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EXTENDING THE ROLES OF ECOLOGICAL NETWORKS IN A SUSTAINABLE LANDSCAPE

MUHAMMAD FARID AZIZUL

Abstract

The ecological network concept has emerged in the past three decades in response to growing expectations of a balance between conservation and development in human-altered environments. This spatial concept has developed to facilitate the connection of critical ecosystems to the protection and restoration of biodiversity. As the concept is a societal construct, it is important to frame the roles and functions of spatial conservation tools within a socio-cultural point of view in order to fully realize the benefits of such kinds of landscape structures. This paper reviews and critiques literature across disciplines – landscape ecology, conservation biology, landscape and urban planning and nature conservation – published between 1995 and 2012. It places an emphasis on the viability of the multiple services needed in the planning and implementation process. Included is a commentary on whether ecological services, as an indicator of value, sufficiently capture the socio-cultural dimension. A range of challenges and issues remain however, about how to integrate biodiversity conservation with other sustainable uses of the landscape. Examining this issue in the context of a socio-ecological system serves to promote a better understanding of such an intricate relationship. This paper suggests potential research directions that could help address these challenges.

Key words:
Ecological network; greenways; socio-cultural process; ecosystem services; socio-ecological system; sustainable landscape.

Introduction

One of the most significant current discussions in biodiversity conservation and planning is the Ecological Network (EN) concept, which has arisen in response to habitat loss and fragmentation. The development of the concept is a result of land use intensification, which has been recognized as a primary threat to biodiversity survival in a man-dominated landscape (Forman, 1995; Cook, 2002; Bennett, 2003; Jongman, 2004; Hellmund and Smith, 2006; Opdam and Wascher, 2004). The threat has resulted from the clash of anthropogenic activities and dynamic natural processes (Hobbs, et al., 2008) which has resulted in habitats becoming smaller and more isolated, and thus unable to support habitat structure and ecological processes (Bennett, 2003).

More recently, literature has emerged that offers contradictory findings about the traditional approach in conserving biodiversity through protected areas (PAs). Such measures of conservation are not considered viable in a rapidly changing world where biodiversity protection should be incorporated into the wider landscape and be ecologically, economically and socially sustainable (summarized in Crofts, 2007). Several authors have emphasized that these PAs are not viable in the long term (e.g. Martinoli, et al., 2006; Maiorano, et al., 2007; Carroll, et al., 2004), and that eventually each is destined to function as an isolated ecosystem (Bennett, 2003). Thus, conventional efforts to safeguard biodiversity in single-site protection areas are being challenged, in order to secure ecological efficiencies as well as socio-economic goals (Crofts, 2007).

In this context, various operational models have emerged in conservation planning. These include the Biosphere Reserves launched by UNESCO in 1974, the Ecological Network programme developed in several European countries, the Reserve Networks in Northern America, Bioregional Planning in America, and Biological Corridors and Eco-regional based conservation. Although these terminologies differ in scope and emphasis, they share the common vision of reconciling biodiversity conservation and sustainable development through a spatial allocation of specific functions based on their ecological value (Bennett, 2004). The EN concept has received increasing attention in recent decades which has moved it beyond single–site PAs by establishing linkages to the wider surrounding landscape, especially in Europe (Jongman, 1995; Jongman, 2004; von Haaren and Reich, 2006; Opdam, 2002). This approach is based on three substantive theories of landscape ecology (Turner, 1989); metapopulation dynamics (Levins, 1969) and island biogeography (MacArthur and Wilson, 1967) in the conservation biology discipline. Further, Opdam, Steingröver, and Rooij (2006, p. 324) define EN as «*a set of ecosystems of one type, linked into a spatially coherent system through flows of organisms, and interacting with the landscape matrix in which it is embedded*».

The key term for this concept is landscape connectivity, which is a critical feature of landscape configuration as it allows organisms to move, migrate, and disperse between habitat patches. This facilitates gene flow and helps maintain physically separated populations (Bennett, 2003; Soulé, et al., 2004). Further-

more, Leitão, et al. (2006) posit that connectivity is an important property in and of itself, resulting as it does from the interaction between landscape structure and function. This in turn keeps ecosystems functioning, and is relevant in conservation planning and management (Naveh and Lieberman, 1994; Forman, 1995; Bennett, 2003).

One question that needs to be asked however is whether integrating biodiversity conservation and other land uses through the establishment of ENs (figure 1) will deliver multiple ecosystem services in conflicting and competing land uses. Implementing this concept into the wider landscape requires other considerations around what the potential ecosystem services as it provides for society (Jongman, 2008). Early thinking in planning ENs focussed narrowly on the conservation and management of specific habitats and green spaces for focal or umbrella species as a proxy for overall ecosystem structure. Inevitably, planners ignored the wider ecological and social patterns and processes that surround the heterogeneous landscape (Hostetler, Allen and Meurk, 2011). A new way of thinking is required in order to manage the complex problematic situations «*that lie at the intersection of social and place-based systems*» (Hostetler, Allen and Meurk, 2011, p. 370). This new perspective on the sustainable use of biodiversity through the EN concept requires an integration of socio-economic and environmental information (Jongman, 2007). Moreover, the use of biophysical and socio-cultural information to suggest opportunities and constraints for decision-making about the use of landscapes needs to be incorporated into the ecological planning process (Steiner, 2000).

Rientjes as cited in Jongman (2007) suggests that information about the importance of ecosystem services at local, regional and national scales is crucial in enabling decision-makers to mobilize public support for its implementation. Innovative methods need to be initiated through a multifunctional spatial conservation concept to provide ecosystem services in an increasingly urban world. Ahern (2011) suggests this can be achieved through intertwining and combining functions (such as

Figure 1
An ecological corridor within a new urban development in Manukau, Auckland, New Zealand (Source: M. van Roon, personal communication 2013)

re-vegetated corridor functioning for animal movement and recreational trail), stacking or time-shifting, that will consequently prove to be spatially and economically efficient. This paper presents a critical review on the viability of the multiple services provided in the EN planning and implementation process. It focuses on the social-cultural dimension, which, it contends, remains unrealized in the decision-making process.

EN development has typically targeted and prioritised biodiversity conservation for ecological coherence. Green infrastructure as now popularly defined by landscape professionals in interdisciplinary fields (see for example Benedict and McMahon, 2006; Selman, 2008; Srinivasan, O'Fallon and Dearry, 2003) could logically encompass terrestrial ecological networks and associated waterways. Ecological Networks focussed on ecological coherence contribute a backbone for a green infrastructure framework that combines with other forms of land use in delivering multiple ecosystem services. The application of ecological principles as an imprint for a successful green infrastructure movement presents a significant and strategic way of achieving ecological and social sustainability simultaneously.

Method

The review is based on literature reported in the root disciplines of landscape ecology, conservation biology and applied disciplines, in landscape and urban planning, nature conservation and ecosystem services. A set of keyword combinations – ecological network, greenways, ecosystem services, socio-cultural process, socio-ecological systems – were used to direct the literature search. A computerized searching technique was applied to online database navigation from Science Direct, Springer, Taylor and Francis and Scopus. Papers were extracted primarily from those published between 1995 and 2012 to illustrate the chronological development of the concept from conservation-focused into integration in development planning perspective. Papers reviewed include theoretical, review, and empirical articles, both quantitative and qualitative. Literature was chosen to illustrate an in-depth understanding of the theoretical side of the EN concept and its role in enhancing both ecological functioning and the social system. A greater emphasis was placed on literature that addresses the impact on the socio-cultural process, along with issues in implementing the concept in the wider landscape and the implications thereof. The aspects taken into consideration in this review include an analytical approach in modeling EN, and the issue that has influenced its efficacy in ecological functioning, including spatial scales in its implementation.

Ecological Networks in a Sustainable Landscape

Spatial Concept and Components

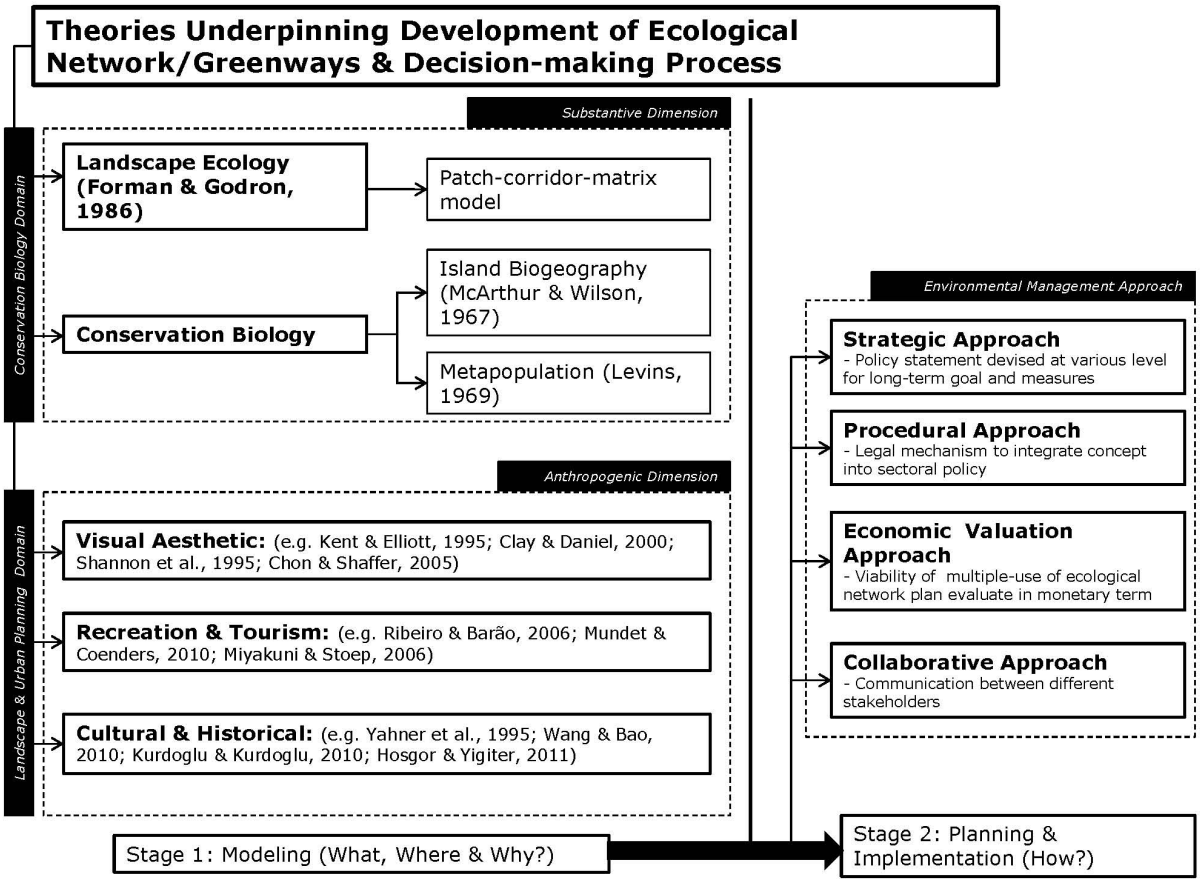
The definition of the EN concept traverses disciplines, and its application extends from a rural to an urban context (Ignatieva, Stewart and Meurk, 2011). This concept is encapsulated in the conservation biology domain by the substantive theories (figure 2) of landscape ecology, metapopulation and island biogeography (Jongman, 2003). The EN model is composed of a core area, a buffer zone and a corridor or stepping stone (Bennett and Mulongoy, 2006; Jongman, 2003, 2004). The core areas have traditionally been existing PAs (such as national parks and forest reserves), with corridors or stepping stones to maintain physical linkages between core areas, buffer zones that protect the core areas from incompatible land uses, and sustainable-use areas for the exploitation of natural resources in the landscape mosaic. The concept embeds the principle of landscape cohesiveness through the connectivity of species that move between landscapes patches (Jongman, 2004; Bennett and Mulongoy, 2006). The development of an EN can facilitate ecosystem functioning at a variety of scales. The model can operate on a supra-continental scale, and on the ecological region, such as a watershed or mountain range. (Bennett and Wit, 2001). The review examines the applicability of an EN as an innovative spatial form integrated into a development pattern in nested hierarchical scales, i.e., a local-scale township, neighbourhood (urban or village) and urban-rural interface that connect to the larger ecological context.

Ecological Networks and Greenways – Spatial Integration

On the other hand, the concept of EN has expanded significantly to include the anthropogenic dimension of ENs in establishing a physical and functional connection to the visual and aesthetic, recreational and cultural resources in the landscape and in the urban planning domain (Beatley, 2000). The greenway concept (Ahern, 2002) developed from this perspective. It was originally intended to provide a linear passage connecting people in urban and rural areas in Northern America. The operational role of this approach evolved to form a spatial coherence which included significant cultural, visual and recreational dimensions (Fábos and Ryan, 2006). Greenways, or green corridors, often cross-link interchangeably but this can vary according to purpose and scale; wildlife corridor, scenic or historic route, or recreational trail (Little, 1995). The concepts of EN and greenway now overlap (figure 2) because of the similarity in its functional interpretation and structural similarities (Jongman and Pungetti, 2004). This progression has, for example, been illustrated in studies published in the special issue of the *Landscape & Urban Planning* journal that was dedicated to greenways (Volume 33, 1995) as an umbrella concept that captured the ecological and anthropogenic dimension of spatial integration (e.g., Burel and Baudry, 1995; Ndubisi, Demeo and Ditto, 1995; Yahner, et al., 1995; Zube, 1995). Therefore in this paper, the terms 'EN' and 'greenways' are both used as a matter of convenience to facilitate the data searching and communication.

Ignatieva, Stewart and Meurk (2010) posit that new models of urban ENs, as a subset of a broader network, should respect, conserve and enhance natural processes that will consequently improve biodiversity, aesthetics, and cultural identity and become an important framework for creating sustainable cities. However, there are questions as to how far the concept of an EN can be implemented (figure 2). Opdam, Steingröver and Rooij (2006) argue that ENs are an effective spatial structure to integrate the ecological, social and economic sustainability of the landscape, but the current body of knowledge is insufficient to support this proposition. This integrative spatial model provides an opportunity for more exploration into the relation of ecological functionality to social and economic values that moves from a spatially-explicit to a spatially-implicit approach (Opdam, 2006). The sustainable development of landscapes demands that «*the landscape structure supports the ecological, social and economic processes required, so it can deliver its goods and services to present and future generations*» (Opdam, Steingröver and Rooij, 2006, p. 323). The future challenge and role of ENs integrated with land use planning, will be their ability to link ecological efficiency to other aspects of social and economic benefits in a multifunctional landscape.

Figure 2
The theoretical underpinnings of the Ecological Network and Greenways concepts, including their implementation approaches in the decision-making process (Source: Author's own interpretation)



Findings and Discussion

Linking an Ecological Network and Socio-Cultural Values

While such planning of ENs is ecologically motivated, and highlights the connectivity characteristics of ecosystem processes through the linkage and connection of adjacent landscape patches *per se* (e.g. Gurrutxaga, Lozano and Del Barrio, 2010; Fleury and Brown, 1997; Fitzsimons and Wescott, 2008), it rarely incorporates data on any social or cultural aspects. Planning therefore relies on general ecological principles and assumptions, and on the success of particular connections, which also contribute to any social-economic sustainability. According to Forman (1991), creating landscape linkages addresses six public policy issues, namely; biological diversity, water resources, agriculture and wood production, recreation, community and cultural cohesion, and climate change. In other words, its roles and functions in the wider landscape should be looked at beyond their conservatorial role in order to realize such potential benefits.

Visual Aesthetic Quality

Besides a raft of attention about EN implications on biodiversity conservation, as discussed earlier, some efforts have been made to investigate the socio-cultural impact. In recent years, an increasing amount of literature has attempted to manifest perspectives on visual and aesthetic quality, and recreation, among others. Franco, et al. (2003) investigated the impact of agroforestry networks on scenic quality and found that the networks have a profound influence on the value of scenic beauty as perceived by respondents. Similarly, further researchers (Kent and Elliott, 1995; Burel and Baudry, 1995; Clay and Daniel, 2000; Zanon and Geneletti, 2011) indicated the integrated values of nature conservation and visual quality that need to be protected. Natori, Fukui and Hikasa (2005) argue that integrating biological and visual qualities at a human dimension into the environment provides a shared venue that addresses biotic and societal needs in nature conservation.

Recreation and Social Interaction

In the urban context, some research has been carried out to investigate the impact of creating a connected open space system on human recreational uses and experiences. For example, Coutts (2012) in his exploratory study found that not only did the community realize the ecological importance of connecting their park into the wider region, but they also increased their recreational activity as a result of having more available space through the interconnectedness. Several attempts have been made to identify and examine people's perceptions of urban greenways and their recreational use i.e.: Gobster and Westphal, 2004; Shafer, Lee and Turner, 2000: Tzoulas and James, 2010; Luymes and Tamminga, 1995; Asakawa, 2004). Greenways as an innovative spatial form also have been integrated in developing planned residential areas. For example, Zakaria (2006) proposed natural, recreational and cultural component to be

integral part of greenways that influence the structuring of communities.

In another study, Yabes, Shetter and Schneeman (1997) recorded the evolving social values of urban waterways that resulted from the change in land use from farming into residential and commercial uses. The canal system plays an important role historically for older residents, as it used to support their agricultural activities, and presently it is an important venue for social interaction among community. Antonson, Gustafsson and Angelstam (2010, p. 3) provide a new perspective of connectivity that not only takes present needs into account but also the relationship to the «*historical connections that still remain*». Although the EN structure is more applicable at a local or regional level, but interestingly Lee, et al. (2008) found a positive correlation between neighbourhood satisfaction and certain landscape structures at site (neighbourhood) scale. The satisfaction increased when tree patches in the neighbourhood environments were less fragmented, less isolated, and better connected. In order to demonstrate the integration of EN as a principle in the green infrastructure framework, figure 3 illustrates an example that provides a multifunctional landscape structure that connects ecological coherence with social and cultural sustainability as argued in this article.

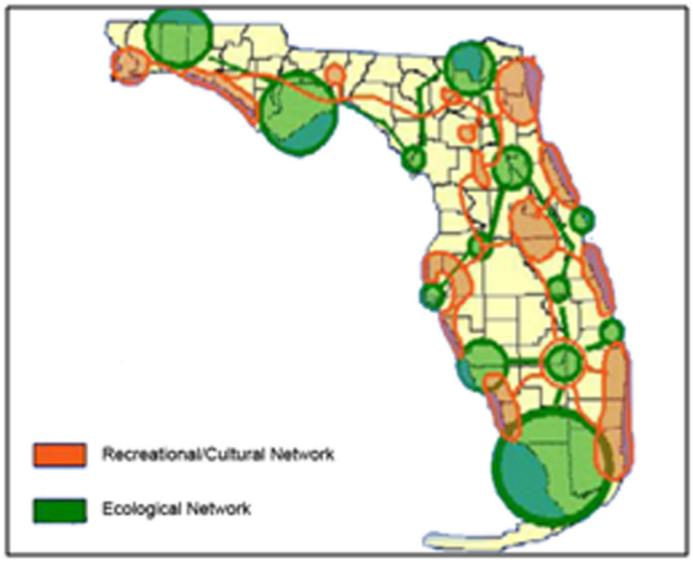


Figure 3
Florida state-level ecological network plan as part of the green infrastructure framework that addresses the vision to reconnect the fragmented protected areas system and urban green spaces based on community-defined typologies (Source: Benedict and McMahon, 2006)

Ecological Networks in Socio-Ecological Systems

The change of paradigm from the traditional ecological roles of ENs into an approach of sustainable development that integrates conservation and other goals is gathering momentum. In practice however, it is rare that information about ecological, social and cultural values is recorded and integrated into the decision-making process (Brunetta and Voghera, 2008). This is mostly due to the lack of research that has been done to un-

derstand and link those different dimensions (Antonson, 2009). Existing research has concentrated on assessing and describing individual values (Mander and Uuemaa, 2010). According to the European Landscape Convention (ELC), landscape is defined as an area, perceived by people, evolving through time due to both natural forces and human factors (Council of Europe, 2000 cited in Mikusiński, et al., 2012), which indicates that landscape is an integrated spatial unit that cannot be separated into individual systems (Matthews and Selman, 2006). From this perspective, the presumed role of an EN in protecting nature should also be extended to reconnecting people, and to a greater or lesser extent, should also be framed from the socio-economic lens (Bennett, 1997; James, Ashley and Evans, 2000).

One way to achieve this requires a holistic approach that integrates knowledge of both environmental and social sciences. One approach that takes this into account is conceptualizing the role of EN in a system thinking that is socio-ecological system (SES) which embodies the concept that humans are not placed as external to ecosystems, as in life science, but are an integral part of the ecological system that dynamically interacts in the whole (Berkes and Folke, 1998). A similar working definition has been defined as follows:

> *A system consists of a bio-geo-physical unit and its associated social actors and institutions. Social-ecological systems are complex and adaptive and delimited by spatial or functional boundaries surrounding particular ecosystems and their problem context* (Glaser, et al., 2010, p. 2).

Although ENs as one aspect of spatial resilience have attracted much attention in ecological research (Cumming, 2011), attempts to include the perceived landscape values that relate to ecological processes have received little consideration in informing decision making in resource management and planning. The inclusion of the socio-cultural aspects of human values is important, as it is one of a community's resilient characteristics which responds and adapts to dynamic landscape changes (Walker, et al., 2004, cited in Alessa, Kliskey and Brown, 2008). Recently, little literature has emerged highlighting the need to integrate ecological and social system assessments which could inform nature conservation and urban planning (e.g. Alessa, Kliskey and Brown, 2008; Bryan, et al., 2010; Donovan, et al., 2009; Kangas and Store and Kangas, 2005; Mikusiński, et al., 2012). As a consequence this research nucleus presents a significant platform for further exploration in the understanding of convergence between ecological and social systems and their implication in the planning process.

The similarities between a social and an ecological system lies in the fact that complex components are linked by dynamic processes open to exchange across their boundaries through connectivity (Limburg, et al.,

2002). Despite these similarities, the previous thinking on EN implementation has concentrated on biodiversity conservation independently, with less consideration of a social response. This development-versus-conservation perspective is contradictory under a socio-ecological system where social and ecological systems are interlinked (figure 4), and their separation is arbitrary when analyzing sustainable use and the enjoyment of ecosystem services (Berkes and Folke, 1998). Therefore, the concept of ecosystem services emerges as a pivotal element in linking the formation of an EN for nature conservation with the social benefits that could be derived from it.

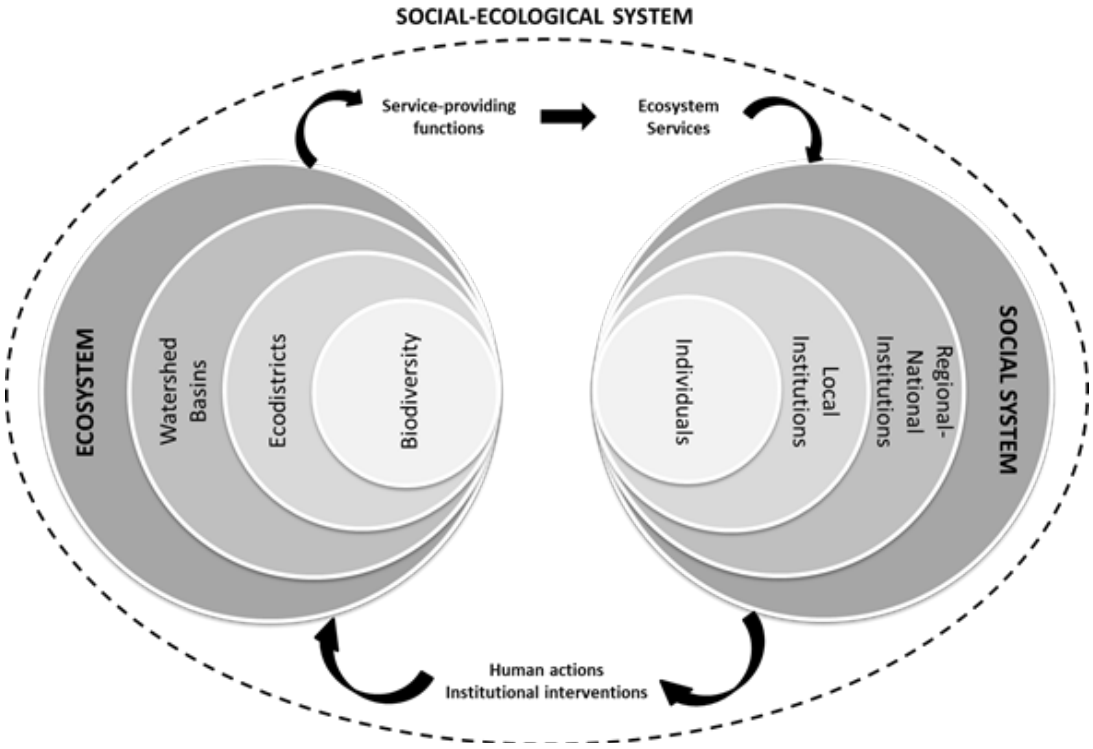


Figure 4
Components and dynamic interaction between ecological and social system at various scales (Source: Resilience Alliance, 2007 cited in Martin-Lopez, et al., 2009, p. 268)

Potential for Delivering Multiple Ecosystem Services

Poor understanding of the true value of nature often leads to poor judgement in environmental decision-making. This has caused severe ecosystem degradation and a lack of achievement in the potential values or services that it can deliver to the people. In a contested landscape, where conservation needs to be integrated beyond the normal protection areas, a wider understanding of potential values needs to be explored when establishing such linkages (Dudley and Rao, 2008). This would generate stakeholder support through a clear contemplation of what the potential benefits of EN implementation would be (Jongman, 2008). This runs in parallel with the sustainability of landscapes, whereby the EN not only facilitates the functioning of an ecosystem by conserving species and habitat, but also promotes the exploitation of natural resources in a sustainable manner (Bennett and Wit, 2001).

The scenario of EN development varies among countries and in the scope of their implementation. In developed countries, the development of ENs reconciles biodiversity conservation and economic development, while also emphasising recreational value in human-dominated landscapes. However, in developing countries, many of which are rich in natural capital, and human welfare is still largely dependent on a functioning ecosystem, the spatial concept provides an additional value that can be incorporated into planning and implementation (Bennett and Wit, 2001). Most of the cases outlined in this review are in developed countries, particularly in regions of Europe and in America, so that a deliberate examination of the progress of ENs in policy making and in their implementation can be made.

ENs are regarded as an innovative structural landscape form that can potentially deliver multiple ecosystem services in an integrated manner (Opdam, Steingröver and Rooij, 2006). However, a policy needs to be supported by evidence so society can gain an increase in value from the development of ENs. Goulder and Kennedy (2011) suggest that this requires an understanding of the various biophysical processes and services provided by ecosystems that contribute to human well-being. The concept of ecosystem services assessment from a socio-ecological point of view provides a framework that combines monetary and non-monetary values in an understanding of how human well-being depends on ecosystems. The Millennium Ecosystem Assessment (2005), defined ecosystem services as falling into four operational categories; provisioning, regulating, supporting and cultural services. Implementation of this concept facilitates biodiversity conservation that will support a functioning ecosystem in terms of the landscape, and in return it translates into ecosystem services, which contribute to human well-being.

A number of researchers have examined the ecosystem services of EN development, including marketable and non-marketable values, using an array of evaluation techniques. For example, Franco, et al. (2001) evaluated the willingness of farmers and citizens to pay to implement an agroforestry network. Using contingent evaluation, they weigh ten roles (variables) in an agroforestry network and a positive preference was observed in regard to the participant's acceptance of its implementation. Lindsey and Knaap (1999) evaluated the willingness of property owners, renters and country residents to pay for an urban greenway project. Although the results showed that most respondents believed that the implementation of the project would increase their quality of life in terms of recreational opportunities, sewage water improvement and property values, most of them (especially non-property owners) were not willing to donate to the trust fund.

In other studies, the implementation of the Dutch National Ecological Network as part of Natura 2000 has had a positive impact on the regional

economy and has increased real estate prices (Berends and Vreke, 2002 as cited in Opdam, 2006). Similarly, the effect of greenways on surrounding property values have been evaluated using a hedonic pricing method (Nicholls and Crompton, 2005; Benhart and Davis, 2002). These studies revealed that the proximity of the greenway to residential areas is significant in terms of the value of houses. In tourism research, Cottrell and Raadik (2008) examined the impact of the Protected Area Network (PAN) on community and tourism development in Poland using qualitative and quantitative methods. Although their pilot study could not claim that the PAN program had a major impact on sustainable tourism development, stakeholders that were involved and familiar with PAN status valued them more highly. This was explained by the institutional benefits that allow a sustainable tourism network via a linking park policy and building up activities that associated local businesses and communities. Whilst some aspects of EN development (species diversity, ecological connectivity and visual aesthetics) as presented above hold ecological and social value, they don't always contain an economic value that can be considered equally in the cost-benefit analysis of such projects. The net benefit of EN establishment through ecological restoration depends on how people value the benefits created. Recent research by Newton, et al. (2012), suggests that the establishment of ENs in an intensively used landscape is unlikely to deliver positive economic outcomes unless the non-marketable values of ecosystem services are considered in the evaluation process. The effectiveness of stated preferences and a revealed preference method to capture certain goods and services that are not reflected in the market is crucial (Mazza, et al., 2011). Moreover, the non-market values which are mostly intangible must be considered in order for efficient resource allocation (Franco, et al., 2001).

Conclusion and Future Direction

Although much research has been done on EN efficiency from an ecological perspective, there are still impediments to be overcome to enable this spatial concept to meet socio-cultural and economic goals in a sustainable landscape. While the ecological and environmental implications of ecological networks are well observed, the intangible non-market societal values are often not able to be described in the decision-making process. This paper summarizes and presents the paucity of research findings that have been carried out to identify and understand the linkages between ENs and the socio-economic processes.

This lack of research may be underlines by the fact that it is integrative in nature, which requires a trans-disciplinary approach (Tress, Tress and Fry, 2006), including social and perceptual research linking to spatial features (Ryan, 2011), and the integration of the aims, perceptions and values of the stakeholders which will then contribute to a greater understanding of the intricate relationship between nature, society, ecology

and economic development (Rosenzweig, 2003). In urban areas where land use policies and biodiversity conservation are often contradictory, the concept of ENs in ordinary landscapes is promising, especially where the functional ecological interdependency of an urban ecosystem and its bioregional context is widely recognized (Vimal, Mathevet and Thompson, 2012).

Conceptualizing the roles of ecological networks through the lens of the socio-ecological approach provides an insight into the holistic thinking required to understand this relationship. This parallels Opdam's (2006) suggestion, which stresses the role of an EN as a spatial integrative concept linking various ecological, social and economic goals in its development in sustainable landscapes. Above all, Mazza, et al. (2004, p. 199) argue that the planning and design of ENs in the conservation of biodiversity «*is often much more based on politics and human sciences than on bio-geographical and bio-historical considerations*». Because the concept is a societal construct, the conservation of biodiversity is a cultural manifestation in which the output form depends on the additional value that humans place on the landscape structure, which can then result in ecological gains.

In urban areas especially, where existing urban green spaces are encroached on and disconnected, the development of ENs presents an integrative approach for the delivery of ecological and social services. Although the urban matrix may be composed of mixed green space typologies, the incorporation of ecological principles in strengthening the coherence of these spaces provides optimistic outcomes from a societal perspective. This warrants a greater understanding of the multidisciplinary definition, and an interaction between those green space typologies with inhabitant, either from the point of view of professionals (scientist, planners, landscape architects and conservationist), or communities.

Finally, the full value of ENs (including intangible values), should be explored from a societal perspective to ensure clarity about how these values are to be incorporated into the decision-making process. The use of ecological theories to inform a spatial organization that enhances the ecological functioning of the landscape has been well explored in the hard science disciplines, but how these 'cultured landscape patterns' influence people's perceptions is a research area that needs further exploration. Consequently, future research should seek to identify the extent to which human society shapes ecological functioning through, for example, valuing residual post-development landscapes. This in turn will clarify how such landscapes evolve, and reinforce the apparent correctness of the initial valuations. A better understanding of this process will assist in efforts to restore functioning ecosystems and any associated ecosystem services.

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Biographical information

Muhammad Farid Azizul
Bachelor of Landscape Architecture (Hons), MSc. in Planning (Information Technology)
Place of work:
Department of Landscape Architecture at University Technology Malaysia (UTM)
Address:
School of Architecture & Planning, University of Auckland, Private Bag 92019, Auckland 1142, New Zealand
E-mail: mazi395@aucklanduni.ac.nz

Muhammad Farid Azizul is a tutor in the Department of Landscape Architecture at University Technology Malaysia (UTM). He holds Bachelor of Landscape Architecture (Hons) and MSc. in Planning (Information Technology) from the same university. His recent research interest area includes human dimension in ecosystem management. He currently is pursuing his PhD degree in Planning at The University of Auckland, New Zealand. His doctoral study investigates the impact of people-place relationships and attitudes towards planning and conservation decisions. He can be contacted at: School of Architecture & Planning, University of Auckland, Private Bag 92019, Auckland 1142, New Zealand, email- mazi395@aucklanduni.ac.nz.