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Review

A Natural Capital Approach to Agroforestry Decision-Making at the Farm Scale

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Abstract: Background: Agroforestry systems can improve the provision of ecosystem services at the farm scale whilst improving agricultural productivity, thereby playing an important role in the sustainable intensification of agriculture. Natural capital accounting offers a framework for demonstrating the capacity of agroforestry systems to deliver sustained private benefits to farming enterprises, but traditionally is applied at larger scales than those at which farmers make decisions. Methods: Here we review the current state of knowledge on natural capital accounting and analyse how such an approach may be effectively applied to demonstrate the farm-scale value of agroforestry assets. We also discuss the merits of applying a natural capital approach to agroforestry decision-making and present an example of a conceptual model for valuation of agroforestry assets at the farm scale. Results: Our findings suggest that with further development of conceptual models to support existing tools and frameworks, a natural capital approach could be usefully applied to improve decision-making in agroforestry at the farm scale. Using this approach to demonstrate the private benefits of agroforestry systems could also encourage adoption of agroforestry, increasing public benefits such as biodiversity conservation and climate change mitigation. However, to apply this approach, improvements must be made in our ability to predict the types and amounts of services that agroforestry assets of varying condition provide at the farm or paddock scale.

Keywords: review; ecosystem services; agroforestry; natural capital; economic benefits

1. Introduction

1.1. Background

The projected increase in global demand for agricultural commodities is expected to be met mainly through the continued intensification of agricultural production [1]. Production gains to-date have placed pressure on stocks of natural capital and the ecosystem services that they provide [2–4]. Future strategies for intensification must balance the need to increase yields with objectives such as climate change mitigation and adaptation, improved soil and water management, and the protection of ecosystem services that support production [5]. Agroforestry is one land management strategy that farmers could employ to meet this challenge. Agroforestry describes any land-use system, practice, or technology, where woody perennials are integrated with agricultural crops and/or animals in the same land management unit (e.g., shelterbelts, alley cropping, integrated remnant vegetation) [6].

Proponents of agroforestry describe it as a 'win-win' approach, as carefully designed systems can balance the production of food, fibre, and fuel while restoring natural capital and thereby enhancing the provision of ecosystem services (e.g., erosion control, microclimate regulation) [7]. Increasing forest cover is also the cheapest and most direct method to reduce atmospheric concentration of greenhouse gases [8], and while most of this is likely to occur on land unsuitable for agriculture, agroforestry has been recognised as an important component of this reforestation effort [9].

Although the benefits of agroforestry systems are well-researched, adoption of agroforestry in temperate developed agricultural systems, particularly in Australia, remains constrained [10,11]. While technical, social and policy impediments exist [12], studies have shown that the perceived economic value of trees is often an important determinant of a farmer's decision to adopt agroforestry [13,14]. Clear demonstration of the capacity of agroforestry systems to deliver long-term economic benefits to the farm enterprise may therefore improve levels of uptake [15], which could increase delivery of public benefits such as biodiversity conservation and climate change mitigation. Concepts that capture both commercial and non-commercial benefits, such as the valuation of ecosystem services as part of a broader natural capital accounting approach, may be useful tools in this regard. These concepts may also be useful for developing tools that improve agroforestry-related decision-making at the farm scale (i.e., deciding what type of agroforestry system best suits the objectives of the enterprise). This review considers how a natural capital approach, which has traditionally been applied at national or regional scales, may be practically applied to demonstrate the value of agroforestry systems and improve agroforestry decision-making at the farm or paddock scale.

1.2. Natural Capital and Agriculture

Natural capital is the stock of renewable and non-renewable resources (e.g., plants, animals, air, water, soils, and minerals) that combine to yield a flow of ecosystem services, which in turn provide a variety of benefits to people [16,17]. All industries depend to some extent on natural capital and its benefits, and most businesses also impact on natural capital through their operations or use of products. Primary industries are particularly reliant on stocks of natural capital. In the case of agriculture, producers manage stocks of natural capital to deliver provisioning services in the form of food and fibre. At the same time, management activities may affect the capacity of the same natural capital to provide services into the future. Because interactions between agricultural businesses and natural capital may not immediately affect market values, cash flows, or prices, impacts and dependencies on natural capital are typically considered externalities and are often under-valued or not considered at all in valuation. Intensified production coupled with a failure to account for impacts on natural capital has led to the depletion of natural capital stocks (e.g., soil, biodiversity, water, vegetation) across many of the world's agricultural landscapes [18–20].

To address this, approaches that account for impacts and dependencies on natural capital have recently been developed [21–23]. Building on several decades of environmental economics research [24], natural capital accounting provides information on the stocks and flows of natural resources in a given ecosystem, region, or indeed enterprise, in physical or monetary terms. This information facilitates measurement and tracking of natural capital and an examination of how actions inhibit or improve its capacity to generate goods and services on an ongoing basis. Most natural capital accounting work that has been undertaken to-date focuses on valuing natural capital stocks for the purpose of conserving biodiversity at global, national, and regional scales [22,25,26]. While interest in the application of natural capital accounting to agriculture is increasing, particularly with the recent release of The Economics of Ecosystems and Biodiversity (TEEB) AgriFood report [27], the System of Environmental-Economic Accounting for Agriculture, Forestry and Fisheries [28], and the Natural Capital Finance Alliance Agriculture Sector Guide [29], the concept is rarely applied in the context of farm-scale decision-making.

When applied to agriculture at the farm scale, natural capital accounting can be used to determine the nature and magnitude of a farming operation's impacts and dependencies on natural capital and the associated business risks and opportunities [21,29,30]. This can help farmers and investors identify the specific types and levels of farming activity that pose material risks in terms of impacts or dependencies on natural capital. Conversely, the same approach can be used to identify management interventions that reduce these risks. In the case of agroforestry, there may be unexploited potential to increase adoption by using natural capital accounting to demonstrate farm-scale benefits or avenues for risk mitigation. Where sufficient information is available, these concepts can also be applied to compare the benefits of alternative agroforestry scenarios at the paddock or farm scale (Section 3).

1.3. Approach

In Section 2, we consider how a natural capital accounting framework could be applied to demonstrate the economic benefits of agroforestry at the farm scale and whether existing methods for quantifying and valuing ecosystem services are suitable in this context, based on a review of:

1. The conceptual framework for natural capital accounting (Section 2.1);
2. Methods for quantifying ecosystem services at the farm scale (Section 2.2);
3. Methods for valuing ecosystem services at the farm scale (Section 2.3).

In Section 3 we discuss how natural capital accounting may be usefully and practically applied to improve farm-scale agroforestry decision-making (Sections 3.1 and 3.2). We present an example of a conceptual model that could be used to this effect (Section 3.3). This conceptual model is based on the findings of existing reviews on ecosystem services in agroforestry systems, as well as direct references from farmers. We also highlight the challenges and opportunities presented by this decision-making approach and suggest areas for further research (Section 3.3).

2. Natural Capital at the Farm Scale

2.1. Applying the Natural Capital Accounting Framework to Agroforestry

The conceptual framework underpinning natural capital accounting (Figure 1) consists of natural capital *assets* which, depending on their condition, provide a flow of ecosystem *services* from which we derive value in the form of *benefits* to business and society. In the context of agroforestry systems, the asset is the integrated 'woody' component, e.g., shelterbelts, woodlots, or integrated remnant vegetation. Ecosystem services and benefits provided by these assets are likely to be numerous and diverse and will depend on the condition of the vegetation (e.g., composition, structure, configuration) [31].

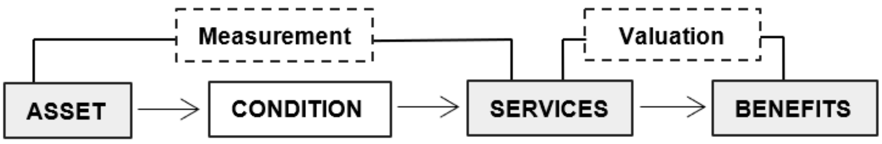

Figure 1. Flowchart adapted from the Natural Capital Protocol [21] illustrating the relationship between a natural capital *asset*, the *condition* of that asset, the ecosystem *services* that flow from the asset, and the *benefits* that those services provide to people.

Identification of ecosystem services and the benefits that they yield is central to the natural capital accounting framework. To reduce inconsistencies in measurement and valuation of services due to omission and/or double counting, the concept of 'final ecosystem services' [32] has been developed within ecosystem accounting frameworks. 'Final services' are directly obtained by specific human beneficiaries and are distinct from ecosystem functions/processes, or 'supporting services' (e.g., photosynthesis) [32–39]. Although the term 'final services' has been retained there is growing consensus among experts that, to reflect the role that they play in producing final services, 'intermediate' services (e.g., pollination) must also be considered in ecosystem accounting [40]. This is an important development in the context of agroforestry systems, as most of the services provided by agroforestry assets are considered intermediate. Although the debate on ecosystem accounting approaches and ecosystem service classification is ongoing [41], coverage of this debate is beyond the scope of this review. Rather, current classification concepts are used in this review to identify relevant ecosystem services for the purpose of discussing the merit of valuing these services to aid in farm-scale decision-making. The classification system currently used in the System of Environmental-Economic Accounting–Experimental Ecosystem Accounting (SEEA-EEA), Common International Classification of Ecosystem Services (CICES) [42], applies a suitably broad interpretation of final ecosystem services, which includes several intermediate services and is therefore well-suited to agroforestry systems. An example of the application of CICES (V5.1) classification is provided below (Table 1) for a list of services compiled from several reviews on agroforestry ecosystem services [7,43,44]. The CICES system provides an efficient means of identifying and classifying ecosystem services in an agroforestry context, reduces double-counting, and allows for inclusion of the full range of services described in the cited reviews.

Table 1. Farm-scale ecosystem services provided by agroforestry assets (adapted from CICES V5.1).

Section	Group	Service
Provisioning	Cultivated terrestrial plants for nutrition, materials, or energy	Cultivated trees or shrubs grown for nutritional purposes (food), fibres and other materials (timber), or energy (fuel)
Regulation & Maintenance	Mediation of wastes/toxic substances by living processes	Sequestration of atmospheric carbon
	Mediation of nuisances of anthropogenic origin	Noise attenuation Visual screening
	Regulation of baseline flows and extreme events	Control of erosion rates Hydrological cycle and water flow regulation (including flood control) Wind protection
	Lifecycle maintenance, habitat, and gene pool protection	Pollination (habitat for pollinators)
	Pest and disease control	Pest control (habitat for pest-predators)
	Regulation of soil quality	Decomposition and fixing processes and their effect on soil quality
	Water conditions	Regulation of the chemical condition of freshwaters through run-off control and nutrient uptake by trees and shrubs
	Atmospheric composition and conditions	Regulation of temperature and humidity, including ventilation and transpiration
Cultural	Physical and experiential interactions with natural environment	Characteristics of agroforestry systems that enable activities promoting health, recuperation, or enjoyment through active or immersive interactions orpassive or observational interactions
	Intellectual and representative interactions with natural environment	Characteristics of agroforestry systems that are resonant in terms of culture or heritage or enable aesthetic experiences
	Other biotic characteristics that have a non-use value	Characteristics of agroforestry systems that have an existence value or an option or bequest value

While there is a good understanding of the services that can be provided by agroforestry systems (Table 1), measurement or valuation of these services at the farm or paddock scale has been more limited. However, research in this area is developing rapidly, and there have been several recent studies that value a combination of private and public ecosystem services at the farm scale [45–47]. In Sections 2.2 and 2.3 we consider the current methodologies for both measurement and valuation to determine their application to agroforestry at the farm scale.

2.2. Measuring Ecosystem Services at the Farm Scale

Measurement of ecosystem services (Figure 1) is often a pre-requisite to their valuation [48]. High demand for information to support decision-making in resource management has stimulated rapid progress in the development of approaches to measuring ecosystem services [49,50]. Here we provide an overview of the leading methods and tools for measuring ecosystem services and their suitability in the context of farm-scale measurement of services provided by agroforestry assets (see Table 1).

Availability and quality of primary data varies between different ecosystem services, but for many services, a lack of data is the most significant constraint to their quantification [51,52]. As a result, most quantitative estimates of ecosystem service provision at the landscape scale are based on secondary data or spatial proxies, which tend to be derived from either topographical data or land use land cover (LULC) datasets [53,54]. While estimates based on LULC proxies are useful for broad or rapid assessments over large areas [55,56], they are generally unsuitable for fine-scale (e.g., farm-scale) assessments as the coarse resolution of LULC data may not account for actual spatial variability in biophysical measurements of ecosystem services [52]. Importantly for farm-scale agroforestry assessments, readily available remotely sensed LULC data often fail to capture fine-scale landscape features such as shelterbelts and individual trees, which provide important ecosystem services at smaller scales. Use of LULC proxies also requires well-established links between land cover and ecosystem service provision. At a fine scale, ecosystem service provision is highly dependent on the condition of the natural capital (e.g., vegetation structure and composition). Although resolution of LULC data is improving, many aspects of condition remain difficult to establish from remotely sensed land cover data. This makes proxy-based techniques particularly unsuitable for farm-scale agroforestry assessments, where the condition of the asset (e.g., the configuration and height of a shelterbelt) has a significant influence on provision of key services (e.g., wind speed reduction).

One alternative to proxy-based measurement is the use of models that can capture processes at finer scales [57]. Models consider a wider set of local ecological variables as inputs and are therefore more reliable for fine-scale assessments, compared to LULC proxy-based measurement. One widely applied fine-scale modelling tool is InVEST: Integrated Valuation of Ecosystem Services and Trade-offs [58]. InVEST estimates levels of ecosystem services and their economic value using a suite of models ranging in complexity from proxy-based mapping e.g., carbon sequestration, to complex site-specific process models, e.g., pollination services [59]. Its ability to capture relatively fine-scale processes makes InVEST a potentially useful tool for measuring agroforestry ecosystem services at the farm-scale, although to our knowledge, it has yet to be used for such purposes. Several other advanced models exist that cater specifically for agroforestry systems, although they focus primarily on provisioning services and typically require a high degree of technical competency, e.g., CABALA, Farm Forestry Toolbox, for predicting quantities of timber/fibre; Yield-SAFE, SCUAF, APSIM, for predicting crop growth with tree interactions; and SPIF, for timber and environmental outcomes [60–66].

To improve the breadth and usefulness of fine-scale models, we first need to improve our understanding of how different natural capital assets influence ecosystem service inflows to agricultural systems and how the condition of these assets affects the types and amounts of services provided. Simple field measurements could then be used as either direct indicators, or model inputs, to accurately quantify multiple ecosystem services. For example, the USDA Forest Service's online toolkit 'i-Tree' contains a series of models that estimate ecosystem services provided by trees based on their physical properties [67]. Using simple input requirements, e.g., diameter at breast height, species, total height, alongside environmental and location variables, i-Tree employs a suite of models to forecast the provision of a range of services such as pollution reduction, public health benefits, carbon sequestration, and avoided run-off. While services important in an agroforestry context such as crop/livestock shelter, erosion control, indirect pollination and biological control are not yet included, an approach similar to i-Tree could be taken to quantify ecosystem services provided by agroforestry systems at the farm scale. However, we first need to address gaps in our understanding of how the condition of agroforestry assets (e.g., species composition, height, root depth, and configuration in relation to crops, livestock, and other landscape features) affects the services that they provide. Using these physical characteristics as inputs alongside environmental data, existing models may be able to predict quantities for several services including provisioning services (e.g., timber/fibre, food, and fuel), and regulating services (carbon sequestration, erosion control, and microclimate regulation).

One approach to improve accuracy of existing models is to conduct 'bottom-up' assessments where services are measured directly at the farm or paddock level, providing fine-resolution site-specific information that is directly relevant to the farmer. Sandhu et al. [68] and Porter et al. [69] measured biophysical indicators of multiple ecosystem services in order to compare land management techniques based on the value of services that they provide. These studies provide examples of how a wide range of services may be quantified at the farm or paddock scale based on observational data. In the case of cultural services where supply is more closely related to user appreciation than to ecosystem condition, measurement can also be achieved through incorporation of qualitative techniques such as interviews and surveys [45,70,71]. Participatory methods could be used in conjunction with biophysical measurement to ensure cultural ecosystem services are adequately represented in farm-scale assessments of agroforestry systems. Although broad uptake of bottom-up approaches is limited by the practical constraints and costs of data collection, they are likely to play an important role in improving the accuracy and relevance of existing models.

For measurement of ecosystem services provided by agroforestry systems at the farm scale, the key is striking an appropriate balance between practicality and the suitability of outputs for decision making. While rough estimates of ecosystem service supply can be derived relatively easily from an LULC proxy, farmers are generally faced with decisions at finer scales (i.e., the paddock or farm scale) that require more detailed site-specific information. In these cases, use of fine-scale models supported by quantitative and qualitative primary data appears to be the most appropriate approach to measuring a wide range of ecosystem services at the farm scale. While there are many promising techniques and packages that could be applied to agroforestry systems, there are still key gaps that need to be addressed, e.g., quantifying the impact of condition.

2.3. Valuing Ecosystem Services at the Farm Scale

Once ecosystem services have been quantified, the next step is to determine the extent to which these services are valued by relevant beneficiaries. Ecosystem service valuation may also be conceptualized as the measurement of the dividends or 'ecosystem income' yielded by natural capital [72–74]. As described by Fenichel et al. [74], marginal valuation of natural capital for the purpose of constructing accounts requires an understanding of the links between natural capital, human behaviour, and valued service flows. They identify the importance of political and social institutions in driving the management of ecosystem assets which impact upon the ecosystem income, or flow of value from ecosystem services. They further relate the values of ecosystem income and ecosystem stocks to sustainability at a country level, in essence as a measure of genuine savings [75]. However, accounting for the value of stocks of natural assets at this macro level is beyond the scope of this review, which focuses instead on the valuation of ecosystem service flows from agroforestry assets to inform decision-making at the farm or paddock scale. Here we describe methods for economic valuation of relevant ecosystem services (Table 2) and discuss different approaches to valuation of agroforestry systems at the farm scale. For the purposes of this review, the value of an asset refers to its Total Economic Value (TEV) (Figure 2), which encompasses both 'use' and 'non-use' values [76]. In this context, TEV is defined as the aggregation of the values of all service flows generated by natural capital both now and in the future [76].

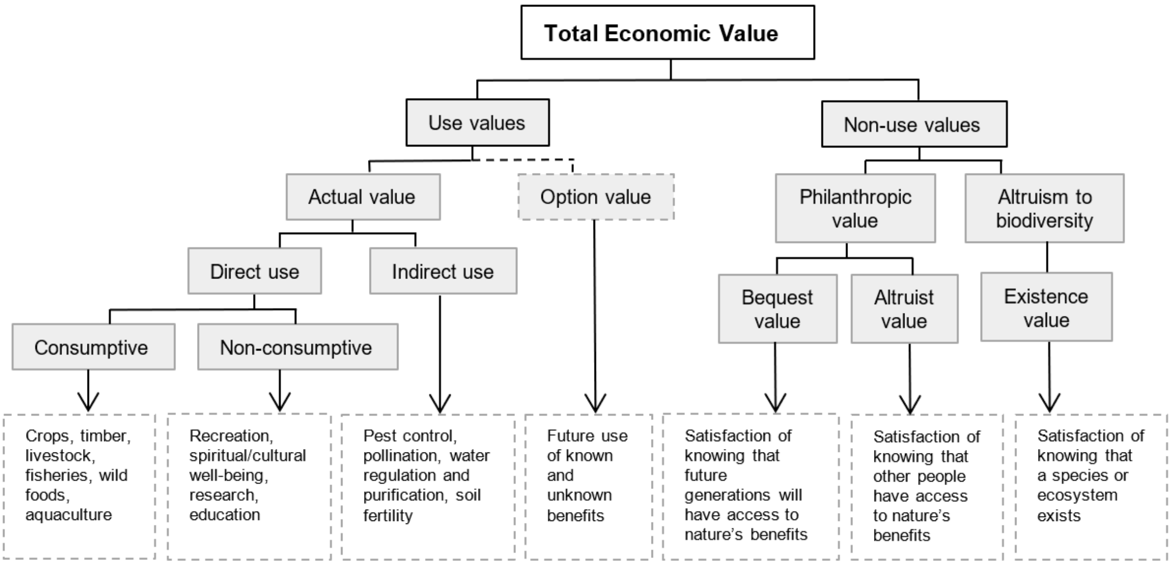

Figure 2. TEV typology adapted from [77], which classifies values associated with direct use, indirect use, and non-use of service flows generated by natural capital.

An important consideration when valuing ecosystem services is defining the beneficiary. Ecosystem services provided by agroforestry assets can be valued based on the benefits that they provide to the public (e.g., erosion control for improved downstream water quality), to the farmer (e.g., erosion control for retention of soil), or a combination of these approaches. As the purpose of valuation in the context of this review is to demonstrate the long-term benefits of agroforestry to farmers, we reviewed valuation strategies focusing on the farmer as the beneficiary.

It is important to note that valuation pathways of ecosystem services provided directly and indirectly by agroforestry assets vary in complexity. While agroforestry provides provisioning services that are directly harvested from the trees/shrubs themselves, e.g., food, fibre, or fuel, agroforestry assets also provide regulating services that indirectly influence other flows of provisioning services on the farm (e.g., increasing lamb survival through regulation of microclimate). In addition, agroforestry assets can also influence stocks of other forms of natural capital (e.g., by providing habitat for insects) which can indirectly influence flows of regulating services such as pollination. Therefore, some valuation pathways lead to monetary values (e.g., market value for provisioning services), whereas others lead to less-tangible forms of value (e.g., farmer well-being). In many cases, particularly where the intention is to justify an investment in agroforestry assets, valuation pathways that lead to a marketable product will form a compelling case. However, non-market values such as amenity, cultural value, and bequest value can also be important drivers for decision-making on farms. Monetary values alone will often fail to capture the full value of an agroforestry asset, which is why it is important to consider a range of ecosystem services that provide a broader perspective of value.

Economic valuation of agroforestry as a land-use system usually takes one of two forms: either a financial analysis of revenues received by the landowner at the enterprise or farm-scale, or an expanded analysis that includes 'externalities' or impacts beyond the farm boundaries [78]. Although some farm-scale financial analyses include hypothetical payments for regulating ecosystem services or taxes for disservices (e.g., pollution) [46,79], non-provisioning ecosystem services are generally not included in traditional farm-scale profitability studies. In studies where regulating and cultural services such as soil protection, carbon sequestration, air quality, and amenity are included, these services tend to be valued with public beneficiaries in mind, rather than as 'inflows' to the agricultural enterprise [80]. Exceptions do exist, including work by Ovando et al. [45], in which the private amenity of Mediterranean agroforestry farms is considered to ultimately be 'consumed' by the farmer through its effect on land prices [47,81]. Despite increasing demand for information in this space, there are still a limited number of studies assessing farm-scale economic benefits of agroforestry systems based on a broad range of use and non-use values, and fewer still that focus on the value of regulating services from a productivity perspective.

Table 2. Methods for valuing ecosystem services provided by agroforestry assets at the farm scale with examples of how they might be applied if the farmer is considered the primary beneficiary.

Valuation Method	Description	Services (See Table 1) that Could Be Valued Using This Method
Direct market valuation	Where commercial markets exist for services, market prices can be used to represent their value.	Food, fibre, timber, or fuel from cultivated trees or shrubs. Sequestration of atmospheric carbon
Production function	Where a service plays an intermediate role in the production of a marketable good, production functions can be used to estimate the contribution of that service as a proportion of the market price.	Pollination (habitat for pollinators), e.g., Morse and Calderone [82]. Regulation of temperature and humidity, including ventilation and transpiration. Wind protection.
Averted expenditure	Service is valued based on costs associated with declining benefits due to the loss of that service.	Control of erosion rates, e.g., [83]. Regulation of the chemical condition of freshwaters through run-off control and nutrient uptake by trees and shrubs. Hydrological cycle and water flow regulation (including flood control).
Replacement cost	Service is valued based on the cost of replacing that service entirely with an artificial or technical solution. This method is often employed to value regulating services in agriculture.	Pollination (habitat for pollinators), e.g., Winfree et al. [84]. Pest control (habitat for pest-predators). Decomposition and fixing processes and their effect on soil quality, e.g., Sandhu et al. [68], Alam et al. [85]. Control of erosion rates. Regulation of temperature and humidity, including ventilation and transpiration.
Revealed preference: hedonic pricing	Estimates the value of people's preferences for characteristics of a place based on their contribution to property prices.	Various (potentially difficult to isolate value of individual services) e.g., Polyakov et al. [86].
Stated preference: contingent valuation or choice experiment	These methods use questionnaires about hypothetical scenarios of environmental change to estimate economic value.	Use and non-use values of a broad range of services including: amenity, cultural heritage, recreation, aesthetics, and existence or bequest value, e.g., Shrestha and Alavalapati [87].
Benefit transfer	Where resources do not allow for original economic valuation using one of the above methods, it is possible to use data from comparable studies to value services.	Any of the above

Most agroforestry valuation studies that incorporate a broad suite of ecosystem services employ an equally broad suite of valuation methods, e.g., Porter et al. [69]. This usually includes market valuation, avoided expenditure, replacement costs, and some form of stated preference. Benefit transfer is often used for some or all of these valuations, depending on the focus of the study and the resources available to the investigator.

Some agroforestry valuation studies consider multiple beneficiaries, combining private and public perspectives. For example, de Jalón et al. [88] and Kay et al. [46] use a range of valuation techniques to compare the productivity and profitability of different agroforestry landscapes against conventional agricultural and forestry systems. Across these studies, the value of sequestered carbon is based on a carbon price, disservices of soil erosion and nitrogen/phosphorus surplus are valued based on the cost of removing these materials from public watercourses, and pollination is valued according to a production function [46,88]. Services such as windspeed reduction and noise reduction are excluded despite their potential to deliver significant private benefits to farmers. Valuation studies that combine private and public benefits may be appropriate in some cases, for example when designing payments for ecosystem services. However, the objectives of the agroforestry venture must be clear to ensure that key ecosystem services are included and that the results of the valuation are relevant to the decision-maker.

If the purpose of the valuation is to encourage private investment in agroforestry, it makes sense to focus on ecosystem services that deliver private benefits to farmers and value those services accordingly. Porter et al. [69] and Alam et al. [85] take this approach, borrowing techniques used by Sandhu et al. [68] to value field-scale ecosystem services in agroforestry systems. Production of food and raw materials is valued at market prices; nitrogen regulation, soil formation, groundwater recharge, and pollination are valued according to replacement costs; biological control of pests according to avoided cost of pesticides; and aesthetics through benefit transfer, derived from a contingent valuation study. The broad range of services included in these studies, and the focus on the farmer as the beneficiary in most valuation methods, ensures that the final estimate of each system's economic value reflects a range of values that are directly relevant to the farmer.

In natural capital accounting, valuation methods should be chosen to suit the purpose of the study and the types of services that are being valued. In the case of agroforestry systems, there is merit in recognising the role of farmers as decision-makers and ensuring that the information produced is directly relevant to them. Strategies for achieving this could include incorporating a broad range of use and non-use values and valuing regulating services from a productivity perspective, rather than as externalities.

3. A Natural Capital Approach to Agroforestry Decision-Making at the Farm Scale

As farmers consider strategies to enhance the long-term productivity of their enterprise while protecting the natural capital base that supports it, they are likely to benefit from the availability of tools that support their decision-making. Here we draw on findings from Section 2 to discuss the usefulness and feasibility of applying a natural capital approach to farm-scale agroforestry decision-making.

3.1. Advantages of a Natural Capital Approach

As demonstrated in Section 2, a natural capital accounting framework can be applied to agroforestry systems to establish the value of agroforestry assets at the farm scale. The framework identifies links between stocks of natural capital, ecosystem service provision, and farm-scale benefits (value). Farmers who conceptualise their farm in this way and understand these links may be more inclined to adopt strategies that protect or enhance natural capital. Natural capital accounting can therefore be useful in justifying private investment in agroforestry. Farmers may also choose to communicate their awareness and management of natural capital impacts and dependencies to internal or external stakeholders to attract new investors or customers. Indeed, agribusiness lenders are showing increasing interest in using natural capital approaches to account for the value of natural capital stocks in farm valuations and credit risk assessments [89].

The natural capital approach also highlights the flexibility of agroforestry systems, i.e., that they can be designed to deliver a range of benefits depending on the objectives of the farm enterprise. Farmers who are looking to adopt agroforestry will be faced with decisions about the type, extent, location, and configuration of agroforestry assets. Natural capital approaches can be used to compare the benefits of different agroforestry options, in terms of the value of the ecosystem services that each might provide. In this way, there is potential for the natural capital framework to be used as the basis for the development of tools that assist farmers in choosing between alternative agroforestry scenarios based on costs and benefits to the enterprise (Section 3.3).

3.2. Existing Frameworks for Natural Capital Accounting at the Farm Scale

While general awareness of the role of natural capital in agriculture is increasing [90], the concept is rarely applied in the context of farm-scale decision-making. There are still relatively few studies that attempt to value or account for stocks of natural capital at a scale that is useful for decision-making on farms. Although natural capital accounting is being used broadly to appeal for changes in agricultural practice that will protect the natural capital base [27], little practical guidance exists for farmers and other practitioners looking to construct accounts of their own. This may be due in part to a lack of consensus on the best approach for farm-scale natural capital assessment and accounting. Here we describe several tools and frameworks that may fill this gap and bring us a step closer to a standardised, practical natural capital approach to farm-scale decision-making.

At the outset, it is necessary to undertake some form of natural capital assessment to understand risks and dependencies relating to natural capital stocks and to gain an appreciation of the value of specific natural capital assets to the farm. The Natural Capital Protocol provides a general approach for natural capital assessments [21]. Although the Natural Capital Protocol offers little guidance on how their approach may be implemented in practice, other projects have applied the framework to undertake natural capital assessments in agriculture, e.g., the FAO's report on Natural Capital Impacts in Agriculture, which highlights trade-offs between different farming practices (e.g., organic vs. conventional) based on costs to human health and ecosystems [30]. Although some case studies touch on internal benefits, most valuations are not considered from the perspective of the farmer, and this approach is therefore not useful as a template for assessments to support farm-scale decision-making. In a more transferable approach, Ascui and Cojoianu [29] provide a generic procedure for lenders to undertake farm-specific natural capital credit risk assessments (based on the Natural Capital Protocol). In their approach, biophysical indicators (such as percentage vegetation cover) are valued based on evaluation of risks to the lender, which informs whether credit should be extended to the farmer. Although their approach focuses on the value perspective of the lender, there is scope for this procedure to be used by farmers to prioritise management interventions based on assessment of key risks to their business.

Once natural capital risks, dependencies, and the value of natural capital assets have been established, farmers may wish to track the value or condition of natural capital assets through time to inform decisions around investment and operations. Three frameworks exist that provide a standardised approach to natural capital accounting at the farm scale. These are founded on the SEEA-EEA, which has not yet developed to cover farm-scale accounts but nonetheless provides a framework for tracking changes in the extent, condition, and monetary value of ecosystem assets over time across a given spatial area [22]. There is also potential for SEEA-EEA itself to be developed for use at the farm scale in the future. The Wentworth Group's 'Accounting for Nature' method is currently being adapted for use at the farm scale [23] and focuses on the construction of 'asset condition accounts' which provide information about changes to the condition of assets over time, based on measuring biophysical indicators. The second framework proposes an 'ecological balance sheet' (EBS) that enables the application of accrual accounting principles to ecological assets at the farm scale [91]. The advantage of the EBS is that it deliberately incorporates natural capital accounts into the farm's existing accounting system so that financial and environmental performance can be tracked simultaneously. Perhaps the most advanced of the existing frameworks is the 'Agroforestry Accounting System' (AAS) which estimates total income accrued from a range of market and non-market products delivered by agroforestry systems [92,93]. While application of the AAS to-date has focused on comparing the value of woodland agroforestry systems to other forest types [45], there is potential for this framework to be applied more broadly: at different scales and for different types of agroforestry systems. Each of these existing frameworks brings us closer to tracking the condition and value of natural capital assets through time at a scale that is useful for decision-making on farms.

Although these frameworks form a sound theoretical foundation for farm-scale natural capital accounting, it is important to recognise that they all rely on evidence-based conceptual models that demonstrate how agricultural systems function. In agriculture, key forms of natural capital may include soils, vegetation, fauna (including livestock and fisheries), and water [91]. Although it is conceptually easy to calculate stocks of the asset (woody vegetation) and determine its condition (i.e., age, structure, species composition, configuration, etc.), each form of natural capital yields multiple ecosystem services and disservices that may interact in additive, synergistic, or detractive ways. Many of these services are difficult to quantify, interactions between them are often poorly understood, and condition is rarely tracked. Additionally, there is a gap in our ability to predict the types and amounts of services that assets of varying condition provide at the farm scale, and how these services translate to benefits received by the farmer. While efforts are underway to improve our understanding of the value of some natural capital assets in complex agricultural systems [94], we do not yet have an adequate model for agroforestry assets. Conceptual models must also account for the impact that changes in asset condition have on value, particularly in agroforestry systems where the condition of the asset can significantly affect service provision. Such a model would greatly improve the applicability of existing natural capital accounting tools to farm-scale agroforestry decision-making.

3.3. A Conceptual Model for Agroforestry Decision-Making

A conceptual model for valuation of agroforestry assets may serve multiple purposes: firstly, to establish common understanding of causal pathways for the flow of benefits from agroforestry assets and, secondly, to facilitate rapid assessment of the benefits of various agroforestry options. Here we present an example of a conceptual model for farm-scale valuation of an agroforestry asset (Figure 3) and discuss how it may be used as the basis for farm-scale decision-making.

The model in Figure 3 illustrates how the framework in Figure 1 can be applied conceptually to an agroforestry system where the 'asset' is a shelterbelt and the farmer is considered the beneficiary. This conceptual model is based on studies describing the ecosystem services provided by agroforestry systems [7,43,44,95] and was developed in consultation with farmers and colleagues working in the field. This model (Figure 3) illustrates benefits in a temperate pasture/livestock system but could be adapted to suit other systems such as dairy or horticulture.

Although many of the services listed in Table 1 are featured in the model, some have been adapted or broken down into a series of biophysical processes to highlight interactions and trade-offs within the system. For example, the service of 'regulation of temperature' is captured in the provision of shade and the reduction in wind speed provided by the shelterbelt. Each pathway within the conceptual model linking the asset to a benefit involves a combination of measurement and valuation of one or more ecosystem services. For example, the extent of wind speed reduction caused by the shelterbelt can be measured, as can the resulting effects on evaporation and pasture growth on the leeward side of the shelterbelt [96,97]. Once the relationship between wind speed reduction and pasture yield has been quantified, this service can be valued based on the extent to which the increase in yield reduces costs associated with supplementary feeding and the positive effect that this has on gross profit margin. Depending on the situation, the effect of competition may also be measured, and the associated pasture yield decrease accounted for. Potential valuation pathways in the conceptual model will vary considerably in terms of methods and complexity.

From an accounting perspective, the development of conceptual models is an important first step in valuing and accounting for changes in natural capital assets on farms. Conceptual models are useful for establishing common understanding of key causal pathways amongst experts and stakeholders, [98]. In this case, it is useful for practitioners to build an understanding of the multiple ecosystem services that may flow from agroforestry assets, and the types of benefits that these services provide. This common understanding will enable more consistent valuation of agroforestry assets in accounting exercises at various scales (e.g., Accounting for Nature, AAS, SEEA-EEA). Conceptual models can be developed further to include a broader range of beneficiaries (e.g., the general public) and used as a 'blueprint' for valuation to suit a range of purposes. For example, government agencies may use an adapted version of the model in Figure 3 to determine the return on investment in agroforestry assets at the farm or landscape scale, considering both private and public benefits. Lenders and investors may also use similar models to conceptualise the value of agroforestry assets from a risk management perspective [29]. Conceptual models are an ideal tool for this purpose given their flexibility and capacity to clearly communicate relationships within complex systems such as agroforestry systems. These models can be more powerful if underpinned by an evidence-based review [99].

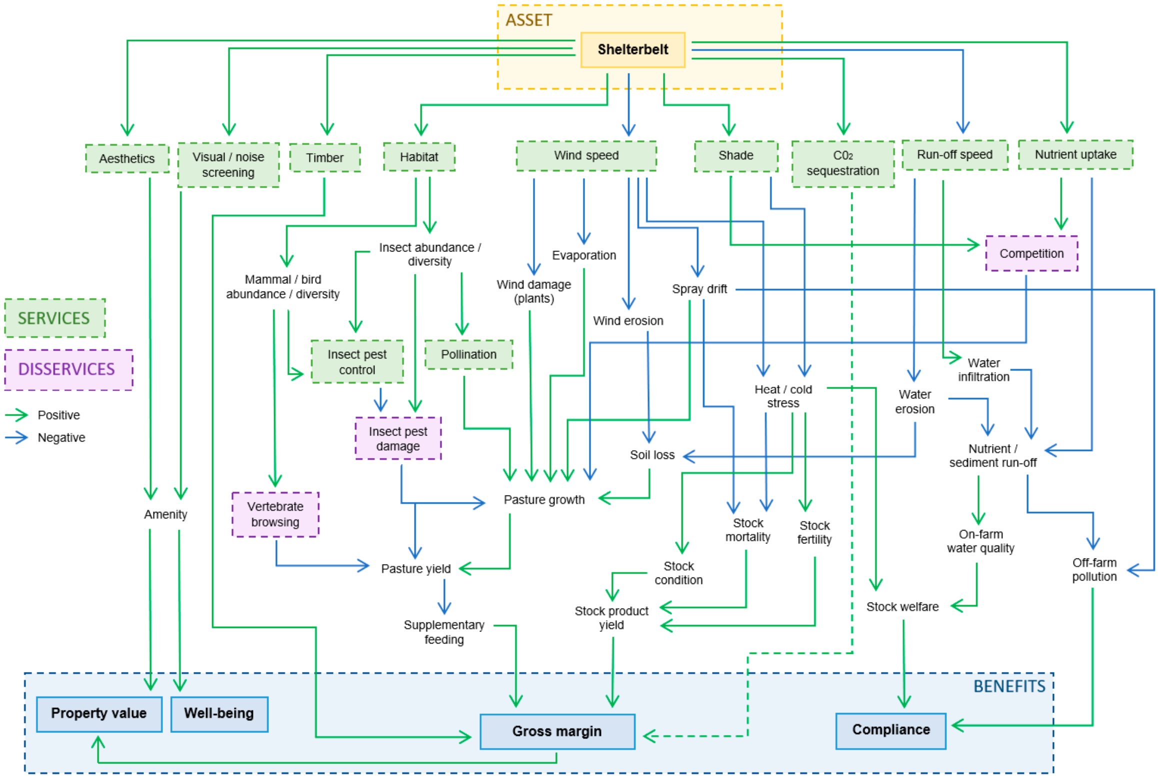

Figure 3. Conceptual model for ecosystem services and associated benefits provided by one common type of agroforestry asset (shelterbelt) in a temperate pasture/livestock system. Blue lines represent negative effects (i.e., reduction), and green lines positive effects.

The conceptual model also provides the basis for development of tools that can assist in agroforestry-related decision-making at the farm or paddock scale. Farmers are the primary decision-makers and creating tools that cater for them and the types of decisions that they face is crucial. The farm-scale value of services provided by agroforestry assets may be highly dependent on the location of the farm, the objectives of the farm enterprise, and the context of the asset within the farm [100]. Farmers require tools that enable them to make decisions about investing in agroforestry systems and designing them in such a way that maximises benefits to their particular enterprise. Conceptual models can enable them to make these decisions without having to undertake complex, expensive natural capital assessments that would require direct measurement and valuation of ecosystem services. For example, a farmer planning to invest in agroforestry would first need to decide what type of asset best suits the objectives of their enterprise. They may seek to maximise provision of services that improve productivity or reduce operational risk while waiting for longer-term returns from marketable wood products. If one of their priorities is to reduce lamb losses due to cold winds they may decide to invest in shelterbelts, based on the benefits demonstrated in a conceptual model of this system (Figure 3). The next phase will involve deciding how many shelterbelts to plant, the dimensions and orientation of each shelterbelt, and their location in relation to other elements of the farm. In making these decisions they may refer to other sections of the conceptual model to consider a wider range of potential benefits (e.g., amenity, reducing spray drift) and disbenefits (e.g., competition effects). Used in this way, conceptual models can provide a low-cost, rapid approach to agroforestry decision-making at the farm or paddock scale.

Although the evidence base that supports conceptual models for farm-scale valuation of agroforestry assets is growing [7], there are still gaps in our biophysical understanding of agroforestry systems [95]. While a lack of quantitative evidence may not necessarily restrict the usefulness of these models for farm-scale decision-making, it is helpful to have confidence in the direction of relationships (i.e., positive or negative) and the relative quantities of ecosystem services provided by different types of assets. Where conceptual models currently fall short is in demonstrating the impact of asset condition on the flow of services and benefits. Having chosen to plant shelterbelts, a farmer may eventually have to decide on the configuration and composition of the shelterbelts. They are also likely to be interested in changes to the flow of services and benefits over time, from planting to harvest/senescence. The effect of asset condition at fine scales is an important research gap that must be filled in order to improve the usefulness of these conceptual models.

Where sufficient quantitative evidence exists, conceptual models can also form the basis of more precise, predictive tools for decision-making. These tools may facilitate fine-scale, quantitative valuation of services that are of particular importance to farmers (e.g., shelter). Increasingly, valuation methods are being incorporated into ecosystem service models (e.g., InVEST, i-Tree Eco v6) and economic analysis tools, some of which are designed specifically for integrated farming systems (e.g., Imagine, Farm-SAFE) [101,102]. Conceptual models can guide the development of these tools by demonstrating the complexity of the system as a whole, ensuring that the tools account for interactions and trade-offs that might otherwise be missed. To improve useability, it may be advantageous to compile all relevant models into a single toolkit (similar in style to InVEST or i-Tree) or to incorporate ecosystem service models into an existing package (e.g., Farm Forestry Toolbox) or farm enterprise platform (e.g., DAS Rural Intelligence Platform, FarmMap4D) [62,103,104]. Data accessibility (including cost and usability) is an important consideration in the development of such a toolkit, as a collaborative approach is likely to greatly improve the scope and reliability of outputs.

Conceptual models can enhance the applicability of existing natural capital accounting tools to farm-scale agroforestry decision-making. They can improve consistency in the valuation of agroforestry assets for accounting purposes, guide rapid decision-making at the farm or paddock scale, and form the basis for development of quantitative decision-making tools. To improve the useability of conceptual models in this context, we need to expand the evidence base that supports them with particular focus on the impact of asset condition on ecosystem service provision.

4. Conclusions

The natural capital accounting framework provides a logical and increasingly consistent approach to the valuation of impacts and dependencies on natural capital. Findings from this review suggest that there is potential for this framework to be usefully applied to demonstrate the capacity of agroforestry systems to deliver sustained private benefits to farming enterprises.

Despite difficulties in obtaining information for many ecosystem services, tools and models for measuring services continue to advance and improve. In the case of measuring ecosystem services provided by agroforestry systems, the key is striking an appropriate balance between practicality and the relevance of outputs to decision-making. Use of fine-scale models supported by quantitative and qualitative primary data may be the most appropriate approach to measuring a wide range of ecosystem services at the farm scale. While promising advancements continue to be made in the development of tools to model service provision at these fine scales, there are still some key gaps that need to be addressed, e.g., quantifying the impact of condition.

As the evidence base for the value of natural capital in agriculture continues to grow, methods and tools for measuring this value are also improving. Methods for valuing ecosystem services should be chosen to suit the purpose of the valuation and the types of services that are being valued. In the context of demonstrating farm-scale benefits of agroforestry, valuations should be directed at farmers as key beneficiaries, incorporate a broad range of use and non-use values, and value regulating services from a productivity perspective rather than as externalities. Natural capital accounting can be applied to communicate the broad range of values that farmers can derive from agroforestry assets, thereby encouraging appropriate levels of investment.

A natural capital approach can also be applied to assist farmers in making decisions about agroforestry at the farm or paddock scale. While work is currently underway to develop a standardised natural capital approach to farm-scale decision-making, existing tools rely on conceptual models for the provision and valuation of ecosystem services that flow from natural capital assets in agricultural systems. To usefully apply a natural capital approach to farm-scale agroforestry decision-making, we should look to develop adequate conceptual models for agroforestry systems. Underpinned by evidence-based reviews, these models could be useful for improving consistency in the valuation of agroforestry assets, guiding decision-making at the farm or paddock scale and supporting development of quantitative decision-making tools.

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References

1. Smith, P.; Gregory, P.J.; van Vuuren, D.; Obersteiner, M.; Havlík, P.; Rounsevell, M.; Woods, J.; Stehfest, E.; Bellarby, J. Competition for land. *Philos. Trans. R. Soc. B* **2010**, *365*, 2941–2957. [CrossRef]
2. Sánchez-Bayo, F.; Wyckhuys, K.A. Worldwide decline of the entomofauna: A review of its drivers. *Biol. Conserv.* **2019**, *232*, 8–27. [CrossRef]
3. Parris, K. Impact of agriculture on water pollution in OECD countries: Recent trends and future prospects. *Int. J. Water Resour. Dev.* **2011**, *27*, 33–52. [CrossRef]
4. Mackay, A. Impacts of intensification of pastoral agriculture on soils: Current and emerging challenges and implications for future land uses. *N. Z. Vet. J.* **2008**, *56*, 281–288. [CrossRef]
5. World Resources Institute. *Creating a Sustainable Food Future*; World Resources Institute: Washington, DC, USA, 2018.
6. Reid, R.; Wilson, G. *Agroforestry in Australia and New Zealand*; Goddard and Dobson: Box Hill, Australia, 1985.
7. Smith, J.; Pearce, B.D.; Wolfe, M.S. Reconciling productivity with protection of the environment: Is temperate agroforestry the answer? *Renew. Agric. Food. Syst.* **2012**, *28*, 80–92. [CrossRef]
8. Bastin, J.-F.; Finegold, Y.; Garcia, C.; Mollicone, D.; Rezende, M.; Routh, D.; Zohner, C.M.; Crowther, T.W. The global tree restoration potential. *Science* **2019**, *365*, 76–79. [CrossRef]
9. Lewis, S.L.; Wheeler, C.E.; Mitchard, E.T.A.; Koch, A. Restoring natural forests is the best way to remove atmospheric carbon. *Nature* **2019**, *568*, 25–28. [CrossRef]
10. Black, A.W.; Frost, F.; Forge, K. *Extension and Advisory Strategies for Agroforestry*; Rural Industries Research and Development Corporation: Barton, Australia, 2000.
11. Stewart, H. *Victorian Farm Forestry Inventory Scoping Study*; Farm Forest Growers Victoria Incorporated: Mansfield, Australia, 2009.
12. Race, D.; Curtis, A. Adoption of farm forestry in Victoria: Linking policy with practice. *Australas. J. Environ. Manag.* **2007**, *14*, 166–178. [CrossRef]
13. Cary, J.W.; Wilkinson, R.L. Perceived profitability and farmers' conservation behaviour. *J. Agric. Econ.* **1997**, *48*, 13–21. [CrossRef]
14. Fleming, A.; O'Grady, A.P.; Mendham, D.; England, J.; Mitchell, P.; Moroni, M.; Lyons, A. Understanding the values behind farmer perceptions of trees on farms to increase adoption of agroforestry in Australia. *Agron. Sustain. Dev.* **2019**, *39*, 9. [CrossRef]
15. Pannell, D. Social and economic challenges in the development of complex farming systems. *Agrofor. Syst.* **1999**, *45*, 395–411. [CrossRef]
16. Atkinson, G.; Pearce, D. Measuring sustainable development. In *Handbook of Environmental Economics*; Bromley, D.W., Ed.; Blackwell: Oxford, UK, 1995.

17. Jansson, A.; Hammer, M.; Folke, C.; Costanza, R. Investing in natural capital: Why, what, and how? In *Investing in Natural Capital: The Ecological Economics Approach to Sustainability*; Jansson, A., Hammer, M., Folke, C., Costanza, R., Eds.; Island Press: Washington, DC, USA, 1994.
18. CBD. *Global Biodiversity Outlook 4: A Mid-Term Assessment of Progress towards the Implementation of the Strategic Plan for Biodiversity 2011–2020*; CBD: Montreal, QC, Canada, 2014.
19. Smith, P.; Clark, H.; Dong, H.; Elsiddig, E.; Haberl, H.; Harper, R.; House, J.; Jafari, M.; Masera, O.; Mbow, C. Agriculture, forestry and other land use (AFOLU). In *Climate Change 2014: Mitigation of Climate Change. IPCC Working Group III Contribution to AR5*; Cambridge University Press: Cambridge, UK; New York, NY, USA, 2014.
20. Jackson, W.; Argent, R.; Bax, N.; Bui, E.; Clark, G.; Coleman, S.; Cresswell, I.; Emmerson, K.; Evans, K.; Hibberd, M.; et al. Overview of State and Trends of Inland Water. In *Australia State of the Environment 2016*; Australian Government Department of the Environment and Energy: Canberra, Australia, 2016.
21. Natural Capital Coalition. Natural Capital Protocol. Available online: http://naturalcapitalcoalition.org/protocol (accessed on 31 October 2018).
22. United Nations; European Commission; Organisation for Economic Co-Operation and Development; World Bank. *System of Environmental-Economic Accounting Central Framework*; United Nations Statistics Division: New York, NY, USA, 2014.
23. Wentworth Group. *Accounting for Nature—A Scientific Method for Constructing Environmental Asset Condition Accounts*; Wentworth Group: Sydney, Australia, 2016.
24. Pearce, D. An intellectual history of environmental economics. *Annu. Rev. Energ. Environ.* **2002**, *27*, 57–81. [CrossRef]
25. TEEB. The Economics of Ecosystems and Biodiversity: Mainstreaming the Economics of Nature: A Synthesis of the Approach, Conclusion and Recommendations of TEEB. In Proceedings of the 10th meeting of the Conference of Parties to the CBD, Nagoya, Japan, 18–29 October 2010.
26. The World Bank. *WAVES Annual Report 2017*; The World Bank: Washington, DC, USA, 2017.
27. TEEB. *TEEB for Agriculture & Food: Scientific and Economic Foundations*; TEEB: Geneva, Switzerland, 2018.
28. FAO. *System of Environmental-Economic Accounting for Agriculture, Forestry and Fisheries: SEEA AFF White Cover Final*; FAO: New York, NY, USA, 2016.
29. Ascui, F.; Cojoianu, T. *Natural Capital Credit Risk Assessment in Agricultural Lending: An Approach Based on the Natural Capital Protocol*; Natural Capital Finance Alliance: Oxford, UK, 2019.
30. FAO. *Natural Capital Impacts in Agriculture—Supporting Better Decision Making*; FAO: Rome, Italy, 2015.
31. Czúcz, B.; Keith, H.; Jackson, B.; Maes, J.; Driver, A.; Nicholson, E.; Bland, L. *Discussion Paper 2.3: Proposed Typology of Condition Variables for Ecosystem Accounting and Criteria for Selection of Condition Variables. Paper Submitted to the SEEA EEA Technical Committee as input to the Revision of the Technical Recommendations in Support of the System on Environmental-Economic Accounting. Version of 13 March 2019*; United Nations: New York, NY, USA, 2019; p. 23.
32. Boyd, J.; Banzhaf, S. What are ecosystem services? The need for standardized environmental accounting units. *Ecol. Econ.* **2007**, *63*, 616–626. [CrossRef]
33. Daily, G. *Nature's Services: Societal Dependence on Natural Ecosystems*; Island Press: Washington, DC, USA, 1997.
34. De Groot, R.S.; Wilson, M.A.; Boumans, R.M.J. A typology for the classification, description and valuation of ecosystem functions, goods and services. *Ecol. Econ.* **2002**, *41*, 393–408. [CrossRef]
35. Fisher, B.; Turner, R.K.; Morling, P. Defining and classifying ecosystem services for decision making. *Ecol. Econ.* **2009**, *68*, 643–653. [CrossRef]
36. Haines-Young, R.; Potschin, M.B. Common International Classification of Ecosystem Services (CICES) V5.1 and Guidance on the Application of the Revised Structure. EEA Framework Contract No EEA/IEA/09/003. 2018. Available online: www.cices.eu (accessed on 10 September 2018).
37. Millennium Ecosystem Assessment. *Ecosystems and Human Wellbeing: Synthesis*; Island Press: Washington, DC, USA, 2005.
38. Nahlik, A.M.; Kentula, M.E.; Fennessy, M.S.; Landers, D.H. Where is the consensus? A proposed foundation for moving ecosystem service concepts into practice. *Ecol. Econ.* **2012**, *77*, 27–35. [CrossRef]
39. Wallace, K.J. Classification of ecosystem services: Problems and solutions. *Biol. Conserv.* **2007**, *139*, 235–246. [CrossRef]

40. United Nations. *Technical Recommendations in Support of the System of Environmental-Economic Accounting 2012—Experimental Ecosystem Accounting*; United Nations: New York, NY, USA, 2017.
41. Obst, C.G.; van de Ven, P.; Tebrake, J.; St Lawrence, J.; Edens, B. Valuation and Accounting Treatments: Issues and Options in Accounting for Ecosystem Degradation and Enhancement (Draft). In Proceedings of the 2019 Forum of Experts in SEEA Experimental Ecosystem Accounting, Glen Cove, NY, USA, 26–27 June 2019.
42. Haines-Young, R.; Potschin, M.B. Common International Classification of Ecosystem Services (CICES): Consultation on Version 4, August–December 2012. EEA Framework Contract No EEA/IEA/09/003. 2013. Available online: www.cices.eu (accessed on 15 September 2018).
43. Asbjornsen, H.; Hernandez-Santana, V.; Liebman, M.; Bayala, J.; Chen, J.; Helmers, M.; Ong, C.; Schulte, L.A. Targeting perennial vegetation in agricultural landscapes for enhancing ecosystem services. *Renew. Agric. Food. Syst.* **2014**, *29*, 101–125. [CrossRef]
44. Jose, S. Agroforestry for ecosystem services and environmental benefits: An overview. *Agrofor. Syst.* **2009**, *76*, 1–10. [CrossRef]
45. Ovando, P.; Campos, P.; Oviedo, J.L.; Caparrós, A. Ecosystem accounting for measuring total income in private and public agroforestry farms. *For. Policy Econ.* **2016**, *71*, 43–51. [CrossRef]
46. Kay, S.; Graves, A.; Palma, J.H.; Moreno, G.; Roces-Díaz, J.V.; Aviron, S.; Chouvardas, D.; Crous-Duran, J.; Ferreiro-Domínguez, N.; de Jalón, S.G. Agroforestry is paying off—Economic evaluation of ecosystem services in European landscapes with and without agroforestry systems. *Ecosyst. Serv.* **2019**, *36*, 100896. [CrossRef]
47. Campos, P.; Oviedo, J.L.; Álvarez, A.; Mesa, B.; Caparrós, A. The role of non-commercial intermediate services in the valuations of ecosystem services: Application to cork oak farms in Andalusia, Spain. *Ecosyst. Serv.* **2019**, *39*, 100996. [CrossRef]
48. Alkemade, R.; Burkhard, B.; Crossman, N.D.; Nedkov, S.; Petz, K. Quantifying ecosystem services and indicators for science, policy and practice. *Ecol. Indic.* **2014**, *37*, 161–162. [CrossRef]
49. Burkhard, B.; Crossman, N.; Nedkov, S.; Petz, K.; Alkemade, R. Mapping and modelling ecosystem services for science, policy and practice. *Ecosyst. Serv.* **2013**, *4*, 1–3. [CrossRef]
50. Crossman, N.D.; Burkhard, B.; Nedkov, S.; Willemen, L.; Petz, K.; Palomo, I.; Drakou, E.G.; Martín-Lopez, B.; McPhearson, T.; Boyanova, K.; et al. A blueprint for mapping and modelling ecosystem services. *Ecosyst. Serv.* **2013**, *4*, 4–14. [CrossRef]
51. Burkhard, B.; Kroll, F.; Müller, F.; Windhorst, W. Landscapes' capacities to provide ecosystem services—A concept for land-cover based assessments. *Landsc. Online* **2009**, *15*, 1–22. [CrossRef]
52. Eigenbrod, F.; Armsworth, P.R.; Anderson, B.J.; Heinemeyer, A.; Gillings, S.; Roy, D.B.; Thomas, C.D.; Gaston, K.J. The impact of proxy-based methods on mapping the distribution of ecosystem services. *J. Appl. Ecol.* **2010**, *47*, 377–385. [CrossRef]
53. Egoh, B.N.; Drakou, E.; Dunbar, M.B.; Maes, J.; Willemen, L. *Indicators for Mapping Ecosystem Services: A Review*; Publications Office of the European Union: Luxembourg, 2012.
54. Martínez-Harms, M.J.; Balvanera, P. Methods for mapping ecosystem service supply: A review. *Int. J. Biodivers. Sci. Ecosyst. Serv. Manag.* **2012**, *8*, 17–25. [CrossRef]
55. Metzger, M.J.; Rounsevell, M.D.A.; Acosta-Michlik, L.; Leemans, R.; Schröter, D. The vulnerability of ecosystem services to land use change. *Agric. Ecosyst. Environ.* **2006**, *114*, 69–85. [CrossRef]
56. Naidoo, R.; Balmford, A.; Costanza, R.; Fisher, B.; Green, R.E.; Lehner, B.; Malcolm, T.R.; Ricketts, T.H. Global mapping of ecosystem services and conservation priorities. *Proc. Natl. Acad. Sci. USA* **2008**, *105*, 9495. [CrossRef]
57. Volk, M. Modelling ecosystem services—Challenges and promising future directions. *Sustain. Water Qual. Ecol.* **2013**, *1–2*, 3–9. [CrossRef]
58. Kareiva, P. *Natural Capital: Theory and Practice of Mapping Ecosystem Services*; Oxford University Press: Oxford, UK, 2011.
59. Lonsdorf, E.; Kremen, C.; Ricketts, T.; Winfree, R.; Williams, N.; Greenleaf, S. Modelling pollination services across agricultural landscapes. *Ann. Bot.* **2009**, *103*, 1589–1600. [CrossRef] [PubMed]
60. Battaglia, M.; Sands, P.; White, D.; Mummery, D. CABALA: A linked carbon, water and nitrogen model of forest growth for silvicultural decision support. *For. Ecol. Manag.* **2004**, *193*, 251–282. [CrossRef]

61. Ensis. SPIF: The Scenario Planning and Investment Framework Tool. In *Commerical Environmental Forestry: Integrating Trees into Landscapes for Multiple Benefits*; Summary Technical Report June 2006; Ensis (the joint forces of CSIRO and Scion): Victoria, Australia, 2006.
62. Private Forests Tasmania. *The Farm Forestry Toolbox Version 5.0: An Aid to Successfully Growing Trees on Farms*; Private Forests Tasmania: Tasmania, Australia, 2008.
63. Young, A.; Menz, K.M.; Muraya, P.; Smith, C. *SCUAF-Version 4: A Model to Estimate Soil Changes under Agriculture, Agroforestry and Forestry*; ACIAR: Canberra, Australia, 1998; p. 49.
64. van der Werf, W.; Keesman, K.; Burgess, P.; Graves, A.; Pilbeam, D.; Incoll, L.; Metselaar, K.; Mayus, M.; Stappers, R.; van Keulen, H. Yield-SAFE: A parameter-sparse, process-based dynamic model for predicting resource capture, growth, and production in agroforestry systems. *Ecol. Eng.* **2007**, *29*, 419–433. [CrossRef]
65. Keating, B.A.; Carberry, P.S.; Hammer, G.L.; Probert, M.E.; Robertson, M.J.; Holzworth, D.; Huth, N.I.; Hargreaves, J.N.; Meinke, H.; Hochman, Z. An overview of APSIM, a model designed for farming systems simulation. *Eur. J. Agron.* **2003**, *18*, 267–288. [CrossRef]
66. Warner, A. *Farm Forestry Toolbox Version 5.0: Helping Australian Growers to Manage Their Trees: A Report for the RIRDC/L & WA/FWPRDC Joint Venture Agroforestry Program*; Rural Industries Research and Development Corporation: Canberra, Australia, 2007.
67. USDA Forest Service. i-Tree: Tools for Assessing and Managing Forests and Community Trees. Available online: https://www.itreetools.org/about.php (accessed on 3 February 2019).
68. Sandhu, H.S.; Wratten, S.D.; Cullen, R.; Case, B. The future of farming: The value of ecosystem services in conventional and organic arable land. An experimental approach. *Ecol. Econ.* **2008**, *64*, 835–848. [CrossRef]
69. Porter, J.; Costanza, R.; Sandhu, H.; Sigsgaard, L.; Wratten, S. The value of producing food, energy, and ecosystem services within an agro-ecosystem. *Ambio* **2009**, *38*, 186–193. [CrossRef]
70. Crossman, N.D.; Connor, J.D.; Bryan, B.A.; Summers, D.M.; Ginnivan, J. Reconfiguring an irrigation landscape to improve provision of ecosystem services. *Ecol. Econ.* **2010**, *69*, 1031–1042. [CrossRef]
71. Petz, K.; van Oudenhoven, A.P. Modelling land management effect on ecosystem functions and services: A study in the Netherlands. *Int. J. Biodivers. Sci. Ecosyst. Serv. Manag.* **2012**, *8*, 135–155. [CrossRef]
72. Fisher, I. *The Nature of Capital and Income*; The Macmillan Company: New York, NY, USA, 1906.
73. Krutilla, J.V. Conservation reconsidered. *Am. Econ. Rev.* **1967**, *57*, 777–786.
74. Fenichel, E.P.; Abbott, J.K.; Yun, S.D. Chapter 3—The nature of natural capital and ecosystem income. In *Handbook of Environmental Economics*; Dasgupta, P., Pattanayak, S.K., Smith, V.K., Eds.; Elsevier: Amsterdam, The Netherlands, 2018; Volume 4, pp. 85–142.
75. Pezzey, J.C.; Toman, M.A. Sustainability and its economic interpretations. In *Scarcity and Growth Revisited—Natural Resources and the Environment in the New Millenium*; Resources for the Future: Washington, DC, USA, 2005.
76. Pearce, D.; Moran, D. *The Economic Value of Biodiversity*; Routledge: London, UK, 2013.
77. Pascual, U.; Muradian, R.; Brander, L.; Gómez-Baggethun, E.; Martín-López, B.; Verma, M.; Armsworth, P.; Christie, M.; Cornelissen, H.; Eppink, F. The economics of valuing ecosystem services and biodiversity. In *The Economics of Ecosystems and Biodiversity: Ecological and Economic Foundations*; Taylor and Francis: London, UK, 2010; pp. 183–256. [CrossRef]
78. Thompson, D.; George, B. Financial and economic evaluation of agroforestry. In *Agroforestry for Natural Resource Management*; CSIRO Publishing: Canberra, Australia, 2009; pp. 283–308.
79. Stainback, G.A.; Alavalapati, J.R.R.; Shrestha, R.K.; Larkin, S.; Wong, G. Improving Environmental Quality in South Florida through Silvopasture: An Economic Approach. *J. Agric. Appl. Econ.* **2004**, *36*, 481–489. [CrossRef]
80. Kulshreshtha, S.; Kort, J. External economic benefits and social goods from prairie shelterbelts. *Agrofor. Syst.* **2009**, *75*, 39–47. [CrossRef]
81. Oviedo, J.L.; Huntsinger, L.; Campos, P. The Contribution of Amenities to Landowner Income: Cases in Spanish and Californian Hardwood Rangelands. *Rangel. Ecol. Manag.* **2017**, *70*, 518–528. [CrossRef]
82. Morse, R.; Calderone, N. The value of honey bee pollination in the United States. *Bee Cult.* **2000**, *128*, 1–15.
83. Wilson, S.J. *Ontario's Wealth, Canada's Future: Appreciating the Value of the Greenbelt's Eco-Services*; David Suzuki Foundation: Vancouver, BC, Canada, 2008.
84. Winfree, R.; Gross, B.J.; Kremen, C. Valuing pollination services to agriculture. *Ecol. Econ.* **2011**, *71*, 80–88. [CrossRef]

85. Alam, M.; Olivier, A.; Paquette, A.; Dupras, J.; Revéret, J.P.; Messier, C. A general framework for the quantification and valuation of ecosystem services of tree-based intercropping systems. *Agrofor. Syst.* **2014**, *88*, 679–691. [CrossRef]
86. Polyakov, M.; Pannell, D.J.; Pandit, R.; Tapsuwan, S.; Park, G. Capitalized amenity value of native vegetation in a multifunctional rural landscape. *Am. J. Agric. Econ.* **2015**, *97*, 299–314. [CrossRef]
87. Shrestha, R.K.; Alavalapati, J.R.R. Valuing environmental benefits of silvopasture practice: A case study of the Lake Okeechobee watershed in Florida. *Ecol. Econ.* **2004**, *49*, 349–359. [CrossRef]
88. de Jalón, S.G.; Graves, A.; Palma, J.H.; Williams, A.; Upson, M.; Burgess, P.J. Modelling and valuing the environmental impacts of arable, forestry and agroforestry systems: A case study. *Agrofor. Syst.* **2018**, *92*, 1059–1073. [CrossRef]
89. National Australia Bank. Natural Value. Available online: https://www.nab.com.au/about-us/corporate-responsibility/environment/natural-value (accessed on 20 June 2018).
90. Cojoianu, T.F.; Ascui, F. Developing an evidence base for assessing natural capital risks and dependencies in lending to Australian wheat farms. *J. Sustain. Financ. Invest.* **2018**, *8*, 95–113. [CrossRef]
91. Ogilvy, S. Developing the ecological balance sheet for agricultural sustainability. *Sustain. Acc. Manag. Policy. J.* **2015**, *6*, 110–137. [CrossRef]
92. Campos, P.; Rodríguez, Y.; Caparrós, A. Towards the dehesa total income accounting: Theory and operative Monfragüe study cases. *For. Syst.* **2001**, *10*. [CrossRef]
93. Caparrós, A.; Campos, P.; Montero, G. An Operative Framework for Total Hicksian Income Measurement: Application to a Multiple-Use Forest. *Environ. Resour. Econ.* **2003**, *26*, 173–198. [CrossRef]
94. Dominati, E.; Mackay, A.; Green, S.; Patterson, M. A soil change-based methodology for the quantification and valuation of ecosystem services from agro-ecosystems: A case study of pastoral agriculture in New Zealand. *Ecol. Econ.* **2014**, *100*, 119–129. [CrossRef]
95. Baker, T.P.; Moroni, M.T.; Mendham, D.S.; Smith, R.; Hunt, M.A. Impacts of windbreak shelter on crop and livestock production. *Crop. Pasture. Sci.* **2018**, *69*, 785–796. [CrossRef]
96. Cleugh, H. Effects of windbreaks on airflow, microclimates and crop yields. *Agrofor. Syst.* **1998**, *41*, 55–84. [CrossRef]
97. Bird, P.R.; Bicknell, D.; Bulman, P.A.; Burke, S.J.A.; Leys, J.F.; Parker, J.N.; Van Der Sommen, F.J.; Voller, P. The role of shelter in Australia for protecting soils, plants and livestock. *Agrofor. Syst.* **1992**, *20*, 59–86. [CrossRef]
98. Olander, L.; Mason, S.; Warnell, K.; Tallis, H. *Building Ecosystem Services Conceptual Models*; NESP Conceptual Model Series No. 1; Duke University: Durham, NC, USA, 2018.
99. England, J.R.; O'Grady, A.P.; Fleming, A.; Marais, Z.; Mendham, D. Trees on farms to support natural capital: An evidence-based review for grazed dairy systems. *Sci. Total Environ.* **2019**, unpublished work.
100. Müller, A.; Knoke, T.; Olschewski, R. Can existing estimates for ecosystem service values inform forest management? *Forests* **2019**, *10*, 132. [CrossRef]
101. Abadi, A.; Lefroy, T.; Cooper, D.; Hean, R.; Davies, C. *Profitability of Medium to Low Rainfall Agroforestry in the Cropping Zone*; Rural Industries Research and Development Corporation Publication: Barton, Australia, 2003.
102. Graves, A.R.; Burgess, P.J.; Liagre, F.; Terreaux, J.-P.; Borrel, T.; Dupraz, C.; Palma, J.; Herzog, F. Farm-SAFE: The process of developing a plot-and farm-scale model of arable, forestry, and silvoarable economics. *Agrofor. Syst.* **2011**, *81*, 93–108. [CrossRef]
103. Digital Agriculture Service. DAS Rural Intelligence Platform. Available online: https://digitalagricultureservices.com/platform (accessed on 20 August 2019).
104. FarmMap4D. FarmMap4D Spatial Hub Factsheet: Turning Big Data into Better Decisions. Available online: http://www.farmmap4d.com.au/wp-content/uploads/2018/02/Turning-big-data-into-better-decisionsV2.pdf (accessed on 20 August 2019).