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More than a 'nice to have': integrating indigenous biodiversity into agroecosystems in New Zealand

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Abstract: Globally, biodiversity is declining due to increasing populations and land use pressures associated with development-induced land conversion, resource use, and food production. In New Zealand, a considerable proportion of remaining indigenous biodiversity occurs on farmland in private ownership outside of the public conservation land. Therefore, coordinated actions on-farm are required to increase the opportunities to achieve biodiversity outcomes beyond the boundaries of the protected area network and increase farm sustainability and resilience. Increasing biodiversity on-farm can be achieved by enhancing existing biodiversity or through reintroducing structural diversity (e.g. planting of indigenous species and excluding livestock to prevent treading and grazing and allow natural regeneration to occur). Successful integration of biodiversity into decision-making on-farm requires explicitly accounting for biodiversity considerations in farm planning and design. A key requirement for this integration to succeed is for current land evaluation and farm planning processes to recognise indigenous species as a mechanism for increasing the sustainability and resilience of the farm business. Recognition of the functional value of biodiversity to the farm system is a step beyond the protection of remnant areas of bush or wetland for conservation alone. In this paper, we propose embedding the natural capital and ecosystem services approach into the farm planning process to quantify and value both the on- and off-farm benefits associated with indigenous biodiversity. This approach enables the inclusion of the previously excluded regulating and cultural services alongside provisioning services in the analysis of the farm accounts. Learning from and applying Matauranga Maori is pivotal to achieving this goal. We use the established principles of land evaluation in farm planning in New Zealand to provide a conceptual illustration of a potential pathway to operationalise this shift. Our approach recognises that indigenous biodiversity contributes to a wide range of benefits including cultural, environmental, social, and economic values, of which conservation is just one, albeit an important, outcome.

Keywords: biodiversity, conservation, decision-making, ecosystem services, farm planning, natural capital, production landscapes

Introduction

Increasing global populations and increased food production have seen ecosystems become increasingly modified throughout the world (MA 2003; Tanentzap et al. 2015). This modification has put sustained pressure on indigenous biodiversity which continues to decline globally (MA 2003; Rockström et al. 2009; Newbold et al. 2015; Steffen et al. 2015), a pattern mirrored in New Zealand (Brown et al. 2015). The lowland areas of New Zealand were rapidly transformed following human settlement (Ewers et al. 2006), and are now dominated by highly specialised farming systems where the structural diversity of the land cover across the landscape is very low (Norton & Miller 2000; Walker et al. 2006). Although there is much greater representation of woody indigenous vegetation in the hill country and less developed country (Walker et al. 2006), even these landscapes have experienced sufficient losses of indigenous vegetation cover in the pursuit of the provision of food or fibre from pastoral and commercial forest land uses to interrupt the provision of other ecosystem services. For example, the regulating ecosystem functions and services including water regulation, storm mitigation, nutrient filtering, and sediment retention that are critical in sustaining the long-term capacity of New Zealand's agroecosystems have been seriously compromised (Parliamentary Commissioner for the Environment 2015; Ministry for the Environment & Stats NZ 2018).

New Zealand is a signatory to the Convention on Biological Diversity (Convention on Biological Diversity 2018), and has set out how it intends to (in part) fulfil this commitment in the New Zealand Biodiversity Strategy with an aim of halting the decline of New Zealand's indigenous biodiversity (New

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Zealand Government 2000). To achieve these goals, effort needs to target both public and private lands (Norton et al. 2016; Ruffell & Didham 2017).

Farming continues to underpin New Zealand's economy and cultural identity, but is increasingly under pressure to operate within a more acceptable environmental footprint and social licence to operate. This pressure comes from international markets as well as domestic expectations. There is also a growing urgency to improve farm resilience against major climatic extremes. Improved indigenous biodiversity management on-farm offers an opportunity not previously recognised for addressing a number of these issues within the farm business. However, the current approach to the protection and management of biodiversity on private land in New Zealand has failed to resonate beyond the protection of fragments by individual farmers, and is not at the level needed to influence the transformative change required to meet goals for the conservation of New Zealand's indigenous biodiversity (Norton & Reid 2013).

Enhancing ecosystem function on-farm will also require increasing structural diversity through the re-introduction of indigenous species (Dominati et al. 2019). Increased structural diversity has the potential to reduce the risk of soil loss and emissions to water and air and improve on-farm resilience to the impacts of severe weather events by increasing the ability to buffer wind, reduce the volume and velocity of overland water flow, and retain soils on erosion-prone slopes as well as increase biodiversity values on-farm (Dominati et al. 2014, 2019). Farm resilience is both the ability to withstand disturbances of greater severity (resistance) and the ability to recover from disturbances when they do impact (see glossary). Improving resilience on-farm is critical, not only for sustaining the viability of the farm business, but also for maintaining healthy rural communities and regional and national economic security. Improving resilience requires recognising and managing within environmental limits and sustaining or enhancing natural capital stocks (including indigenous biodiversity, see glossary) to provide for the full range of ecosystem function, not just food production. Thus, sustaining natural capital is critical for sustaining human well-being (Rockström et al. 2009).

The objective of this paper was to design a process to integrate indigenous biodiversity in farm business decision-making in response to New Zealand's biodiversity crisis (Bradshaw et al. 2010; Brown et al. 2015) and as a mechanism to advance long-term sustainability of farming and on-farm resilience. We suggest that broadening the scope of farm planning by adding an ecosystem approach that brings together the concepts of natural capital and ecosystem services (see glossary) to capture all of a farm's natural assets and flow of services, provides the basis for bringing the management of biodiversity and farming into the same decision-making frame on a more equal footing.

Across New Zealand, farm plans are an established and accepted mechanism to plan for and manage the farm within the regulatory environment, and address environmental risks (such as erosion) while taking into account the farm's intrinsic and built capability and assets (Manderson et al. 2007). Several regional councils around New Zealand rely on some form of farm plan; either as a regulatory requirement to manage nutrient leaching (e.g. Waikato Regional Council, Hawke's Bay Regional Council, Environment Canterbury), or in support of non-regulatory programmes such as erosion control (e.g. Horizons Regional Council, Gisborne District Council). Agricultural industry groups also provide guidance and support for farm planning that align with council requirements, for example: Beef + Lamb NZ's Land and Environment Plan (LEP) programme (Beef + Lamb New Zealand 2018a), and DairyNZ's Canterbury Sustainable Milk Plan (DairyNZ 2018). The logical progression for the next generation of farm plans is to expand their scope to explicitly include indigenous biodiversity assets as an additional tool for improving farm resilience. Internationally, the need to expand land evaluation to capture indigenous biodiversity, greater consideration of sustainability, and ecosystem service provision has been explicitly argued for in The Food and Agriculture Organization's (FAO) discussion paper on land evaluation (FAO 2007).

Here, we first provide a brief history of farm planning in New Zealand and an assessment of the degree to which biodiversity and ecosystem service provision could be advanced within current farm plan approaches. Second, we highlight the case for shifting the way indigenous biodiversity is considered and managed in agroecosystems in New Zealand by placing current approaches in the context of New Zealand's biodiversity conservation challenges. Third, we conceptually illustrate how farm planning, embedded within an ecosystem approach can integrate biodiversity assets into on-farm decision-making, and quantify the wider benefits of increasing indigenous biodiversity on-farm. Finally, we highlight important next steps needed to operationalise this approach. Thus, providing greater potential to achieve real gains for both the management of biodiversity and the farm business.

We focus on the farm-scale as this is where intervention and change happens and outcomes are experienced. We also acknowledge that consideration needs to be given to wider catchment, regional, and national objectives for indigenous biodiversity conservation, and the role of the farm in achieving those goals. While this is crucial, it is equally challenging on an operational level. Embedding these larger-scale goals and statutory requirements into farm planning provides the opportunity to identify, and seek solutions to overcome potential barriers to achieving not just conservation goals but also wider environmental challenges.

Land evaluation and farm planning in New Zealand

Internationally, farm planning has long been underpinned by land evaluation, being 'primarily the analysis of data about the land – its soils, climate, vegetation, etc.– in terms of realistic alternatives for improving the use of that land' (FAO 2007). Land as the basis for agriculture includes other biotic and abiotic factors, including other natural resources (FAO 2007), but land evaluation has typically been focused on soils and land-use capability. The need for this focus to evolve in response to declines in biodiversity and critical resources, climate change, and food security challenges has been recognised (Bouma et al. 2012). Current farm planning in New Zealand also has its roots in land evaluation and this internationally recognised need to evolve practice to more fully account for all natural capital is equally relevant here.

Although the focus of traditional land evaluation in New Zealand was on production (Mackay et al. 2018), soil and water conservation have long been the drivers for implementing farm plans (Manderson et al. 2007). Reintroducing vegetation (by planting or by allowing paddocks to revert back to woody vegetation) was, and continues to be, the most commonly used tool to reduce the risk of loss of soil capacity due to accelerated erosion and to protect waterways from sedimentation (Manderson et al. 2007). As a result, soil conservation has resulted in the retention of some indigenous forest fragments and regeneration of indigenous scrub on landscape units less conducive for agricultural land use despite indigenous biodiversity conservation not being a primary consideration for these practices. Thus, explicitly accounting for indigenous biodiversity assets in farm planning is a matter of broadening established practice rather than introducing entirely new concepts.

There are several different mechanisms operating in New Zealand by which farm planning is currently implemented and that have evolved from historical efforts targeted at soil and water conservation (Manderson et al. 2007; Fig. 1). Manderson et al. (2007) identify eight categories of environmental farm plans: farm riparian plans; farm shelter plans; soil conservation plans; erosion control farm forestry plans; environmental checklists; comparative issue plans; sustainable land management plans; DIY farm plans; and discretional issue plans.

Further to this, we identify four main categories of land-based farm-scale plans in common contemporary usage in New Zealand (riparian plans, nutrient management plans, land environment plans, whole farm plans) and an additional category, environmental management systems, to generically capture systematic approaches for managing environmental impacts on-farm (Table 1). These farm-scale plans are driven by local authorities and/or industry, or in the case of environmental management systems can be self-driven, and are designed to either:

- deliver specific work programmes e.g. riparian plans;
- align on-farm actions and impacts within regulatory parameters e.g. nutrient management plans;
- provide a detailed outcome-orientated work plan that addresses a wide range of issues on-farm as they apply

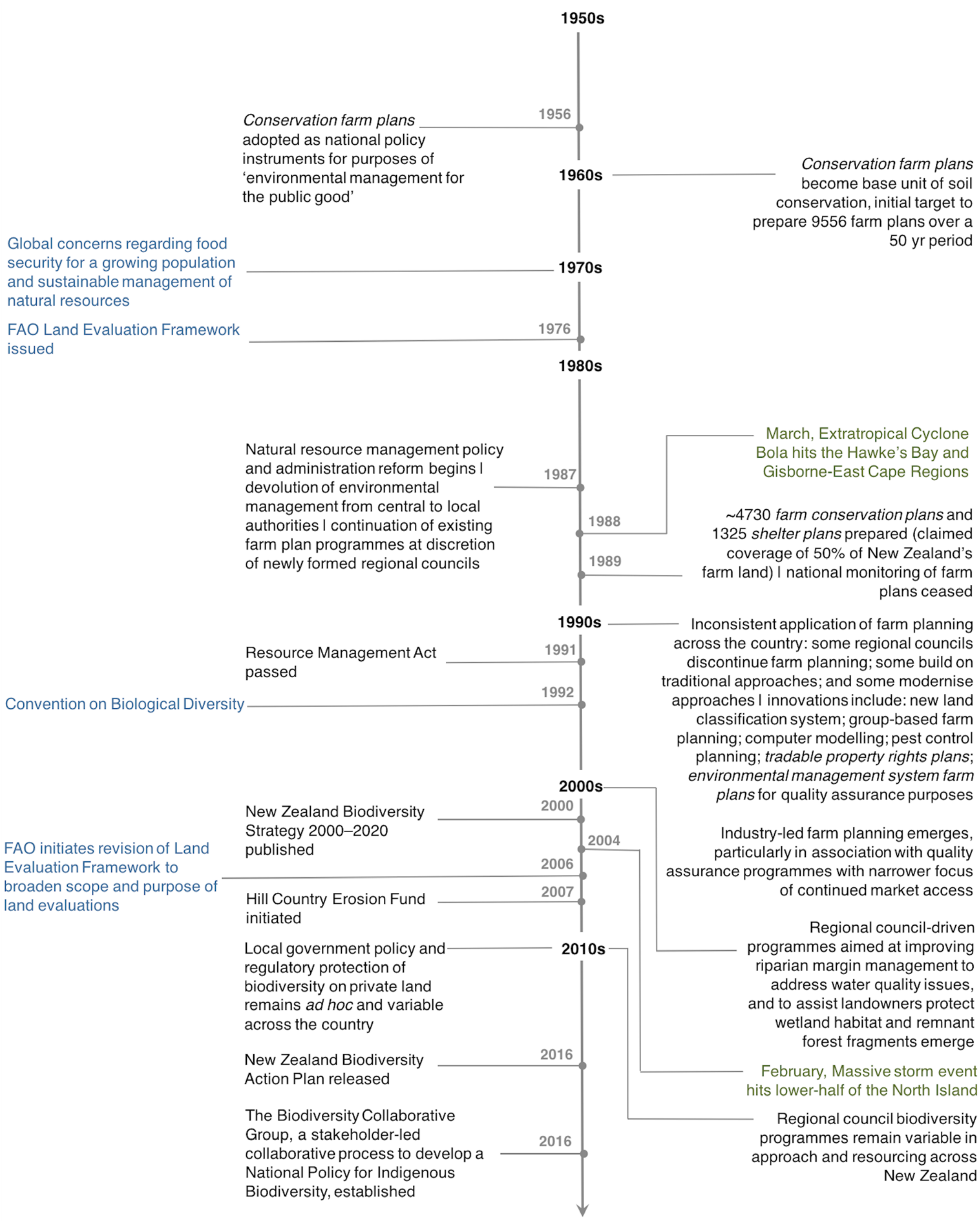

Figure 1. Time-line of major developments in the use of land evaluation and land-planning mechanisms and biodiversity policy in New Zealand. Policy and legislative developments are shown to the left of the axis, with central international developments shown in blue text on the far left. Storm events that caused substantial soil loss on-farm and which were catalysts for a focus on sustainable land use and resourcing (e.g. the Hill Country Erosion Fund; Ministry for Primary Industries 2018) are shown in green. (Data on farm plans taken from Manderson et al. 2007).

to both the business and the underlying natural resources e.g. land environment plans and whole farm plans; or

- systematically plan and audit e.g. environmental management systems.

The focus of these contemporary plans varies and the plans unintentionally capture biodiversity and ecosystem services to differing degrees (Table 1).

Voluntary indigenous biodiversity protection and enhancement programmes delivered by local government (such as conservation covenants and funding for fencing and pest and weed control) may also be operating in parallel at a district or regional scale. The Department of Conservation and Queen Elizabeth II Trust (an independent statutory organisation and registered charity that partners with private landowners to

Table 1. Assessment of how five farm-scale planning mechanisms commonly in-use capture biodiversity and ecosystem service assessment in New Zealand.

Planning mechanism	Purpose	Description	Captures indigenous biodiversity?	Captures ecosystem services?
Riparian plans[1]	Riparian margin fencing and planting in response to land use induced water quality issues and streambank erosion.	Riparian management (e.g. stock exclusion and restrictions for land use activities) is subject to regional regulations and condition of supply for the dairy industry. In some regions, riparian management may be supported by voluntary council-supported riparian plans. Riparian plans are limited to the riparian zone of farm system and set out a time-bound plan for fencing and planting riparian margins on-farm.	No. Riparian plans are work programmes (which sometimes reach to planting) and only incorporate input monitoring. Limited in their ability to capture a wider assessment of biodiversity outcomes on-farm. Introduction of native riparian plant species may occur but improving biodiversity values is a secondary outcome of riparian management, and not evaluated.	Protection of water quality regulation and food production potential via protection of the soil resource. No consideration of wider service provision. No assessment or quantification.
Nutrient management plan	Actions needed to optimise use of major plant nutrient (nitrogen, phosphorus, sulphur, and potassium) inputs to maximise production, while avoiding or minimising adverse effects of these nutrients on receiving environments.	Nutrient management plans include a nutrient budget to balance nutrient inputs with nutrient losses to ensure nutrient management meets regulatory and industry requirements. Nutrient management plans are becoming a regulatory tool for obtaining consent from local authorities for land use activities.	No. Nutrient management plans largely disregard indigenous vegetation and wider considerations of biodiversity on-farm.	Nutrient management plans include an indirect and limited assessment of ecosystem services and natural capital, focussing only on production and maintenance of water quality services.
Land environment plans (and variations)[2]	Designed primarily for sheep and beef farm systems to optimise resource use.	Industry (Beef + Lamb NZ) designed and delivered. Land environment plans spatially identify on-farm environmental risks and management opportunities within regulatory specifications. The focus is on land, water, and soil resources. Voluntary, although resource management regulations in several regions require a farm plan, and land environment plans have been tailored to meet these regulations.	Yes, in terms of presence/ absence and quantity (e.g. ha of forest). Does not describe quality. Does not assess impact of farm activities on biodiversity or contribution of biodiversity to farm system or ecosystem service provision.	Inherently (protection of water quality and provisioning potential via protection of the soil resource).
Whole farm plans[3]	Increase on-farm capacity to reduce and recover from negative impacts of large storm events and drive land use change to sustain and enhance natural resources.	Whole farm plans are relatively narrow in current focus, with the primary purpose of implementing a whole farm plan being the management of erosion and sediment contributions to receiving environments. Whole farm plans integrate environmental, social, and economic goals and capture enterprise development. They contain a strong spatial element. The development and implementation of a whole farm plan is voluntary and only a few regions across New Zealand have adopted their use.	Yes, in terms of presence/ absence and quantity (e.g. ha of forest). Does not describe quality. Does not assess impact of farm activities on biodiversity or contribution of biodiversity to farm system or ecosystem service provision.	Inherently (protection of water quality and provisioning potential via protection of the soil resource). Strong potential to transition whole farm plans to integrate an ecosystem service approach into farm-planning.

Planning mechanism	Purpose	Description	Captures indigenous biodiversity?	Captures ecosystem services?
Environmental management systems[4]	Improve environmental management and provide farm quality assurance based on a plan-do-check-act cycle.	Environmental management systems sit between regulatory controls and the free-market, and systematically formalise on-farm efforts to meet environmental standards, which can be audited and used as evidence for accreditation. The drivers for environmental management systems are varied and include: market-drivers (access to markets, price premiums); self-imposed conditions by industry to avoid regulatory controls; as a tool by which to meet regulations; or individual desires to achieve sustainable production systems. Content of environmental management systems is system dependent, but can be wide-ranging and include management and utilisation of soil, water, or inputs (e.g. pesticide, herbicide, fertiliser), energy conservation, health and safety, social concerns, and conservation; and vary in credibility and effectiveness as well as content.	Yes, environmental management systems have the flexibility and depth of scope to include biodiversity, although if they do, to what extent, and how, is specific to the system. For example, the NZ Farm Assurance Programme recommends that 'establishing, maintaining and supporting biodiversity and native flora should be encouraged' (Red Meat Profit Partnership 2017). Biodiversity assets on farm not explicitly quantified.	Ecosystem services tend to be recognised and sustainable management practices recommended (e.g. protection of water quality and provisioning potential via protection of the soil resource), but practices for doing so are not explicitly stated, nor service provision quantified.

[1] For example see Taranaki Regional Council (2011).
[2] http://www.beeflambnz.com/compliance/environment/environment-plans
[3] See Mackay (2007).
[4] See Parminter et al. (2004).

protect indigenous biodiversity) also administer and help fund legal protection (via conservation covenants) of indigenous biodiversity on private land, and can advise on the on-going management of these areas. Such programmes may be captured in some informal way in farm plans, although biodiversity-enhancement programmes and farm planning are rarely, if ever, considered in conjunction with each other. Certainly, biodiversity outcomes have not been a primary focus of farm plans, although they may be a secondary consideration. Two good examples of this are where erosion control regulations include the protection of woody indigenous vegetation, and riparian plans that include the introduction of indigenous riparian plant species.

However, there is an increasing awareness of the need for farm systems to sustain natural capital stocks and operate within the limits of receiving environments. These limits are typically defined by evidence-based policies and rules in local government resource management plans or informed by industry best-practice and community expectations. To achieve this, land evaluation and farm planning will need to broaden from current practice to include consideration of all natural capital stocks, including indigenous biodiversity on-farm.

The current state and protection of indigenous biodiversity in production landscapes in New Zealand

The rapid transformation of New Zealand's land cover following human settlement (McGlone 1989; Ewers et al. 2006; Hall & McGlone 2006) has resulted in production landscapes within which indigenous ecosystems have been almost completely replaced with highly modified exotic species dominated ecosystems (Norton & Miller 2000). An internationally impressive 32% (8.5 million ha) of New Zealand's land mass is protected as public conservation land (Department of Conservation 2014). However, this large area of protected land is skewed in its representation of the country's indigenous ecosystems and is largely concentrated in the backcountry – montane areas and hill country not well suited to other land use – while in the more fertile lowland areas of the country (23% of New Zealand's total land area), less than 10% of indigenous vegetation cover remains (Walker et al. 2006). Just under half (49%) of land above 500 m, but only 18% of land below 500 m is public conservation land (Norton & Miller 2000). Despite the substantial proportion of the country in public conservation land, indigenous biodiversity in New Zealand continues to decline (Craig et al. 2000; Walker et al. 2006; Myers et al. 2013; Brown et al. 2015). In contrast, indigenous biodiversity remaining on private land is largely unprotected, and that remaining in areas where historic loss has been the greatest is both of considerable conservation value and highest risk of further loss (Walker et al. 2006; Cieraad et al. 2015).

The extreme modification of New Zealand's indigenous ecosystems means that in many places and situations, exotic species have an important functional role and cultural value, as indigenous species are under-represented or missing entirely. For example, carbon storage and soil retention processes will be provided by exotic tree species (McGregor et al. 1999), and our sense of place and appreciation of amenity can be informed by pastoral landscapes (Swaffield & McWilliam 2013). Exotic species also underpin provisioning services and New Zealand's primary industry economy. This lack of indigenous representation in areas that have experienced considerable loss (such as our lowland areas) means that almost all remaining indigenous biodiversity in these areas has a high conservation value. Further, some exotic species that contribute to provision of services in one aspect are also invasive and impact on ecosystems and their ability to function and provide services elsewhere. For example, exotic conifer species grown as commercial plantations (provision of timber products) are causing immense issues in non-forested habitats where they spread rapidly and can permanently alter the landscapes they invade (Peltzer 2018). Exotic freshwater fish (e.g. brown trout *Salmo trutta* L.) with significant recreational values are also recognised as invasive species which out-compete or prey upon indigenous aquatic species, including several that are threatened with extinction (e.g. non-migratory *Galaxias* spp.) or are of cultural value (e.g. koura *Paraneophrops* spp.) (McIntosh et al. 1992, 2010; Townsend 2003; McDowall 2006). These tensions further highlight that biodiversity should not be considered in isolation from all other aspects of farm management.

Indigenous biodiversity protection measures on-farm

The Resource Management Act 1991 (RMA) extends statutory functions for the protection and maintenance of indigenous biodiversity on private land to local authorities, the implementation of which can include both regulatory and non-regulatory tools. However, there is currently no national policy statement (NPS) giving direction to this function and therefore, the manner in which indigenous biodiversity is provided for in regional policy statements and regional and district plans is variable across the country. Section 6(c) of the RMA directs that local authorities must recognise and provide for 'significant areas of indigenous vegetation and significant habitats of indigenous fauna' as matters of 'national importance'. What constitutes significant is not defined by the RMA and this ambiguity has led to sustained debate and litigation as to what, where, and how much indigenous biodiversity should be protected (Norton & Roper-Lindsay 2004; Walker et al. 2008; Maseyk & Gerbeaux 2015). Such disputes have contributed to the exclusion of much indigenous biodiversity from regulatory protection under resource management plans and has not been useful in the debates between land managers/farmers, industry groups, conservation interests, local authorities, and the wider community regards indigenous biodiversity protection on-farm (Maseyk & Gerbeaux 2015).

Despite the lack of clarity around what constitutes important indigenous biodiversity, and largely in recognition of the public good in doing so, rate-payer funded, council-run biodiversity enhancement programmes are common across the country. Numerous landowners are protecting indigenous biodiversity on their farms as illustrated by the high uptake of Queen Elizabeth II Trust Open Space Conservation Covenants which protect areas of indigenous biodiversity on-farm in perpetuity. At June 2016, there were a total of 4626 protected open spaces (including registered covenants, approved covenants, and formal agreements), covering 182 677 ha (QEII National Trust 2017). Covenanting has occurred either independently, or alongside council-driven biodiversity programmes, or has been compelled as a condition of resource consent. Self-organised community land-care groups are also investing substantial effort and resource into local projects throughout the country. Despite these efforts, New Zealand is still facing an indigenous biodiversity crisis spanning all land tenures (Bradshaw et al. 2010; Brown et al. 2015), in no small part due to the impact of invasive exotic plant and animal species as well as habitat loss. Thus, while current achievements outside of the public conservation land are admirable and to be applauded, in the absence of a more coordinated and comprehensive approach to retaining, managing, and increasing indigenous biodiversity nationally, they will remain an inadequate response to the crisis.

Why have current on-farm enhancement programmes failed to achieve more?

Current approaches have failed in large part because they consider indigenous biodiversity in an isolated way, with greater emphasis on conservation objectives for a restricted number of high-value, significant areas at the expense of considering the wider functional values of indigenous biodiversity on-farm in underpinning the provision of services. Further, we suggest that indigenous biodiversity programmes have failed to achieve greater outcomes because the objectives for managing biodiversity are rarely communicated from the perspective of relevance to the landowner. This lack of engagement prevents the integration of the actions needed to include biodiversity considerations in farm design, planning, and management, and indigenous biodiversity protection remains an additional 'nice-to-have' activity.

The policies and goals underpinning indigenous biodiversity programmes (at either national or local level) have failed to be explicit about what actions are sufficient, where, and by whom and tend to focus more on promoting a collaborative approach to achieving outcomes, without explicitly defining these outcomes. This further adds to a lack of engagement by farmers, many of whom are unlikely to have a complete understanding of the wider functional value of the indigenous biodiversity found on their farm, or even what is present. Without this insight, it is challenging to identify what needs protecting, and, critically, how to manage it, and hence what doing so offers to themselves, their farms, and the wider community.

The lack of clarity for national or regional goals for indigenous biodiversity have made it difficult to translate to the necessary management practices at the farm-scale in an easily digestible, farmer-relevant way. Regulatory controls on activities impacting on indigenous biodiversity can serve to provide clear guidance on what biodiversity is regionally and nationally important. However, weak enforcement of compliance where regulatory protections do occur (Brown 2017) has not only allowed indigenous biodiversity losses to continue but has also obscured signals on the conservation and functional importance of indigenous biodiversity found on private land.

First-steps towards a solution

To turn this situation around requires the dichotomy of indigenous biodiversity that we preserve and that which we do not (and thus perceive to have little or no value) to be dissolved (Craig et al. 2013; Norton & Reid 2013). A shift in mind-set towards viewing indigenous biodiversity in a more nuanced manner will be required and would be reflected in a management portfolio that includes a spectrum of protection and regulatory control where required, to a more utilitarian approach that recognises indigenous biodiversity as another option in the tool-box to address a growing number of issues on-farm and advance the farm business. Demonstrating that enhancing indigenous biodiversity on-farm will contribute directly and positively to a number of cultural, environmental, social, and economic values, of which conservation is just one outcome will be critical in achieving this shift.

Māori as partner signatories to the Treaty of Waitangi, and through guardianship, partnership, and ownership roles are more than merely stakeholders in natural resource management; and this is becoming increasingly reflected in practice. For example, The Waikato River Authority (Waikato River Authority 2018) and the Rangitāiki River Forum (Bay of Plenty Regional Council 2018) are both formally mandated co-governance arrangements established as part of Treaty settlements. Shifting towards a holistic and equal consideration of all values will require learning from and applying Mātauranga Māori (Māori knowledge) and applying tikanga and kawa (protocols and practices) to capture cultural values (Lyver et al. 2017, 2018). It must also be recognised that much of our farming landscape will require targeted and sustained efforts to reintroduce lost biodiversity to recreate biodiverse, culturally relevant and resilient landscapes (Meurk & Swaffield 2000), that result in biodiversity persistence, increased resilience of ecosystems, people and communities, and maintains sustainable productive use of land. Similar challenges to maintain biodiversity and food security occur elsewhere in the world (Rockström et al. 2009; Brown 2012). We suggest that the two challenges are not incompatible, but require a shift in both national biodiversity policy and practice at the farm-scale.

The recent focus on ecosystem services research has yielded studies exploring the optimisation of land use to provide for biodiversity conservation and ecosystem service provision (e.g. de Groot et al. 2010; Schneiders et al. 2012; Dymond et al. 2013), trade-offs between these objectives and commodity production (e.g. Nelson et al. 2009; Balbi et al. 2015; Cordingley et al. 2016) and the development of tools to facilitate these assessments (e.g. Tallis & Polasky 2009; Natural Capital Project 2017). While this body of work has advanced the integration of biodiversity considerations into regional-level land use planning, it has been informed by land use and land cover, rather than land evaluation. There remains a critical operational gap for integrating biodiversity and ecosystem services into land-evaluation and farm planning processes targeted at the farm-scale (but see Dominati et al. 2016), although the need to do so is recognised internationally (FAO 2007).

However, the accepted concepts of evaluation of assets, monitoring performance, operating within constraints, and working towards sustainability objectives are well established and can be extended to measure and report on current performance and progress towards targets across all of the cultural, social, environmental, and economic dimensions of a farm system. Taking an ecosystem approach represents a 'modern expression' of the land quality concept inherent in historic land evaluation, and shifts the decision-making from more subjective judgements on land suitability to the use of quantitative data and options to consider the full range of services and values, and is a proven platform by which to undertake quantitative assessments (Dominati et al. 2016). Importantly, it would also provide the platform by which to embed traditional knowledge and practices into farm planning. Thus, an ecosystem approach to farm planning represents one mechanism that can contribute to fulfilling Treaty of Waitangi obligations, by providing the platform by which to consider cultural values on an equal footing with other environmental, social, and economic values also important to Māori.

The next step is to recognise biodiversity in farm planning as natural capital stocks that can be manipulated to make a fundamental contribution to the provision of a whole range of ecosystem services on- and off-farm. The quantity, quality, spatial arrangement and temporal dynamics of stocks can be measured, and differentiated by their amenability to change (Maseyk et al. 2017b), making them the logical target for management interventions aimed at influencing change in ecosystem service provision on-farm.

Whole farm plans (WFPs) are an established and accepted expression of farm planning. The current formulations of WFPs can be extended in depth and breadth to account for and manage the multiple values that indigenous biodiversity contributes (alongside other forms of capital including natural, cultural, social, and built). Thus, an evolution of the current WFP template provides the practical mechanism to bring about the integration of biodiversity considerations into farm planning. Supporting this with policy and wider industry good-practice guidance, would allow a clear message to emerge which would help shift the conversation on-the-ground from one of 'why?' to one of 'how?'. For example, Beef + Lamb New Zealand (the farmer-owned industry group representing sheep and beef farmers) has included 'thriving biodiversity' as one of four pillars underpinning their recently released environmental strategy (Beef + Lamb New Zealand 2018b).

Further, a WFP would provide a useful platform to evaluate the impact of farm practices on natural capital stocks and the performance and sustainability of the farm system in providing a range of ecosystem services in a single integrated farm-scale assessment. Critically, this would provide a clear link between performance of service provision on-farm and management decisions, and an expansion of the concepts of: (i) natural capital, as determined by compositional state or stocks (Dominati et al. 2010); (ii) capability, the inherent properties of stocks that describe potential functionality (e.g. strength of topsoil, or root architecture of tree species); and (iii) condition, the current state the stock is in (e.g. canopy intactness, presence/absence of understorey), in terms of quality and quantity. Condition is a manageable property of stocks (McBratney & Field 2015) and therefore a logical target for management interventions for the purpose of enhancing service provision and long-term resilience of farm-systems (Maseyk et al. 2017b).

The process of managing natural capital to increase or sustain capability also lends itself to identifying opportunities for enhancing natural capital stocks on-farm, including the potential to increase indigenous representation in the landscape, especially in areas where biodiversity has been degraded or greatly depleted. In areas of New Zealand where this is currently occurring, for example in the Taranaki Region under the riparian planting programme (Taranaki Regional Council 2011), farmers are perceiving a wide range of benefits including but not limited to biodiversity outcomes (Maseyk et al. 2017a).

Pathway for capturing description and consideration of biodiversity in whole farm planning using an ecosystem approach

We propose a six-step process to integrate biodiversity considerations into the whole farm plan process (Fig. 2). Each key step is further explained below.

A: Clearly define goals and objectives

Goals for managing biodiversity as an integral part of all aspects of farm management and its potential contribution to cultural, environmental, social, and economic outcomes should be identified alongside all other goals for the farm. Although typically in farm planning, many targets are defined at the farm-scale to reflect the mix of resources and aspirations for the farm business and operation, biodiversity targets will apply at multiple scales as set by local and central government policy documents. Thus, the goal-setting exercise needs to be able to translate these broader biodiversity outcomes to farm-scale targets to include in the planning process. It also needs to be recognised that there will be some farm-scale biodiversity goals that may not relate to goals at other scales. Goal-setting for biodiversity outcomes both on and beyond the farm boundaries is no trivial task. However, continuing to divorce biodiversity considerations and environmental outcomes generally from farm business planning relegates environmental issues to a secondary consideration isolated from other decisions on-farm. Considering all values side-by-side will also enable consideration of future economic opportunities in the context of sustainable management of on-farm resources and the best use of land, such as adding additional enterprises into the farm system. A diversification of land use has benefits beyond the farm, by diversifying landscapes and enhancing biodiversity.

B: Perform a stocktake of existing capital

An inventory of existing capital is required. This inventory would describe all the farm assets including natural (e.g. soils, waterways, wetlands, vegetation, significant species), social (e.g. staff safety and well-being), cultural (e.g. access to sites of significance, use of cultural practices), and manufactured capital (e.g. farm infrastructure, roads). Farm assets can be described in terms of stocks, capability, and condition (quality and quantity; see glossary).

C: Determine boundaries

The cultural, environmental, and social boundaries within which economic activity can occur must be defined and understood. This step will be informed by Steps A and B, and also guided by, but not restricted to, environmental regulations

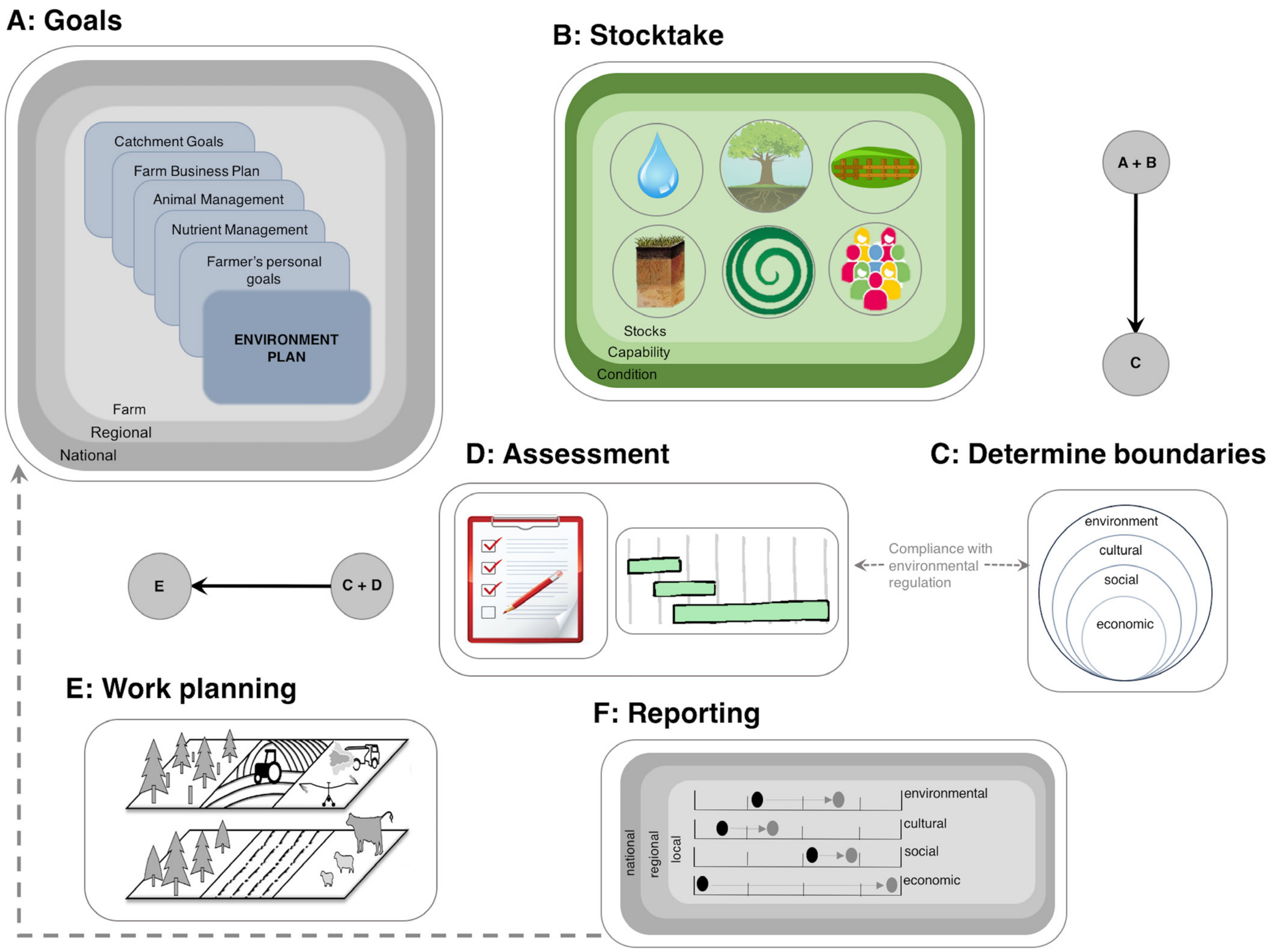

Figure 2. A conceptual diagram for integrating biodiversity into land evaluation and the farm planning process using a whole farm plan. Components are not distinct and do not operate in isolation, linkages are indicated by circles and arrows. (Schmatic in Box E adapted from Dominati et al. 2016).

described in regional or district resource management plans. Environmental regulation can help to parameterise environmental limits (e.g. policies targeted at maintaining water quality may define allowable nutrient leaching limits) and thus related performance targets. However, regulatory bottom-lines should not be used as an end-goal for farm planning as doing so runs the risk of restricting management practice on-farm to only the minimum required to be compliant. Entrenching the minimum curtails opportunities to manage the farm towards long-term sustainability and increasing resilience.

D: Undertake assessment of the stocktake of existing capital (Step B) in the context of the stated goals and targets (Step A)
This step is necessary to identify gaps between current farm capacity and condition, and that needed to achieve on-farm goals and off-farm objectives such as regional indigenous biodiversity objectives. Opportunities to consider new management options, land use change, or investment in ecological infrastructure such as the reintroduction of indigenous biodiversity into the landscape are identified at this stage. For example, planting of riparian margins to deliver both water quality targets and shade and shelter for animals, or conversion of marginal land from pasture to woody vegetation to manage erosion as well as lift animal performance.

E: Prepare a work plan
Preparing a work plan involves the identification of management actions required to sustain or enhance capital to achieve stated farm aspirations and cultural, environmental, and social targets (Step A). Once identified, management actions should be scheduled alongside other farm management tasks. This step is informed by Steps C and D.

F: Report on progress
Current outputs must be measured in order to track farm performance towards goals. A range of indicators identified both at the farm and at scales beyond the farm boundary will be required to report on progress. For example, condition measures for remnant bush blocks; kg meat per ha for food production, cfu per 100 ml per ha of pathogen filtering (*E. coli*), kg N leached per ha for nitrate filtering etc. This reporting will feedback into future goal-setting, and like traditional farm-planning, the process will be iterative and evolving as the farm system performance changes with time.

Integrating biodiversity considerations into land evaluation and the farm planning process will require additional effort, ecological understanding, and access to existing data and the ability to gather new information. For example: a stocktake (Step B) of biodiversity will require identification of indigenous flora and fauna on-farm, its connectivity and function on and beyond the farm boundary and an assessment of its current state and condition. The stock-take should also include current capability to provide ecosystem services. This process will require understanding of indigenous biodiversity assets and ecological processes on and beyond the farm, and comparison with appropriate reference values to determine both relative condition (Step B) and ecological or conservation importance as guided by regional and national objectives, priorities, and regulations (Steps C, D). This step provides the ability to explore indigenous biodiversity benefits beyond the farm arising from on-farm decisions, and contributions to regional and national conservation objectives. The WFP will need to be expanded from its current common focus to also include a management plan for biodiversity (Step E) for each land management unit and ecosystem type, within the context of relevant environmental regulations relating to indigenous biodiversity (Step C), and opportunities to enhance existing stocks or reintroduce lost indigenous biodiversity to the farm. The farm management plan should also reflect an assessment (Step D) of the influence of farm practice on the condition of biodiversity stocks, and on the provision of services.

While this appears to be a data hungry process, the specificity of information does not initially need to be any more detailed than that required to help decision-making, and existing datasets, tools, and templates can greatly assist. As we learn and understand more about the relationship between biodiversity and ecosystem service provision, managing biodiversity will get more complex, new challenges will arise, and management priorities will shift. This process is no different from any other aspect of natural resource management, and the urgency to sustain our natural capital is such that imperfect knowledge should not prevent taking the first steps towards integrating indigenous biodiversity into farm management decisions.

Key next steps for progressing this approach include: further investigation into data requirements and field-testing the concept using real case studies; exploring approaches for the quantification of a wider range of ecosystem services provided by the non-pastoral parts of the farm; and increasing understanding of the interactions between ecotones (the boundary between adjoining ecosystems) and the resulting flow of ecosystem services.

Conclusions

Global declines in biodiversity have increased the urgency to advance conservation outcomes beyond protected areas. Land evaluation and farm planning provide a potential vehicle to integrate biodiversity considerations into on-farm decision-making in a manner that allows for both enhanced indigenous biodiversity management within agroecosystems and increased long-term sustainability and farm resilience to climatic extremes. This proposal represents a major shift in current thinking and practice on achieving biodiversity outcomes on private land, and a shift within the farming industry as to the value of indigenous biodiversity to the farm business. Advancing this shift will not be without its challenges.

We conceptually illustrate that an evolution of the current WFP approach can be used for the full cycle of farm-planning: identification of goals and targets (at farm and catchment scales); stocktake of current assets (capital) and their condition; reporting of current performance in relation to goals; identification of management actions needed to shift from current performance to target performance including modification of quantity or quality of stocks; and monitoring and reporting change in underlying assets. In this proposed framework, aspirations and performance targets are simultaneously identified and considered across all aspects of the farm-business and across a full range of values (cultural, environmental, social, and economic). Critically, targets are directly linked to capability and condition of the farm assets, including the current and potential condition of natural capital stocks and the management actions required to effect change.

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Glossary

Capability of natural capital stocks refers to the ability of a stock to perform a particular ecosystem function and thus contribute to the provision of particular ecosystem services, based on its inherent characteristic properties. For example, properties of soils include depth, texture, stoniness, and properties of vegetation include morphological, physiological, and functional traits such as growth form, root depth, nutrient uptake rate (Maseyk et al. 2017b).

Ecosystem approach to natural resource management brings together the concepts of natural capital and ecosystem services (Banwart 2011). The ecosystem approach provides the opportunity to broaden service provision at the farm-scale beyond a primarily singular focus on food and fibre provision; increase long-term farm-resilience; and allows for more informed decision-making for maintaining critical resources (Dominati et al. 2016). It also provides the basis for shifting towards multifunctional landscape analysis and management to deliver a range of ecosystem services and provide quadruple (cultural, environmental, social, and economic) bottom line outcomes.

Ecosystem services flow from natural capital (and other forms of capital) and are experienced as the benefits consumed or used by humans to sustain or advance wellbeing, including the goods generated by ecosystems that people value (Maseyk et al. 2017b). Provisioning services are those that are extracted and consumed (e.g. food, fibre, raw materials); regulating services provide benefits derived from the regulation of ecosystem processes (e.g. regulation of water quality, mitigated storm impacts, stable climate); and cultural services capture those benefits that humans gain from interacting with nature (e.g. sense of place, connections to ancestors, recreation, conservation) (Haines-Young & Potschin 2011).

Natural capital comprises all abiotic and biotic elements of ecosystems and all physical, biological, and chemical processes (Mace et al. 2015), including natural elements that have been modified by human activities and other capitals (e.g. social, human, built) (Arias-Maldonado 2013).

Natural capital stocks natural resources (e.g. water, soil, vegetation, species, air) are stocks of natural capital, and this includes but is not restricted to, the indigenous species and ecosystems typically captured by biodiversity conservation objectives.

Farm resilience is described and measured as the ability of the farm system to withstand disturbances (resistance) and the ability to recover from disturbances when they do impact. Farm system resilience captures both scientific concepts of 'bouncing back' and sociological concepts of adaptation and transformation. Building on social-ecological resilience work, the concept of farm resilience comprises buffer capability, adaptive capability, and transformative capability (Darnhofer 2014).