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Title: From landscape ecology to forest landscape restoration

Review Article

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Abstract

Context: Forest landscape restoration (FLR) was first defined in 2000 and has emerged from several disciplines, including conservation biology and landscape ecology. As it has gained in popularity, it is useful to go back to its origins and explore its similarities and differences with the discipline of landscape ecology.

Objective: This article aims to identify the relationship between forest landscape restoration (FLR) and landscape ecology.

Methods: It draws on a historical overview of FLR, an analysis of the definition of FLR and examples from existing FLR projects to illustrate this relationship. The article then analyses the convergence and divergence between FLR and landscape ecology.

Results: Three areas of convergence – landscapes, integration and connectivity - and three areas of divergence – process versus analysis, transformative and political nature of FLR- are identified and described.

Conclusions: Going forward, some areas of integration between the two disciplines are proposed.

Keywords

FLR; restoration; landscape ecology

1.Introduction

In the late 1990s and early 2000s the environmental conservation community began scaling up its interventions beyond protected areas to larger areas such as hotspots, ecoregions and landscapes (e.g. Myers et al. 2000, Olson and Dinerstein 1998). In parallel, much of the tree planting that was taking place around the world was using a handful of exotic species (Sayer et al. 2004, Lamb et al. 2005) and frequently leading to negative social outcomes such as dispossessions or displacements (Rai et al. 2018). Acknowledging the rapid loss of habitats, and forests in particular, brought the conservation community to recognise that protected areas alone were insufficient to conserve biodiversity, and that restoration was now necessary. Also, expanding beyond protected areas, it became clear that it was necessary to consider humans as more integral to the achievement of broader conservation objectives (McShane and Wells 2004). These two issues (spatial scale and the human dimension) had a strong influence on the definition of forest landscape restoration (FLR) which was coined in 2000 at a workshop in Segovia (Spain) convened by WWF and IUCN (WWF and IUCN 2000). The workshop brought together over 30 specialists from both social and natural sciences to define (among other priorities) a feasible process and approach for 'forest restoration'. The focus on larger spatial scales was in turn influenced by landscape ecology. As such, FLR was shaped by forestry, conservation biology, landscape ecology and integrated conservation and development approaches (Mansourian 2018). Since then, FLR has evolved significantly, from scattered pilot projects to a political movement (led by the Bonn Challenge on FLR) and wider uptake. In this article I review key articles on landscape ecology and on FLR to identify areas of convergence, divergence and opportunities for better cross-fertilization across both areas of research.

2. Overview of landscape ecology

The origins of landscape ecology can be traced back to the 1930s with Troll defining it in 1939 as "*the study of the main complex causal relationships between the life communities and their environment in a given section of a landscape"* (in Wu 2013). More broadly, Wu (2013) has defined landscape ecology as the "s*cience and art of studying and improving the relationship between spatial pattern and ecological processes on a multitude of scales and organizational levels*." The International Association of Landscape Ecology (IALE) was founded in 1982 (Clark 2010). That same year saw advances in imagery and geographic information systems which had a strong influence on landscape ecology as it enabled better observations of patterns across large scales. For Wu and

Loucks (1999) this technology was fundamental in securing the place of landscape ecology as a distinct science within ecology.

The focus of landscape ecology is on the analysis of patches within a broader matrix. It concentrates on structure and dynamics within the wider landscape system (Turner 1987 in Cushman et al. 2010). The interactions between distinct elements and processes in the landscape are seen as fundamental to an understanding of the ecology of the landscape. The term "landscape" itself was first defined as the total character of a region by the German geographer Alexander Von Humboldt in the early 1800s (Bastian 2001). Over time, the term "landscape" has been interpreted in many different ways, from a spatial scale to a space in which to reconcile human and ecological dimensions (Sayer et al. 2013, Wu 2013). As an area of research, landscape ecology was seen as unifying ecology and geography.

While some consider that landscape ecology appears to have evolved to become more interdisciplinary (Cumming 2011, Wu 2013), others suggest that landscape ecology remains centred in the natural sciences (Hobbs 1997, Cassar 2013). This is reflected in the diversion over the course of the twentieth century between the European landscape ecology school for which the interaction between human and ecological dimensions is important, and the North American one. which emphasises the interaction among ecological features within the landscape (Wu and Hobbs 2002, Field et al. 2003).

3. Overview of Forest Landscape Restoration

Whereas landscape ecology has evolved as a specific branch of ecology, forest landscape restoration evolved through an NGO-led project (co-led by WWF and IUCN) which then mutated into a political process, spearheaded by the Bonn Challenge on FLR (a global political effort to bring up to 350 million ha under restoration by 2030) (Aronson and Alexander 2013).

The definition agreed in 2000 for FLR was that it is "a *planned process that aims to regain ecological integrity and enhance human wellbeing in deforested or degraded landscapes*" (WWF and IUCN 2000). Although different interest groups have modified this definition, it remains in use, and has significant credibility, as it is aligned with the most recently agreed principles of FLR (as per the Global Partnership on FLR which re-groups over 30 international organisations and governments - Besseau et al. 2018).

It is useful to take each element of the definition in turn, starting with the idea of a "planned process". The term "planned" was used to define human intervention and intentionality rather than a haphazard process. This does not necessarily have to signify active tree planting, but could be simply the removal of causes of degradation, but the intention to do so is important. Indeed, it can be argued that without planning, then trees that may naturally regenerate, could rapidly be removed by the same initial cause of forest loss and/or degradation (e.g. subsidies for large scale conversion to crops). ***Planning*** takes place at the level of landscapes, while action on the ground, is most often site-based. However, the sites are selected through a larger scale planning process (e.g. Stanturf et al. 2019). The "***process***" dimension in the definition recognises the long term temporal nature of restoration as well as the need for adaptive management.

The term "***ecological integrity***" is subject to many definitions. In the minutes of the Segovia meeting where FLR was first defined, "ecological integrity" was loosely defined as "*a combination of biological diversity and ecosystem functions which allow the ecosystem to support life and adapt to change*" (WWF and IUCN 2000), acknowledging that further work was necessary. In the context of restoration ecology, "ecological integrity" is frequently seen as a fundamental principle (e.g. Suding et al. 2015). The Society for Ecological Restoration defines ecological integrity in terms of biodiversity (particularly species composition and ecosystem structure) (Van Andel and Aronson 2006). It may be seen as associated to an "original" or reference ecosystem, or as portraying certain characteristics related to the ecosystem's structure, dynamics etc. For Parrish et al. (2003) for instance ecological integrity is the "*pre-disturbance composition, structure, and function of an ecosystem in relation to the natural or historical range of variation*".

In turn, "***human wellbeing***" displays many dimensions. The Segovia meeting defined "human wellbeing" as being "*influenced by a range of factors including: quality of life, economic factors, equity, risk and power relationships*" (WWF and IUCN, 2000). The UNDP and other international development agencies have identified the many facets making up human wellbeing, which include money, health, shelter, culture, food (see for e.g. OECD 2001, UNEP 2004, MEA 2005, UN 2015, Smeeding 2016). Thus, forests can play a role in addressing many of these different dimensions of wellbeing both as an intrinsic constituent of human wellbeing and as an external element or determinant that can contribute to wellbeing (Schleicher et al. 2017).

The conservation community's growing recognition of the importance of the "human" dimension stems largely from experiences with more exclusionary approaches to traditional conservation as practised through strict protected areas. Lessons from these approaches demonstrated the importance of the role of people (particularly communities living in or near forested areas) in securing ecosystems (McShane and Wells 2004). In the late twentieth century, research into the "ecosystem services" provided by nature (MEA 2005, TEEB 2009) also generated renewed interest in the relationship between humans and nature and the role of nature in supporting human life. More recently, the importance of "nature's contributions" to humanity has been highlighted by the IPBES report (Díaz et al. 2018). Ecosystem services have been used in restoration as a justification and objective for restoring landscapes (e.g. Rey-Benayas et al. 2009, Bullock et al. 2011) as they can be used as proxies for the delivery of "human wellbeing" in conservation and restoration projects (e.g. Adams et al., 2004; Fisher et al., 2007; Daw et al., 2011). Critics of this approach have highlighted both the difficulty in quantifying the values of ecosystems, in determining trade-offs between human and intrinsic biological values and in the distribution of the benefits of those values (e.g. Telesetsky 2012, Korhonen-Kurki et al. 2014, Apostolopoulou and Adams 2017).

The term '***deforested***' is ambiguous as it implies a reversal of a forested landscape which relies on the term 'forest' for which there is no universally agreed definition. A forest may be interpreted as a type of land cover (trees), a type of land use (forestry) or an administrative unit (national forests – Lund 2002). Thus, identifying a 'deforested landscape' may not be so straightforward.

The term '***degraded'*** is even more ambiguous as different stakeholders will have different perceptions of what is a degraded forest landscape (Blaikie and Brookfield 2015, Hobbs 2016). For example, China's large-scale reforestation efforts have been cited by some (Zheng and Wang 2014) as a success story and by others criticized for lacking most of the features of a diverse forest ecosystem delivering foods and services to people (e.g. Cao et al. 2011, Hua et al. 2016).

Influenced by the growing trend in conservation to scale up (e.g. Olson and Dinerstein 1998, Myers et al. 2000) experts defining FLR chose the ***landscape*** scale as an appropriate one at which to consider restoration. In the context of FLR, landscape was defined loosely and interpreted as both a spatial scale (with unclear and dynamic borders) and a way of reconciling both social and ecological priorities (Sayer et al. 2008).

4. Areas of Convergence

There are clear areas of convergence between FLR and landscape ecology. FLR builds on many principles, ideas and tools of landscape ecology. Already in 1994 Naveh made the link between restoration more generally and landscapes (Naveh 1994). In 1997, Bell et al. also explored the complementary nature of landscape ecology and restoration. They noted the importance of spatial heterogeneity in landscape ecology which can provide valuable indications for setting restoration objectives, while also noting that restoration can be a valuable tool to return structure and processes to a given landscape (Bell et al. 1997).

In this section, I highlight three key areas of convergence: landscapes, connectivity and the integrative nature of both.

4.1. Landscapes

The emphasis on landscapes is central to both landscape ecology and FLR. Both refer to landscape mosaics and acknowledge the heterogeneity of landscapes. Unlike the generally more site-based focus of ecological restoration, FLR takes into account the wider landscape and the role of forests within them, as exemplified by the first principle of FLR adopted by the GPFLR (Besseau et al. 2018). For example, up and downstream considerations in forest and watershed restoration in the Copalita-Zimatan-Huatulco watershed in Mexicos's Oaxaca State take into account how forests have an impact beyond their immediate surrounding (Mansourian et al. 2020). Importantly, the landscape implies more and diverse stakeholders, and stakeholder interests (Perring et al. 2015) which requires that attention be given to governance matters - often outside the competence of ecologists (Mansourian and Sgard 2019). For FLR, landscapes are where negotiations and engagement are necessary, where planning takes place and priorities for restoration are designed. Landscapes evolve over time (Reed et al., 2016), something which both FLR and landscape ecology acknowledge and contend with.

At the same time, both landscape ecology and FLR are afflicted to a certain extent by the complex and subjective term "landscape" (e.g. see Forman and Godron 1981, Sayer et al. 2008, Wu 2008). Its fuzziness has generated challenges for defining priorities, identifying stakeholders to engage and consult, framing activities, among others.

4.2. Integration

Landscape ecology, particularly as promoted by the European school, emphasises its integrative nature, notably between research and application (Wu and Hobbs 2002). FLR has also been defined as specifically integrating both human and ecological dimensions, as well as integrating policy, science and practice (Mansourian and Parrotta 2018). Integration across disciplines (interdisciplinarity) is important for both landscape ecology and FLR. Both disciplines acknowledge that landscapes are shaped not only by natural processes but also by human interventions and thus their analysis requires a more comprehensive approach that cuts across disciplines. For example, in Mexico, WWF partnered with several local community development organisations to advance social dimensions of FLR (Mansourian et al. 2020). Through IUFRO's Task Force on Transforming Forest Landscapes, scientists from several disciplines have come together to collaborate on specific dimensions of FLR (e.g. Stanturf et al. 2019).

In practice, integration remains a challenge at multiple levels, with at least six integration challenges for FLR recently highlighted including across spatial and temporal scales (Mansourian and Parrotta 2019). Although fundamental to landscape ecology, Tress et al., 2005 have also identified the lack of a common understanding as an obstacle to a truly integrative approach in landscape ecology.

4.3. Connectivity

Connectivity between patches is central to landscape ecology. Equally, in the framework of the ecological dimensions of FLR, the role of restoring forest to recover connectivity was initially fundamental in FLR endeavours. For example, the vast range needed for the endangered tiger in Nepal determined the restoration priorities across the Terai landscape (Thapa et al. 2017). For conservation biologists, connectivity between protected areas remains fundamental (e.g. Bennett 1999, Margules and Pressey 2000, Brooks et al. 2004). Restoration is the main approach to achieve connectivity in a degraded landscape. In Sabah (Borneo) for example, restoration of forest focused on improving conditions for the critically endangered orangutan. Connectivity of forest fragments in between plantations of oil palm was a priority to allow movement of the orangutan (Simon et al. 2019). Improving connectivity frequently requires addressing the parts of the landscape that have undergone the most anthropogenic pressures, and may require addressing underlying drivers, such as incentives for agriculture. Interestingly, the concept of connectivity is not explicitly included in the six FLR principles promoted by the Global Partnership on FLR, although landscapes and resilience are.

5. Areas of divergence

Landscape ecology and FLR also have areas of divergence. Here I review three areas of divergence: process versus analytical nature of each; the transformative and political nature of FLR.

5.1. Process versus analysis?

FLR is an active intervention within a landscape, while landscape ecology is the study of elements within a landscape. Indeed, the process and interventionist nature of FLR set it apart from the analytical nature of landscape ecology, although there are calls to improve the application of science to landscape design (Lovell and Johnston 2009). Hobbs (1997) noted the tendency of research in landscape ecology to emphasise the analysis of landscape structure (or pattern) and change with less focus on landscape function. Landscape structure, which refers to the spatial relationship between patches in the landscape, represents an analytical frame, while landscape change has a temporal dimension, highlighting an evolution in landscape structure between two given dates. On the other hand - while all three are important to FLR - landscape function which refers to the interaction between spatial elements in the landscape is essential to FLR, as it provides the ultimate objectives for an FLR intervention, including for example: restoring habitat for an endangered species, restoring connectivity between forest fragments or restoring riparian forest for improved water quality.

Nevertheless, as a process, FLR interventions may at times fail to consider the underlying analysis of the landscape and its features to help set its priorities, instead favouring a quantifiable hectare-based metric (Mansourian et al. 2017). The long term nature of the FLR process is often negatively impacted by short term funding which signifies that the study and monitoring of these long term changes in the landscape may be at times sacrificed for the short term results expected by donors (Hodge and Adams 2016).

5.2. Transformative nature of FLR

The restoration dimension of FLR signifies that it explicitly aims to transform the landscape; while for landscape ecology the landscape is the object of analysis. The transformative nature of FLR is important and is intrinsic to the restoration process but not to landscape ecology. Restoring forest landscapes signifies changing the landscape – often, but not always, to return to something that was there before; but in many cases, to a new landscape ('novel ecosystem' – e.g. Hobbs et al. 2006). This change in landscape dynamics – be it to a preceding state or to a new one - requires some degree of planning and acceptance from stakeholders for it to be sustainable. The role of stakeholders in determining where, what and how to restore, who is involved, who benefits and who loses, is paramount, yet is often neglected in FLR (Boedhihartono and Sayer 2012, Mansourian and Sgard 2019). Furthermore, returning trees to a degraded (forest) landscape may improve the provision of ecosystem services, thereby generating value which, particularly in conditions where tenure is uncertain, is more likely to lead to conflict (Light and Higgs 1996, Barrow 2014). Restoration may turn an erstwhile degraded landscape (for example after mine exploitation) to a more valuable landscape providing numerous ecosystem services, thus generating renewed interests by powerful stakeholders (Rai et al. 2018). Thus, this transformation of the landscape may have unexpected negative consequences, changing the dynamics among landscape stakeholders. For example, in many countries, such as Madagascar, the planting of exotic trees is seen as a productive use of the land which entitles those carrying it out to the right to use the land, while land where native species regenerate or are planted reverts to the State for protection. As a result, such a situation leads to a disincentive for restoration with native species. While FLR is fundamentally transformational, landscape ecology remains more analytical, even if the research can be used for landscape design (Lovell and Johnston 2009).

5.3. FLR has erred towards a political process

As with many new concepts, with time, the proponents of FLR have evolved. Initially defined by the conservation community, with a strong focus on the role of FLR for biodiversity conservation (Mansourian and Vallauri 2014), the rise of the economic dimension of ecosystems notably with the MEA at the turn of the century, led to a change in tactic by proponents of FLR leading to a growing emphasis on the role of FLR in meeting Party commitments under the different conventions, particularly climate change mitigation as an important ecosystem service (Pistorius and Kiff 2017). More recently, the importance of the Bonn Challenge as a growing political movement promoting FLR has led to the concept being captured by a political process (Mansourian 2020). The Bonn Challenge on FLR launched by IUCN and the German government in 2011 to encourage governments to commit millions of hectares to FLR epitomises this politicisation of FLR (Rai et al., 2018). On the one hand, political awareness of the importance of FLR is welcome and has led to the UN to declare the Decade on Ecosystem Restoration (2021-2030), a way of mobilising greater attention and effort towards restoration, further raising the profile of FLR. On the other hand, relegating FLR to a political process risks losing the practical and scientific dimensions of the process. In this context, the GPFLR may not be the most suited champion body to carry FLR forward, but may require a scientific body, similarly to the IALE or the Society for Ecological Restoration (SER). Indeed, the SER may decide to subsume the FLR approach as one dimension of its work. Alternatively, FLR may be represented by its own, independent scientific body that would uphold its quality standards.

6. Collaboration going forward

In the context of specificities of both disciplines, I discuss three areas of potential collaboration across both disciplines going forward.

Technology

Technology appears more centrally in landscape ecology than in FLR. Basic technology (including artistic depictions of landscapes – e.g. Boedhihartono 2012) has allowed the description of landscape features, and subsequent zoning. A few FLR projects have applied such zoning exercises, for example, in Fandriana-Marolambo in Madagascar, zoning maps were produced to delimit the different land uses in the framework of an FLR project (Mansourian et al. 2018). Numerous softwares (e.g. Zonation or Roboff) are available to analyse landscapes and some may be adapted for the purposes of restoration. Mapping landscape features and condition is particularly important both for objective setting (e.g. determining suitable and realistic restoration objectives) and for monitoring whether change is as anticipated. Technological advances – particularly GIS mapping and related tools - have been fundamental to the development of landscape ecology (Clark, 2010). Unmanned aircraft systems (UAS) or drones are increasingly used in conservation to detect, map and monitor wildlife and landscapes (Marvin et al. 2016). Technology may also support scenario building in the framework of FLR. Scenarios are powerful decision support tools, notably in the context of normative scenarios which could provide an 'ideal' restored landscape (Nassauer and Corry 2004). FLR can benefit from such technological developments more widespread in landscape ecology, while landscape ecology can apply some of these technologies and monitoring protocols in the context of temporal and transformational processes associated with restoration of the landscape.

Setting informed targets and objectives

The analysis carried out through landscape ecology can help to better understand the direction that transformation through FLR can take. In setting restoration objectives beyond tree based or hectare-based targets, a focus on regaining ecological and landscape functionality is more relevant to FLR (Mansourian et al. 2017). Indeed, the third principle of FLR is to "Restore multiple functions for multiple benefits" (Besseau et al. 2018). Analysing and understanding landscape patterns, processes and functions can help to determine realistic objectives for FLR and define appropriate technical interventions to reach those. For example, in Colombia, the restoration opportunities assessment methodology (ROAM) led by IUCN, provided an overview of different elements of the landscape of Oriente Antioquia, including ecosystem services provided and opportunities for connectivity – notably framed as an adaptive measure for climate change (Isaacs Cubides et al. 2017). This detailed analysis was partly founded on principles of landscape ecology. However, not all ROAM processes follow such approaches.

Beyond ecology for sustainability

Forest landscape restoration is not an end in itself, but rather a process. There is much to be learnt from sustainability science in terms of better understanding what are the ultimate objectives of an FLR process.

Calls to bridge disciplines with a view to achieve wider landscape integration and sustainability have come from both landscape ecologists (Naveh 2007) and FLR scientists (Mansourian 2018). An understanding of the biophysical and sociocultural composition and configuration of the landscape is inherent to landscape sustainability (Wu 2013). In the context of landscape sustainability, understanding the patterns, processes and functions of the landscape with a view to promoting a state whereby the landscape aims to meet human needs while maintaining its ecological values into the future, could be a strong point of convergence between landscape ecology and FLR research and practice. More generally, the mobilization around FLR - political, financial and practical - and the associated movements, such as the Bonn Challenge or the trillion trees initiative (1t.org) recently launched at the World Economic Forum, represent an opportunity for a more refined and sustainable approach to both tree planting and wider landscape interventions. Situating such interventions within the context of the sustainable development goals adopted by all UN member states in 2015 (UN 2015) also presents an opportunity for both FLR and landscape ecology.

7. Conclusions

Forest landscaper restoration was partly grounded in landscape ecology originally although it has erred from these roots. Nevertheless, there remain areas of convergence and opportunities for improved collaboration, some of which I have highlighted here. Clarifying and bridging points of divergence can help both disciplines to improve collaboration. The framework of sustainable landscapes provides a particularly attractive long term objective for both disciplines.

It took 53 years between the first definition of ‘Landscape Ecology’ and the establishment of an association for landscape ecology. During that time the discipline faced many challenges, teething problems and scepticism. Will FLR follow the same path? Already in the 20 years since it was first defined, FLR has faced numerous definitions and has swayed from being more biodiversity focused, to a more ecosystem services focus as well as a political focus. Lessons from the development of landscape ecology as a formal scientific discipline may apply to FLR going forward. Currently FLR has the umbrella political body, the GPFLR, as its champion., but would it benefit from the creation of a scientific body to consolidate and secure its integrity?

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