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Sustainable multifunctional landscapes: a review to implementation

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Historic land use practices have dramatically altered landscapes across all scales, homogenising them and restricting opportunities for humans and wildlife. The need for multifunctional landscapes which simultaneously provide food security, livelihood opportunities, maintenance of species and ecological functions, and fulfil cultural, aesthetic recreational needs is now recognised. Numerous theoretical and technical tools have been developed to understand different landscape elements, in particular the emerging research area of ecosystem services. A brief review of these tools not only shows considerable growth and opportunity, but also serves to highlight a lack of research integration and a lag in implementation. The effective implementation of sustainable multifunctional landscapes requires true transdisciplinary engagement. We suggest the use of learning organisations to bring together the multiple stakeholders necessary for multifunctional landscapes to take purchase.

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Understanding dynamic landscapes

Past approaches to meeting human development needs have resulted in extensive transformation of natural ecosystems, with both agriculture and urban areas having dramatically increased their ecological footprints in the last century [1,2,3•]. A critical component enabling this development has been the natural capital base and the ecosystem services that flow from it. The Millennium Ecosystem Assessment clearly demonstrated that the majority of our ecosystem services are being degraded and that drastic action, such as restoring natural capital, is required to ensure the long-term continued flow of these services [4]. Overlaid on these existing challenges is the threat of climate change [5,6]. Whilst the exact effects of this additional dynamic are largely unknown, we can anticipate significant shifts in natural processes and in turn this will require adjusting our production strategies and survival mechanisms. The last ten years has seen a call to redirect our research efforts to meet human-induced global landscape challenges and to focus on this new ecology [2].

The emergent research area of sustainable multifunctional landscapes provides just such a focus. Sustainable multifunctional landscapes are landscapes created and managed to integrate human production and landscape use into the ecological fabric of a landscape maintaining critical ecosystem function, service flows and biodiversity retention. This is essential if we are to halt and reverse declining trends in the majority of our ecosystem services. Furthermore we need landscapes that assist species in responding to increasing climate pressures, facilitating movement and establishing in new emerging ecosystems. Only by doing this we will be able to maintain some degree of ecosystem service provision into the future.

A detailed understanding of the workings of our ecological systems, their thresholds, robustness and drivers is required if we are to develop and maintain such landscapes [1,7]. Coupled to this is the development of land use strategies, which incorporate the notion of agility or the ability to quickly shift production emphasis. This will allow for increased socio-ecological resilience and improved service provision under scenarios of change. Musacchio [8•] calls for attaining this human production and ecological balance through the better management of the 'global commons' and in certain places this is being proven possible. For example, we are realising that agricultural landscapes can be managed to host biodiversity with simultaneous positive livelihood outcomes [3•]. However we have been engaging in this realm for long enough to know that landscapes are complex entities; dynamic in and of themselves and further complicated in the human dimension of how they are perceived [9]. Every landscape is a function of its abiotic and biotic template combined with its own unique history of human intervention [10,11]. Landscape ecology and conservation biology have been established research areas for the last 30 years and have substantive bases with developed theory. The enactment and implementation of their principles however has lagged [12]. We attribute this to what Antrop [11] calls the chaos of landscape systems and the convolution required in engaging with these processes. Hope is offered with emerging areas of transdisciplinary research in fostering sustainable futures [13•].

In this review, we consider the theoretical building blocks and emerging approaches that come together in the pursuit of sustainable multifunctional landscapes. We reflect on current tools and approaches to the development of sustainable ecological and resilient landscapes. Attention is given to the theoretical role of ecosystem services in guiding thinking around multifunctional landscapes in urban and agricultural settings. The promise offered by transdisciplinary approaches to the design and creation of landscapes to meet current and future needs is discussed [2,8•,14]. Latest work also highlights the gap between science, policy and implementation [14] and demonstrates the necessity of engaging with stakeholders at multiple scales in order for the concept of multifunctional landscapes to find purchase [15,16].

Tools and approaches for developing and managing sustainable multifunctional landscapes

In response to the biodiversity crisis, a substantive body of information has been generated [17]. Increasingly it is recognised that these biodiversity and ecosystem issues stretch beyond the purely ecological and into the social and economic realms. Emerging from within these disciplinary areas, and between them, are a number of theoretical approaches and technical tools, which speak to the multifunctional landscape agenda. These can broadly be divided into those tools and approaches used to explore and understand landscapes and their functioning and those tools that serve as interventions whereby we may manage a landscape to a desired end.

Exploratory tools

The research area of ***ecosystem services*** has largely emerged in response to biodiversity loss and the need to demonstrate the importance and value of biodiversity to human well being [18,19]. The rapid growth in research in this area has demonstrated the tremendous collection of services on which we depend [19,20]. These multiple ecosystem services range from food production and water provision, to aesthetic and recreational aspects [4,21]. These can seldom be ring fenced; with manifold services interacting in an inter-related manner in the landscape. Recent studies have demonstrated that ecosystem services do not necessarily equate directly with species richness, but relate rather to the ecosystems capacity to self correct, sustaining function, composition and structure [18,22,23••,24,25] we know enough to realise that adopting a precautionary approach is prudent [18,19,25]. For instance monocultures of crops provide high food yields in the short term, heterogeneous multifunctional production systems and landscapes have been shown to be more robust [26]. Ecosystem services underpin the concept of multifunctional landscapes, and growing empirical literature on ecosystem services demonstrated how tools developed for economic, landscape ecology and socio-political studies, are being drawn on and integrated in their assessment, valuation, spatial analysis and social benefit analysis.

Economics is a major driver of production strategies which in turn affect landscape design and change. In the past economic assessments focussed on determining the advantages of growing one crop in favour of another, now ecosystem service values are being incorporated into assessments [3•]. Detailed understanding of economic values associated with production strategies, opportunity costs and ecosystem services enables us to engage in trade-off analysis and identify the potential losses associated with certain landscape patterns [27,28].

The emerging literature on ecosystem service valuation approaches demonstrates diverse approaches derived for different services [29,30]. A sound understanding of opportunity costs and trade-offs allows for a more transparent decision-making system where the environmental cost is apparent [31•].

Economic valuation allows for the exploration of payments for ecosystem services [32] as a tool for promoting sustainable land use buy providing financial incentives for service providers [33,34]. This has the effect of creating opportunities and increasing the potential variety of land use options. This speaks to the need, and opportunity, for agility in terms of production strategies, with value recognised in having a diversity of production options and the retention of intact ecosystems for future use options. Multifunctional production systems can be highly valuable, and Jordan *et al.* [26] demonstrate the significant values in this regard. Whilst valuation and PES may provide opportunities, both the potential for undervaluation and the inability to derive value for critical ecosystem services introduces inaccuracies into any analysis [23••]. We recognise both the need to consider nonmarket goods within assessments [35] and the significance of the scale at which benefits are realised [16]. These aspects are still being grappled with and the tools for valuing elements such as noncommodity outputs show considerable promise [21,36].

Reflecting on economic valuation makes apparent the need for including a *social* value dimension or noneconomic valuation, including people's intrinsic values and the spatial arrangement of these [14,16,37]. These values have been assessed by means of a variety of approaches including interviews and questionnaires, citizen juries, Delphi surveys, participatory rural appraisal and action research. In addition to these, designing and creating multifunctional landscapes requires the understanding of social conditions such as power relations, political agendas and politicised issues [8•]. A clear understanding of who decides what constitutes a desirable environment, who 'owns' it, and who uses or benefits from

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the ecosystems and ecosystem services, is an imperative for any enactment of a vision. Emerging tools to elicit this information are political analysis, social network analysis and community mapping [37,38].

Understanding landscapes from a purely *ecological* perspective is well advanced with assessments having focussed on issues such as the spatial arrangement, size, shape, connectivity, and ecological functioning of landscapes [17]. Assessing the landscape structure, or composition, configuration and properties of different patches across a landscape provides us with an understanding of the potential of that landscape. Linked to this are the concepts of landscape function, understood interns of each element interaction, and landscape connectivity, or how spatially continuous these elements are, and these determine the ability of a landscape to achieve its potential. A variety of approaches have been put forward in this regard, including graph theory [39,40], modelling [40], ecological network analysis [41], scalar analysis of connectivity [42] and fragmentation analysis [43,44] to name a few. Fischer *et al.* [45] and Fischer and Lindemayer [43] have identified key principles for the structural design and management of working landscapes in order to retain biodiversity. These focus firstly on pattern-orientated management, where structural complexity, heterogeneity and environmental gradients are incorporated into management along with the retention and creation of corridors, stepping stones, buffer areas, and large structurally complex patches of natural vegetation; and secondly on process-orientated management where key and important species are retained, appropriate disturbance regimes applied, invasive species controlled and threats to ecosystem to processes minimised.

Two key *integrating exploratory tools* also standout, these being the development and advancement of Geographical Information Systems (GIS) and scenario planning.

GIS and their ability to integrate spatial socio-economic and ecological data have been remarkable in advancing spatial analysis capabilities [9,46]. Continuous developments in this field like software package MARXAN and MARZONE now allow for the assessment of multiple land types, according to a variety of cost data, in meeting multiple objectives [47].

Scenario planning is a tool focussed on highlighting a range of possible future states, outcomes and alternatives, based on both quantitative and qualitative data and models. Applied at the landscape level it allows scientists and stakeholders to establish a shared understanding of potential alternative futures of a linked social ecological system, determine key drivers of these states, identify desired states and develop ideal landscape level blue prints for the future [48,49]. Metzger *et al.* [50] demonstrate how both GIS and scenario planning approaches can be combined in determining the effects of land use change on ecosystem services. In addition to these, new tools which quantify ecosystem services under different scenarios, such as InVEST are under development [51]. The InVEST tool is a ground breaking exploratory tool capable of modelling and mapping ecosystem services and assessing their value under a variety of predefined scenarios. There is however a clear opportunity for developing further tools and indicators which effectively integrate ecological, economic and social assessments.

Implementation tools

Exploratory tools typically identify priorities for landscape management and design. Implementing these options and designs is a further challenge. Ecological restoration is a classic example of an implementation tool, requiring identified social and ecological needs and economic viability. Restoration typifies the type of engagement required in the pursuit of multifunctional landscapes where numerous tools and disciplines must come together for 'designed ecological solutions' that provide multiple ecosystem services benefits in contrast to degraded landscapes [2,14]. This requires a pragmatic ecological science and approach, beyond the desire of reconstructing historical landscapes, towards the actual creation of a new landscapes which meet our multiple and diverse demands [3•]. Lovell and Johnston [52••] present practical implementation suggestions for the urban landscape where ecological principles are applied to the design of infrastructure to improve ecological performance and service delivery. Oberndorfer *et al.* [53] similarly give a practical demonstration of techniques, technical specifications and advantages of green roof development within the urban biodiversity and ecosystem service context. Likewise Pretty [54] discusses the need for integrating biological and ecological processes into food production systems, to enhance natural capital and derive improved benefits from ecosystem services, and Dale *et al.* [55] present guidelines for land managers that provide practical approaches for incorporating ecological principles into land use decisions. Whilst, Antrop [11] reminds us of the chaos of landscapes, the difficulties of understanding and measuring their complex interactions and cautions that they are hard to control, these efforts noted above are examples of growing practical attempts at making our landscapes more multifunctional.

Transdisciplinarity

Multifunctional landscapes should be perceived as tangible mixed natural and cultural interacting systems [56•]. Therefore the creation and design of sustainable multifunctional landscapes requires transdisciplinary approaches [13•,57] that make full use of available science and technology [58]. We have moved on from simple interdisciplinary research [59] which by definition

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requires only communication between different disciplines, to a recognised need for a transdisciplinary approach which calls on a true engagement between scientists, practitioners and professionals involved in land use decision making where goals and a vision for the future are negotiated, co-developed and worked towards [14,60,61].

Reflecting on the available tools reaffirms the transdisciplinary nature of the issues at hand. Despite an apparent wealth of landscape analysis tools, the examples of integrated approaches for tackling the implementation of integrated landscape planning are limited. Polasky *et al.* [31•] present an excellent example of effective integration of ecological and economic criteria in determining spatial arrangements in land use planning, using the InVEST tool. However, on the whole the scarcity of implementation tools hampers the realisation of multifunctional landscape development [14,58]. The theoretical, and even empirical, literature grows, but the enactment in broader society is lacking. Furthermore the focus of research to date has been questioned, with misalignments identified between actual problems facing society and current research foci [13•,61]. Related to this is a lack of agreement on ***how*** to bring together social, cultural, economic and ecological views [62]. Whilst success stories are out there, for example in the European agricultural sector [35], this has yet to be achieved on the regional and global scales necessary to address our current environmental crises [58]. The need for collaboration and the exchange of ideas with stakeholders is now being recognised as critical to achieving this necessary transformation [15].

A call for learning organisations

Achieving true interdisciplinary and transdisciplinary engagement in the pursuit of multifunctional landscapes requires the development of mutual learning, interacting and cooperation between researchers, land managers, various government and industry sectors and decision makers [16,63]. This could be achieved through the formation of learning organisations [64••]. Learning organisations are organisations that share and develop knowledge, resources and ideas towards a common goal and are constantly transforming themselves in order to meet this goal. They are typically informal temporary groups, assembled to focus on a particular problem, however they are not excluded from being attached formal institutions, depending on the nature of the problem. Such organisations would serve to make research socially relevant and user-informed and simultaneously serve the ends of stakeholder empowerment [3•,64••]. By bringing together stakeholders from multiple disciplines and hierarchical levels (empirical, pragmatic, normative, and purposive) [3•,60,62] and providing a forum for adaptive processes where approaches can be repeatedly revisited and revised we will come closer to achieving socially engaged science [15,63]. This is central to the goal of attaining sustainable multifunctional landscapes better adapted to cope with current dynamic systems [5,11,15,64••].

A starting point to such an approach would be the co-development of a common future sustainable landscape vision among all relevant stakeholders [17] through, for example, scenario analysis [48,49,65]. This would need to be based on a sound understanding of the social, ecological and economic systems in question developed through the multiple tools available and with input from technical specialists with understandings of thresholds and boundaries [35,48,49,65]. Local champions who anchor this vision in the landscape, providing leadership in terms of sustainable practices to other land owners, with good working relationships with enablers, such as scientists, local government officials and industry representatives, are a critical component for successful establishment [66]. Novel product creation and certification programmes, and PES schemes may provide required incentives. Institutions such as biosphere reserves and stakeholder forums have a role to play in retaining momentum, and guiding land use practice contributions to this vision of the future [63,67]. Whilst a recent study has demonstrated the value of adopting prescriptive approaches over those where the goals are set in collaboration with stakeholder in achieving environmental benefits [68], we believe that learning organisations can play a key role in entrenching the notion of sustainability in establishing a long term vision for a landscape. Furthermore, our approach is more likely to succeed in landscapes which lack effective regulating authorities.

The iterative learning process suggested in such learning organisations should also revisit data generation with the growth and refinement of available tools [64••]. Ecosystem services require monitoring, evaluation and reevaluation. Iterative approaches would address Antop's [5] concerns over the dynamic nature of landscapes, where approaches adopted in pursuing multifunctional landscapes need not be static [5,11]. This iterative process, or adaptive management, should also allow for policy formulation and reformulation and legislation development. At all levels information products and management aids need to be co-developed with stakeholders to ensure accuracy and uptake [15]. These actions should allow for an understanding of and development of multifunctional landscapes.

Issues that we continue to grapple with

Whilst we have developed a variety of tools for the analysis and assessment of landscapes we do not yet have the necessary tools for implementing sustainable multifunctional landscapes on the scale required to address current ecological crises. More work is needed in developing tools, methods and indicators for valuing and assessing multiple ecosystem services where ecological,

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social and economic variables are enmeshed. Existing tools need to be further developed, in the context of a transdisciplinary environment geared towards the development of learning organisations.

In closing the science policy gap we need to reevaluate our role as academics and researchers, and determine where we should be putting our efforts in suppressing deleterious system drivers and shifting paradigms towards sustainability. We need to deviate from the traditional, and revisit our obligations to society [58,61], and in doing so be prepared to embrace different academic paradigms. Establishing functioning and appropriate transdisciplinary learning organisations will be necessary for fostering sustainable futures, and is likely to require the realignment of the goals and mandates of research institutions.

Conflicts of interest

No conflicts of interest to declare.

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