td>
<td>Predominantly moderate N filtering index (i.e. mod loss)</td>
<td>The peat soils in W Pukekohe are also likely to act as a filter for some contaminants. In terms of nutrients, NE Pukekohe soils have lower nutrient filtering capacity and therefore are more likely to leach more nutrients than W Pukekohe. Soils in W Pukekohe have low microbial filtration potential and are likely to lose more microbes (e.g. E. coli) than NE Pukekohe. This will affect stream swimmability. Soils in W Pukekohe have better structural vulnerability and are less likely to erode when compared to NE Pukekohe. The soils in W Pukekohe have a greater ability to attenuate heavy metals (esp. peat soils) than NE Pukekohe, and therefore result in fewer heavy metals reaching waterways. In terms of development, the downstream benefits on water quality are likely to be greater from developing the NE Pukekohe area. Overall, the soils in W Pukekohe are probably better for horticultural production than NE Pukekohe, while the soils in NE Pukekohe are better for livestock production than W Pukekohe. Sites for land-based recreation were not found within either development area, but further afield. We assume that affects are the same for each area. In the estuary area downstream of both areas there is some kayaking/boating, swimming and fishing, but the area appears less popular than other areas (e.g. Clarks Beach, Port Waikato, Karitotahi). Water quality is a key determinant for continued water-based recreation. Historic Pukekohe East School is within the NE Pukekohe development area.</td>
</tr>
<tr>
<td>• phosphorous losses</td>
<td>High P filtering index (i.e. low P loss risk)</td>
<td>Moderate P filtering index (i.e. mod P loss)</td>
<td></td>
</tr>
<tr>
<td>• microbial losses</td>
<td>Low microbial filtering index (i.e. high loss risk)</td>
<td>Moderate microbial filtering index (i.e. moderate loss risk)</td>
<td></td>
</tr>
<tr>
<td>• sediment loss</td>
<td>Low to very low structural vulnerability (i.e. less likely to erode)</td>
<td>Moderate to high structural vulnerability (i.e. more likely to erode)</td>
<td></td>
</tr>
<tr>
<td>Urban contaminant loss</td>
<td>Medium to high metal attenuation index</td>
<td>Medium metal attenuation index</td>
<td></td>
</tr>
<tr>
<td>Recreation and ecotourism:</td>
<td></td>
<td></td>
<td>Sites for land-based recreation were not found within either development area, but further afield. We assume that affects are the same for each area. In the estuary area downstream of both areas there is some kayaking/boating, swimming and fishing, but the area appears less popular than other areas (e.g. Clarks Beach, Port Waikato, Karitotahi). Water quality is a key determinant for continued water-based recreation. Historic Pukekohe East School is within the NE Pukekohe development area.</td>
</tr>
<tr>
<td>• Land-based recreation</td>
<td>Similar</td>
<td>Similar</td>
<td></td>
</tr>
<tr>
<td>• Water-based recreation downstream</td>
<td>Similar</td>
<td>Similar</td>
<td></td>
</tr>
<tr>
<td>Ethical and spiritual values</td>
<td>Low</td>
<td>Low (depending on development design)</td>
<td></td>
</tr>
</tbody>
</table>
Therefore, it is the difference in the change in these services that is relevant to the decision. For this reason, some costs or benefits that may normally be included in a development versus no development scenario are not relevant. For example, the cost of travel to employment can be assumed to be the same for NE and W Pukekohe as they are relatively close to each other, and the distance to Auckland, the main employment centre, is similar.

It is important to note that the loss of some of these services from development is irreversible, so the loss is felt indefinitely into the future. Therefore, we separate these services from the one-off costs of development. Later (Table 6) we put the services in Table 4 under the headings of costs and benefits, and determine whether the loss is more significant when developing NE or W Pukekohe.

If 290 ha of W Pukekohe is developed, crop and livestock provision services will be totally lost, affecting the livelihood of people working in farming. The land in this area is some of the best land for horticultural production in the country (LUC 1–3), and if paved over this production capability will be irreversibly lost. We use agricultural revenue as an indicator for the cost of lost agricultural production and assume that this will also account for the flow-on effects of agricultural production, such as labour wages, input, and living expenditures in the local area.

The recurring annual loss 2 in W Pukekohe from vegetable production is $1,770,108 and from pastoral farming and fruit production is about $1,733,888. In comparison, the agricultural revenue losses in NE Pukekohe are approximately $1,181,822, all from livestock and dairy production (Table 4). These annual losses represent a stream of lost revenues into the future. We do not use discounting to obtain a present value of these revenues because of (as noted in the introduction) the irreversibility of this decision. While pastoral farming and fruit production losses can be substituted from many other areas within New Zealand, the vegetable production is not so easily substitutable. The unique frost-free microclimate around Pukekohe means that there are no other places in New Zealand where these vegetables can be grown all year round. These dollar figures for lost production do not capture the lost option value from paving over productive soils. Given the higher versatility of the soils in W Pukekohe, we expect the option value to be higher in this area than in NE Pukekohe.

Wild foods harvest/collection and water-based recreational activities occur along waterways and in coastal areas. From the community survey there was little wild food collection downstream of the development area, so the proposed developments may not affect wild food collection values to any great extent. The survey did, however, indicate that developing in other areas such as Clarks Beach and Port Waikato is likely to have an impact on wild food collection. What was not ascertained by the survey was whether the existing development or intensive agriculture in Pukekohe had already affected downstream wild food collection, causing this collection to move to the other freshwater and estuarine habitats in the area.

In terms of water purification services, the soils in W Pukekohe have a lower risk of leaching nutrients and losing sediments than in NE Pukekohe, but they are likely to have greater microbial losses. However, the often-higher nutrient leaching rates associated with horticultural production (Waikato Regional Council, 2008; Meijer et al., 2016) and the length of time the area has been in production will put pressure on the water purification services provided by these soils.

Even though the soils in W Pukekohe have higher water run-off potential than those in NE Pukekohe, the flatter topography of the area will mitigate this run-off risk as well as the risk of microbial loss (which is related to livestock). Microbial losses affect the downstream (current or potential) water-based recreational activities (Nagels et al., 2001). Despite the low water run-off in NE Pukekohe, the hillier topography is likely to generate some run-off. Combining this with the moderate microbial loss in NE Pukekohe and the area’s greater suitability for pasture production indicates that the area is likely to have greater impacts on downstream water quality, and consequently on water-based recreation.

We do not expect any direct negative impacts on land-based recreational activities, as these activities tended to be outside the development areas and there are other frequently visited alternative locations in the vicinity. There were no historical, religious, personal, or culturally significant sites identified in W Pukekohe, so no impact from development is expected. In NE Pukekohe the Pukekohe East School (established 1880) was identified by survey respondents as a historically significant site and it is located within the development area. However, this site is likely to remain even with development.

While no clear preference for where to develop emerges from our assessment of wider ecosystem services, the assessment does show greater agricultural revenue losses associated with developing W Pukekohe and greater benefits to water quality associated with developing NE Pukekohe (Table 4). This suggests that developing NE Pukekohe would have less impact than developing W Pukekohe. But there are trade-offs, namely potentially greater water run-off (related to both the slope and soils of NE Pukekohe), greater contaminant loss (primarily resulting from the peat soils in W Pukekohe being better at attenuating heavy metals), and continuing dust and irrigation water use associated with cropping in W Pukekohe.

3.2. Summary of one-off costs

Table 5 summarises the one-off cost premiums of construction in NE and W Pukekohe due to land characteristics. We include only these premiums because, as with the characteristics presented in Table 4, it is the difference in development costs that is needed for the decision. The base cost of development is assumed to be equal in both areas, and the difference in overall cost will be determined by these premiums.

Land marked for development in W Pukekohe is flat, with approximately 69 ha of unstable peat soils, which are less suitable for development. Developing peat soils requires additional stormwater infrastructure and construction works compared to other soil types. The estimated additional construction cost is about $6,334,700, plus an additional infrastructure development cost of $2,133,150, and stormwater infrastructure cost of $2,179,825. NE Pukekohe is hilly. Page and Fung (2011) estimate that building on a slope increases building costs by 4.9% per dwelling. We assume this additional cost affects all land being developed in NE Pukekohe, with an estimated cost premium of $26,624,093 for building costs and an additional $8,881,250 infrastructure development cost (Table 5).

The one-off monetary cost of development is $24,877,695 higher in NE Pukekohe than in W Pukekohe. Furthermore, construction in NE Pukekohe is likely to produce more dust, resulting in lower air quality during the development process. Assessing just the one-off costs therefore supports development in W Pukekohe over NE Pukekohe.

3.3. Comparing the development sites

Considering the one-off costs of development and the ongoing ecosystem services costs and benefits separately we get different indications of which site is preferable to develop. Table 6 attempts to synthesise this information by placing each service or development cost under the heading of either a cost or benefit of develop-
The table also states whether this cost or benefit is larger in the case of developing NE Pukekohe or W Pukekohe, and which area it supports the development of. While this table does not provide a clear answer as to which option is preferable, it synthesises information from diverse sources in a way that can inform discussion.

When the quantitative but not monetised information is considered, the story is still not clear. As seen in Table 6, the better area to develop changes depending on the ecosystem service in question. What it does show is which services will be further impacted (or improved) when an area is urbanised. This provides an opportunity for communities to understand what is being sacrificed or potentially enhanced, as well as providing decision-makers with information on what additional mitigation is needed to reduce the negative impacts on a broader range of ecosystem services.

### 4. Discussion

Many cities around the world face the challenge of losing their most productive land to urban development, and with it their ability to supply food for growing populations (Sheridan et al., 2015). Auckland is no different, with its growing need for housing creat-

---

### Table 5
Summary of the one-time cost differentials of urban development between the two sites.

<table>
<thead>
<tr>
<th>Cost</th>
<th>W Pukekohe</th>
<th>NE Pukekohe</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction costs ($)</td>
<td>Same</td>
<td>Same</td>
<td>Base construction costs are assumed to be the same for both areas.</td>
</tr>
<tr>
<td>• slope premium</td>
<td>$0</td>
<td>$26,624,093</td>
<td></td>
</tr>
<tr>
<td>• unstable soils premium</td>
<td>$6,334,698</td>
<td>$0</td>
<td></td>
</tr>
<tr>
<td>Total cost premium</td>
<td>$6,334,698</td>
<td>$26,624,093</td>
<td></td>
</tr>
<tr>
<td>Infrastructure costs ($)</td>
<td>Same</td>
<td>Same</td>
<td>Base infrastructure costs are assumed to be the same for both areas.</td>
</tr>
<tr>
<td>• slope premium</td>
<td>$0</td>
<td>$8,881,250</td>
<td></td>
</tr>
<tr>
<td>• unstable soils premium</td>
<td>$2,113,152</td>
<td>$0</td>
<td></td>
</tr>
<tr>
<td>Total cost premium</td>
<td>$2,113,152</td>
<td>$8,881,250</td>
<td></td>
</tr>
<tr>
<td>Stormwater costs (total annualised $)</td>
<td>$2,179,825</td>
<td>$0</td>
<td></td>
</tr>
<tr>
<td>Additional employment during development</td>
<td>Same</td>
<td>Same</td>
<td>Assumed to be same for both areas</td>
</tr>
<tr>
<td>Air quality:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>dust emissions during construction</td>
<td>Low to very low</td>
<td>Moderate (80%) to high (10%) structure vulnerability</td>
<td>The higher the vulnerability index, the less resistant the soils are to physical changes and the more likely to generate dust. Therefore, more dust is likely to be created in NE Pukekohe during construction.</td>
</tr>
</tbody>
</table>

* Indicates an assumption that the costs are the same for both areas under existing use and the development scenarios.

### Table 6
Classification of the costs and benefits related to urban development in Pukekohe (drawing from Table 4 and only listing those benefits and costs expected to be affected differently between sites).

<table>
<thead>
<tr>
<th>Infrastructure &amp; ecosystem services</th>
<th>Benefits</th>
<th>Costs</th>
<th>Best development option</th>
</tr>
</thead>
<tbody>
<tr>
<td>One-time costs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Construction</td>
<td></td>
<td></td>
<td>W Pukekohe</td>
</tr>
<tr>
<td>Air quality (dust during construction)</td>
<td></td>
<td></td>
<td>W Pukekohe</td>
</tr>
<tr>
<td>Recurring benefits and costs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Employment</td>
<td></td>
<td></td>
<td>NE Pukekohe</td>
</tr>
<tr>
<td>Agricultural revenue (and option value)</td>
<td>Less irrigation water use in W Pukekohe</td>
<td>Loss of employees in agricultural sector (greater loss W Pukekohe)</td>
<td>NE Pukekohe</td>
</tr>
<tr>
<td>Freshwater</td>
<td></td>
<td></td>
<td>W Pukekohe</td>
</tr>
<tr>
<td>Air quality maintenance (dust and agricultural chemicals)</td>
<td>Less dust and chemicals associated with agricultural production (W Pukekohe benefits more despite lower structure vulnerability as area has greater periods of fallow/tillage)</td>
<td>Loss of agricultural production (greater losses in W Pukekohe)</td>
<td>W Pukekohe</td>
</tr>
<tr>
<td>Water regulation</td>
<td></td>
<td></td>
<td>More run-off associated with urban development (greater run-off in NE Pukekohe based on slope; not soils)</td>
</tr>
<tr>
<td>Water purification (nutrients)</td>
<td>Fewer nutrient losses from agriculture (greater agricultural losses in NE Pukekohe based on soils)</td>
<td></td>
<td>NE Pukekohe</td>
</tr>
<tr>
<td>Water purification (E. coli)</td>
<td>Less E. coli from livestock (currently greater benefits likely in NE Pukekohe due to higher livestock numbers)</td>
<td></td>
<td>NE Pukekohe</td>
</tr>
<tr>
<td>Water purification (sediment)</td>
<td>Less sediment loss (greater benefits in NE Pukekohe based on slope and erodibility of soils)</td>
<td></td>
<td>NE Pukekohe</td>
</tr>
<tr>
<td>Water purification (contaminants)</td>
<td></td>
<td></td>
<td>More urban contaminants (greater in NE Pukekohe based on soils and slope)</td>
</tr>
</tbody>
</table>

* Based on what area was least cost for development or had lesser environmental impacts from development.
ing pressure for greenfield urban development on agricultural land. One area where this is most evident has been in the horticultural areas south of Auckland on highly versatile soils.

We accept, in our assessment, that there will be some degree of urban development on land around the township of Pukekohe and our focus is on where development will have the least impact on the wider suite of ecosystem services. Using an ecosystem services framework with community stakeholders helped to identify the important services provided by rural land in the area, and to justify which costs and benefits should be considered in a CBA. Bartke and Schwarze (2015) emphasise that urban development decisions must trade off different stakeholder, societal, and ecological demands, and this could be one approach to identify, prioritise, and describe (quantitatively and/or qualitatively) these trade-offs based on community values.

Unlike Wegner and Pascual (2011), who clearly outline and question the theoretical validity and empirical applicability of CBA in the context of ecosystem services, we aimed to refine how ecosystem services could be used to improve the practice of CBA. Instead of taking the approach of monetising ecosystem services of authors such as Tallis and Polasky (2009) and Dominati et al. (2014), we have used ecosystem service concepts to demonstrate how they can be used to prioritise the services when making trade-offs. Our use of an ecosystem services framework also prevents important values being overlooked due to the sometimes ad hoc nature of deliberative processes.

The difficulty in comparing one-time financial costs and benefits of development with the recurring benefits of agricultural production was apparent in our assessment. Discount rates, which are commonly used to express future costs and benefits in today’s equivalent value, act to favour short-term benefits over longer-term benefits. While this is appropriate in some evaluations, it creates challenges where there are ecological thresholds, where the resources or ecosystem services being provided are not substitutable, when loss of services is irreversible, and where there are intergenerational implications (Sumaila and Walters, 2005; Wegner and Pascual, 2011; Baveye et al., 2016).

Our assessment found that the one-time costs to develop on the hillier NE Pukekohe area were higher than for the flatter W Pukekohe area, and the agricultural returns were higher on the flatter W Pukekohe area. In other words, the classic conundrum of agricultural vs urban development exists (Paill and McKenzie, 2013).

Based purely on the one-time financial cost of development, W Pukekohe would be the preferred place to develop, as the development costs are lower because of the flatter land (Table 4). Coupled with the lower risk of dust pollution during the construction phase in W Pukekohe, community acceptance may be higher and dust mitigation costs lower during development. However, it is the recurring costs that highlight the real loss of the broader array of ecosystem services and the option value of this land where decisions are irreversible. Arguably it is these costs that should drive development decisions, not one-time costs, especially where decisions are irreversible.

We can capture many of the broader ecosystem services costs and benefits using a soils lens (Hewitt et al., 2015). Air quality, water regulation (timing and flows), and water purification were deemed most directly related to soil characteristics, with wild foods and some recreational activities indirectly related to soils through their reliance on water quality or quantity. Agricultural use is directly linked to the land and soil characteristics, as they are limiting factors for many agricultural activities (Lynn et al., 2009).

We found W Pukekohe not only has the larger loss of agricultural revenue, but also the larger agricultural opportunity costs, as this land is more versatile and able to produce a wider range of agricultural commodities. Similarly, W Pukekohe has greater provision of regulating services important for agricultural areas, making it the better location for agricultural production. Articulating the recurring costs and benefits related to ecosystem services to differentiate between areas can effectively highlight the full range of costs and benefits of development.

While this assessment does not overwhelmingly and conclusively indicate that one area is better to develop than another, it does:

1. indicate that using a greater number of ecosystem services does identify some key considerations for the choice of which area to develop
2. provide some cost-effective approaches to use to elicit information on cultural services
3. show how soil characteristics can be used to support CBA, through ecosystem services
4. reiterate the continuing challenges with irreversible decisions countering the financial benefits from developing rural land, and the implications for the loss of land use versatility once land is developed
5. outline a mechanism to engage communities in discussions and deliberations around the implications of urban development and potentially increasing the public acceptability of outcomes
6. provide decision-makers with a potentially more credible justification of the costs and benefits used to compare sites.

5. Conclusions

One of the challenges for CBA practitioners is what costs and benefits to include. There has been a tendency to include costs or benefits that have been used in previous analyses (e.g. employment, infrastructure, income, capital costs, and some environmental costs such as carbon), leading to a persistence of unaccounted-for intangible benefits and costs. In other cases, analyses are restricted to those costs and benefits that can be easily monetised, or to where monetised values already exist. This tends to ignore many of the less tangible values people have (and that are challenging to monetise), or to overlook key non-market costs or benefits (that could be monetised) that should influence final decisions.

As CBA has evolved, much effort has gone into refining the methodology and improving the accuracy of the data. However, there appears to be less emphasis in the literature on what costs and benefits to include in a CBA. We have demonstrated the use of a structured ecosystem services framework to identify the costs and benefits that are most relevant to a decision via community engagement and deliberation. The use of such a framework adds more rigour to the stakeholder engagement process by ensuring key values are less likely to be missed. Without a guiding framework, such processes can be ad hoc and rely on individuals to identify values or impacts of a decision, many of which are those values that ‘come to mind’ on the day. An ecosystem services framework adds another tool to the practitioner’s toolkit to ensure all relevant values are included in an assessment.

We faced similar challenges to other authors with the use of CBA (as noted in Wegner and Pascual, 2011, and Baveye et al., 2016) in situations where there are irreversible and potentially unintended consequences of decisions. Our approach ensured that future and difficult-to-value costs and benefits were not overshadowed, as they might have been in a more traditional CBA. However, the approach was unable to entirely overcome the challenges associated with irreversibility, comparison of long- and short-term
costs and benefits, and the non-substitutability of resources/ecosystem services by providing a quantitative comparison in a common metric. This puts into question the use of CBA for decisions of agricultural production on versatile soils versus urban development, and other questions related to ecosystem services and environmental values. Even though the results of where to develop are not definitive, knowing where the greater benefits and costs accrue, which our approach allowed, can be used to inform where to develop as well as recognising the potential trade-offs, which may then be mitigated.

There are still unanswered questions and research needed to determine the extent to which ecosystem service concepts can be used to improve the practice of CBA. This includes testing the approach outlined in this paper in other contexts that are not affected by issues of non-substitutability and irreversibility; testing the community/decision-maker acceptance of these approaches; the use of mixed metrics; and exploring approaches to better quantify and describe the costs and benefits represented by ecosystem services.

Acknowledgements

This work was jointly funded by Auckland Council and the Ministry of Business, Innovation, and Employment (MBIE). This work was supported by Auckland Council, core funding for Landcare Research NZ Ltd and Plant and Food Research/Crown Research Institutes from MBIE, and MBIE contestable contract C09X1307 (BEST).

We would like to thank Susan Fairgray (Market Economics) for her insightful comments and suggestions, and Mehrnaz Rohani (Research and Evaluation Unit, Auckland Council) for her review assistance; and acknowledge Alex Kravchenko for survey programming, Georgina Hart for assistance with the community workshop, and Ray Prebble for editing the manuscript. Last we acknowledge the community members who generously gave their time to attend the community ecosystem service workshop.

References


Spash, C., 2008. How much is that ecosystem in the window?: the one with the biodiverse trail. Environ. Value 17, 259–284.


