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Urban ecosystems: What would Tansley do?

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Abstract The ecosystem concept was introduced in ecology originally to solve problems associated with theories of succession and ecological communities. It has evolved to become one of ecology's fundamental ideas, and has proven to be applicable to a wide variety of research questions and applications. However, there is controversy about whether or how well the ecosystem concept is suited to urban habitats. By examining Arthur Tansley's original presentation of the ecosystem concept, and exploring how the ecological context of the concept has changed, we indicate that the fundamental concept of the ecosystem is well suited to urban ecological studies. The concept can be clarified for urban use by including a social complex and a built complex to insure that human social institutions and actions, and the structures and infrastructure they build are explicitly included in the ecosystem concept. The ecosystem concept is thus seen as clearly robust to use in urban areas.

Keywords Concept · Ecosystem · Urban · Human

The study of urban ecosystems is a relatively new pursuit in ecology, dating to the middle 1970's (Stearns 1970). Interest in this subject has grown markedly over the last decade, and studies in urban ecosystems are no longer the rarity they once were (Grimm et al. 2008). Still, some ecologists express concern as to whether urban areas merit attention as ecosystems.

The contemporary ecosystem concept is one that hews remarkably closely to its first definition (Likens 1992). This is in spite of the fact that the concept accommodates and supports a broad variety of today's ecological concerns (Hagen 1992; Golley 1993; Chapin et al. 2002; Kingsland 2005). Because of the robustness of the basic concept, it is worth

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examining what Tansley's (1935) original conception suggests about the relevance of the ecosystem idea to modern urban ecological studies.

Tansley's dilemma: Problems to solve

In the first third of the 20th century, community ecology was beset by persistent problems. Several of these problems emerged from the dominant theory of the time—community succession as articulated by Frederick Clements (1916). These issues have been reviewed extensively, and so can be summarized only briefly here (Johnson 1979; McIntosh 1985; Pickett and Cadenasso 2005). Five points emerge that were taken as given by many ecologists: 1) communities were conceived of as organisms; 2) communities devoid of disturbance were considered to be stable, persistent climaxes; 3) the process of recovery from rare disturbances was seen to be directional and deterministic; and 4) the recovery process was considered to be gradual. In addition, the process of succession was 5) assumed to be driven by processes characteristic of the community level of organization. In other words, causation was thought to reside in the community. The wholes themselves were the drivers of community change. Many of these assumptions were embodied in the conception of the community as an organism, with definite, orderly developmental stages leading to maturity (Golley 1993).

Tansley (1935), along with many other critics (Cooper 1913; Cooper 1926; Gleason 1926), thought the organismal explanation to be merely an analogy or metaphor, not a homology. There were many responses to the perceived shortcomings of the Clementsian, organismal theory. Gleason (1936) placed causal power in the organismal criterion of observation, and emphasized species migration and species specific characteristics as the fundamental roots of plant community change. Cooper (1926) emphasized a realistic approach, and recognized multiple pathways of change and acknowledged shifting conditions as drivers of succession and community composition.

Tansley's (1935) *The Use and Abuse of Vegetational Concepts and Terms* introduced an entirely new concept to ecology in his attempt to replace what he saw as Clements's (1916) flawed assumptions. Instead of an organismically motivated theory, he said, "I plead for empirical method and terminology in all work on vegetation, and avoidance of generalised interpretation based on a theory of what *must* happen because "vegetation is an organism" (Tansley 1935: 295). This stance led him to take a more neutral approach to the structure of assemblages in nature. He drew on the idea of system, which had gained considerable influence and utility in physics and engineering by the early 20th century (Golley 1993). This is the core of his contribution: "But the more fundamental conception is... the whole system (in the sense of physics), including not only the organism-complex, but also the whole complex of physical factors forming what we call the environment..." (Tansley 1935: 299). By a complex, he means a suite of interacting factors. By more fundamental, he means more fundamental than an organismic conception. He is beginning to break down the unitary conception of communities as organisms into a rigorous conception that can be analyzed. In taking this step, he also strips biotic units of the assumptions of indivisibility, determinism, and maturation to a set end point. Such assumptions are not required to support a view of natural units as comprising organismal and physical complexes.

The physical complex was further subdivided. The specific terms that Tansley used to describe the components of his ecological systems are a climatic complex, a soil complex, and an organism complex. Of course, just as with the system concept in physics, the concept of ecological system required recognizing a spatial and temporal boundary (Jax et al. 1998). Indeed, the concept of system is only meaningful if it can be separated from its surroundings (von Bertalanffy 1968). The term for external surroundings in systems theory is environment. When ecosystem ecologists use "environment" to stand for the physical complex of soils and climate, they are carrying forward the basis of ecology in organismal biology (McIntosh 1985), in which environment referred to the conditions and factors external to individual organisms.

The problem of humans and ecosystems: Relevance and a social complex

Now the question arises: Is the ecosystem concept relevant when humans are a part of the system? Tansley opens the door to the possibility that ecosystems would have many components other than just plants and animals: "What we have to deal with is a system, of which plants and animals are components, though not the only components" (Tansley 1935: 301). Of course contemporary ecosystem ecology also explicitly mentions microbes. Tansley was also careful to note that "...It is obvious that modern civilised [humanity][1] upsets the 'natural' ecosystems or 'biotic communities' on a very large scale. But it would be difficult, not to say impossible, to draw a natural line between the activities of the human tribes which presumably fitted into and formed parts of 'biotic communities' and the destructive human activities of the modern world. Is [humanity] part of 'nature' or not? Can [its] existence be harmonised with the conception of the 'complex organism'? Regarded as an exceptionally powerful biotic factor which increasingly upsets the equilibrium of preexisting ecosystems and eventually destroys them, at the same time forming new ones of very different nature, human activity finds its proper place in ecology."

To build upon Tansley's prescient essay, two issues come to the fore. First, how is the organismal complex modified to include the species *Homo sapiens* and account for its social dynamics? Second, does the ecosystem concept have to be modified as its application moves from anthropogenic ecosystems dominated by hunter-gatherers, pastoralists, agriculturalists, and foresters to also include industrial and post-industrial societies?

Attention to incorporating the role of humans as part of the organismal complex is long-standing. Social scientists have contributed to an expanded view of ecosystems inclusive of humans along a continuum from wilderness to urban areas since the 1950's (Hawley 1950; Schnore 1958; Duncan 1961, 1964; Burch and DeLuca 1984; Machlis et al. 1997).

More recent efforts have tried to build upon these foundations to account for human derived structures, actions, and interactions in urban areas—the landscape mosaics comprising cities, suburbs, and exurbs. One representation of the kinds of things to include (Fig. 1) is derived from a workshop of the Long-Term Ecological Research Network, which included both social and biophysical scientists (Redman et al. 2004). The workshop added a list of social patterns and processes, and identified the key interactions, while maintaining the familiar list of ecological patterns and processes that the LTER sites had been charged to investigate since their origin in 1980. Note that two urban sites in Baltimore, Maryland and Phoenix, Arizona, were established in 1997, following the augmentation of the work of several other LTER sites (Northern Temperate Lakes, in Wisconsin, and Coweeta in the Southern Appalachians), to include human processes several years earlier. More recently, the LTER Network has developed a model template for addressing feedbacks between biophysical structure and function, ecosystem services, and human perceptions and actions

[1] The term humanity, and appropriate pronouns, have been used in place of Tansley's original terminology that is often now interpreted as sex biased.

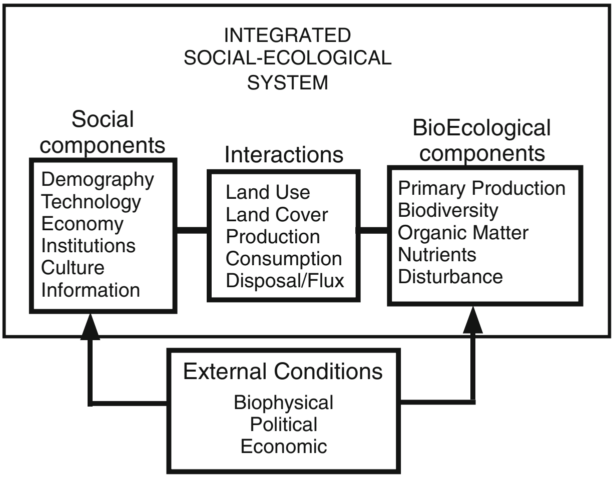

Fig. 1 A representation of social-ecological systems. Social components and bioecological components are linked through key interactions shown in the central box. External conditions of economy, biophysical environment, and economics can influence any given socio-ecological system. The lines linking the three boxes within the integrated social-ecological system indicate two way influences. Modified based on Redman et al. (2004)

(Collins et al. 2007). An additional and more detailed accounting and organization of social structures and processes to include is found in the human ecosystem framework, a causal repertoire similar to those used within ecology (Machlis et al. 1997).

Do the complexities recognized in the LTER and other modern frameworks for addressing humans, especially in industrial and post-industrial societies, fit what Tansley proposed in 1935? Here are the things that he considered to characterize ecosystems. He considered them (Tansley 1935: 299ff) “to be the basic units of nature on the face of the earth”; “of the most various kinds and sizes;” to “isolate systems mentally for the purposes of study;” to “overlap, interlock and interact with one another;” to “show organisation;” and to be “delicately adjusted in equilibrium.” The question is, do ecologists still consider these things to characterize ecosystems at the beginning of the 21st century. Do these characteristics exclude ecosystems inhabited or structured largely by people?

The answer is that the list that Tansley (1935) considered to characterize all ecosystems has been greatly modified in the years since the publication of his paper. Indeed, contemporary ecology can fairly be said to operate under a different set of background assumptions than when Tansley penned his initial thoughts about the ecosystem. This means that a different paradigm holds in ecology now than in 1935. Several changes are particularly relevant (Egerton 1973; Pickett et al. 1992; Wu and Loucks 1995; Pickett and Cadenasso 2002): Ecosystems may express different degrees of organization. Ecosystems may be tightly or loosely organized. Similarly, ecosystems may not necessarily be in equilibrium. Furthermore, they may not necessarily be autotrophic and self-contained. Nor are they necessarily persistent over time.

The contemporary ecological paradigm recognizes that humans can be, and often are, parts of ecosystems (Egerton 1993; McDonnell and Pickett 1993; Holling 1994; Cronon 1995; Alberti et al. 2003; Turner et al. 2004). Indeed, some ecosystems in which humans are not now present show the effects of past occupancy and human action, or the results of distant human decisions and activities (Cronon 1995; Russell 1997). This explicit extension of the scope of the ecosystem concept to include humans is something that Tansley (1935) would likely have been sympathetic to. He recognized a gradient of human involvement in ecosystems: “But it would be difficult, not to say impossible, to draw a natural line between the activities ... which presumably fitted into and formed parts of ‘biotic communities’ and the destructive human activities of the modern world” (Tansley 1935: 303). Furthermore, Tansley indicated that ecology should appropriately consider the activities and effects of humans in ecosystems. The fact that he recognized new kinds of ecosystems that result at least in part from human actions is important. These two points emerge from his statement noted previously that humans are "regarded as an exceptionally powerful biotic factor which increasingly upsets the equilibrium of preexisting ecosystems and evidently destroys them, at the same time forming new ones of very different nature, human activity finds its proper place in ecology" (Tansley 1935: 303).

If Tansley really accepted the narrow, equilibrium assumptions about how ecosystems function, he did not let them get in the way of including human ecosystems among the kinds of ecosystems suitable for ecological study. The following quote, in which he returns to terminology focusing on the problem of vegetation theory, but which is equally applicable to the ecosystem solution he offers, demonstrates his inclusion of anthropogenic ecosystems as ecological subjects: "We must have a system of ecological concepts which will allow the inclusion of all forms of vegetation expression and activity. We cannot confine ourselves to the so-called 'natural' entities and ignore the processes and expressions of vegetation now so abundantly provided us by the activities of [humanity]" (Tansley 1935: 304).

Although Tansley was clearly a pioneer in promoting the linkage of human and ecological sciences, he was not alone. The issue in which Tansley's (1935) paper appeared was dedicated to Henry Chandler Cowles, another of ecology's pioneers, who helped cement and promote the concept of succession. Such festschrifts often give the opportunity to leading thinkers in the field to stretch the boundaries of the discipline. C.C. Adams (1935) who also contributed a paper to the celebratory issue, was particularly concerned with the linkage between ecology and humans. Two powerful quotations stand out. Adams (1935:332) said that "A fertile field awaits the attention of the student who will prepare [herself or] himself for this next advance, and cultivate the neglected borderland between general ecology and human ecology." In pursuing his argument, Adams (1935) cites a book by Tansley (1922) entitled *The new psychology and its relation to life*. This is further indication of Tansley's concern with human sciences, and suggests that his statements about humans in introducing the ecosystem concept were far from incidental. Adams' paper is a further reminder of the early 20th century concerns with the linkage between social sciences, which were being codified at the University of Chicago by a team that drew heavily on ecological concepts of the community, competition, and succession (Park and Burgess 1925). It is in that context that Adams (1935:332) said that "The present gap between the relatively advanced stage of several of the physical and biological sciences, and of the distinctly social sciences calls for special research before the next great advance can be made, and human ecology, broadly conceived, occupies a large part of that field." Looking back on the introduction of the ecosystem idea by Tansley (1935) and the current growth of urban ecology, indicates that the concept he bequeathed us is robust to the ecological-social integration envisioned so long ago.

Conclusion

An explicit conception of the human ecosystem brings all the resilient ideas in Tansley's original, core ecosystem concept together. Tansley's core definition of ecosystem was focused on the main ecological topics of his day: organisms and the physical environment. That way of conceiving the ecosystem is outlined in the inner, dashed box in Fig. 2. However, if ecologists are to account for all the kinds of patterns, processes, and

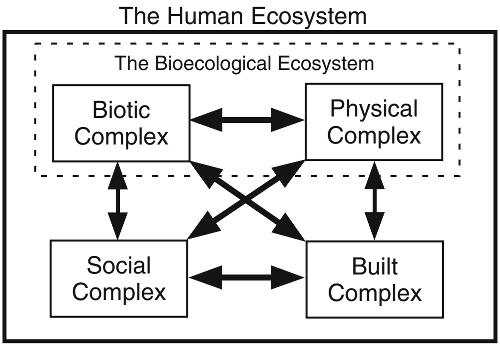

Fig. 2 The human ecosystem concept, bounded by the bold line, showing its expansion from the bioecological concept of the ecosystem as proposed originally by Tansley (1935) in the dashed line. The expansion incorporates a social complex, which consists of the social components referred to in Fig. 1, and a built complex, which includes land modifications, buildings, infrastructure, and other artifacts. Both the biotic and the physical environmental complexes of urban systems are expected to differ from those in non-urban ecosystems

interactions that the LTER committee and others have identified (Redman et al. 2004), then it is useful to include two more kinds of complex within the idea of the ecosystem appropriate to the 21st century (Fig. 2).

People are certainly organisms, or "biota," but they are also much more than that. They generate many social structures and interactions that are crucial to the functioning of ecosystems. Such social structures include formal and informal institutions, norms of action, households, governments, and so on. Similarly, they alter the physical complex by moving earth, changing hydrology, building structures for shelter, commerce, and a myriad other purposes, and installing infrastructure to support those buildings and functions. Hence, the contemporary definition of the ecosystem can be expanded—without violating either the letter or the spirit of Tansley's precedent—to incorporate humans, their institutions and economies, their buildings and engineered networks of transport and communication.

Change in concepts is common in ecology. Often such change is accommodated by the fact that ecological concepts are multilayered (Hagen 1992). It is important to recognize that all ecological concepts have a core definition as well as attendant models that apply that idea to the material world. The core concept of any successful idea tends to be stable, whereas the models evolve to account for new knowledge, new scales of observation, and new theoretical perspectives (Pickett et al. 2007). The incorporation of humans into the explanatory toolkit of ecologists is one such expansion in the realm of models that attend the core concept of the ecosystem. Labeling this expanded kind of model a human ecosystem, or a social-ecological system, extends the core idea of Tansley to incorporate the general kinds of biotic and physical features people generate. In other words, we have a new type of ecosystem model that is appropriate to urban areas, but that also fits comfortably with the core definition or meaning that Tansley (1935) established. This sort of change is reflected in the view of ecological historian, Sharon Kingsland, who identified "The need for ecologists always to think about the core mission of their science: to teach us all how to meet change with change" (Kingsland 2005: 6). In other words, dealing with change—both conceptually and environmentally—is one of ecology's great responsibilities as a science and as a tool for improving the public dialog about the world we live in, care for, and depend on. The fact that the human population of the Earth has become predominantly urban (United Nations Population Fund 2007), and that cities, suburbs, and exurbs are expanding worldwide, suggest that one of the main changes that must be confronted now is the ecology of urban systems. The core ecosystem concept, and the refinement of conceptual models to account for built and social components, along with their interaction with the traditionally recognized biotic and physical components of ecosystems, can serve this change well. Indeed, Tansley, with his awareness of the "exceptionally powerful" human factor, would likely welcome this refinement of his resilient and important concept.

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References

Adams CC (1935) The relation of general ecology to human ecology. Ecology 16:316–335 doi:10.2307/1930072
Alberti M, Marzluff JM, Shulenberger E, Bradley G, Ryan C, Zumbrunnen C (2003) Integrating humans into ecology: opportunities and challenges for studying urban ecosystems. Bioscience 53:1169–1179 doi:10.1641/0006-3568(2003)053[1169:IHIEOA]2.0.CO;2
Burch WR Jr, DeLuca DR (1984) Measuring the social impact of natural resource policies. University of New Mexico Press, Albuquerque
Chapin FS III, Matson PA, Mooney HA (2002) Principles of terrestrial ecosystem ecology. Springer-Verlag, New York
Clements FE (1916) Plant succession: an analysis of the development of vegetation. Carnegie Institution of Washington, Washington
Collins SL, Swinton SM, Anderson CW, Gragson TL, Grimm NB, Grove JM, Knapp AK, Kofinas G, Magnuson JJ, McDowell W, Melack J, Moore J, Ogden L, Reichman OJ, Robertson GP, Smith MD, Whitmer A, Benson BJ, Brunt JW, Henshaw DL, Porter J, Vande Castle JR (2007) Integrated science for society and environment: a strategic research initiative. Albuquerque, Long-Term Ecological Research Network, Publication No. 23. 32 pages. http://www.lternet.edu/decadalplan/
Cooper WS (1913) The climax forest of Isle Royale, Lake Superior, and its development. Bot Gaz 55:1–44 115 doi:10.1086/330990
Cooper WS (1926) The fundamentals of vegetation change. Ecology 7:391–413 doi:10.2307/1931166
Cronon W (1995) The trouble with wilderness; or, getting back to the wrong nature. In: Cronon W (ed) Uncommon ground: toward reinventing nature. Norton, New York, pp 69–90
Duncan OD (1961) From social system to ecosystem. Sociol Inq 31:140–149 doi:10.1111/j.1475-682X.1961.tb00518.x
Duncan OD (1964) Social organization and the ecosystem. In: Faris REL (ed) Handbook of modern sociology. Rand McNally & Co., Chicago, pp 37–82
Egerton FN (1973) Changing concepts of the balance of nature. Q Rev Biol 48:322–350 doi:10.1086/407594
Egerton FN (1993) The history and present entanglements of some general ecological perspectives. In: McDonnell MJ, Pickett STA (eds) Humans as components of ecosystems: the ecology of subtle human effects and populated areas. Springer-Verlag, New York, pp 9–23
Gleason HA (1926) The individualistic concept of the plant association. Bull Torrey Bot Club 53:7–26 doi:10.2307/2479933
Gleason HA (1936) The individualistic concept of the plant association. Am Midl Nat 21:92–110 doi:10.2307/2420377
Golley FB (1993) A history of the ecosystem concept in ecology: more than the sum of the parts. Yale University Press, New Haven
Grimm NB, Faeth SH, Golubiewski NE, Redman CL, Wu J, Bai X (2008) Global change and the ecology of cities. Science 319:756–760 doi:10.1126/science.1150195
Hagen JB (1992) An entangled bank: the origins of ecosystem ecology. Rutgers University Press, New Brunswick

Hawley AH (1950) Human Ecology: a theory of community structure. Ronald, New York

Holling CS (1994) New science and new investments for a sustainable biosphere. In: Jansson A (ed) Investing in natural capital: the ecological economics approach to sustainability. Island, Washington, pp 57–97

Jax K, Jones C, Pickett STA (1998) The self-identity of ecological units. Oikos 82:253–264 doi:10.2307/3546965

Johnson EA (1979) Succession, an unfinished revolution. Ecology 60:238–240 doi:10.2307/1936484

Kingsland SE (2005) The evolution of American ecology, 1890–2000. Johns Hopkins University Press, Baltimore

Likens GE (1992) The ecosystem approach: its use and abuse. Ecology Institute, Oldendorf/Luhe

Machlis GE, Force JE, Burch WR Jr (1997) The human ecosystem. 1. The human ecosystem as an organizing concept in ecosystem management. Soc Nat Resour 10(4):347–367 doi:10.1080/08941929709381034

McDonnell MJ, Pickett STA (1993) Humans as components of ecosystems: the ecology of subtle human effects and populated areas. Springer-Verlag, New York

McIntosh RP (1985) The background of ecology: concept and theory. Cambridge University Press, Cambridge

Park RE, Burgess EW (1925) The city: suggestions for investigation of human behavior in the urban environment. University of Chicago Press, Chicago

Pickett STA, Cadenasso ML (2002) Ecosystem as a multidimensional concept: meaning, model and metaphor. Ecosystems (N Y, Print) 5:1–10 doi:10.1007/s10021-001-0051-y

Pickett STA, Cadenasso ML (2005) Vegetation succession. In: van der Maarel E (ed) Vegetation ecology. Blackwell Publishing, Malden, pp 172–198

Pickett STA, Kolasa J, Jones CG (2007) Ecological understanding: the nature of theory and the theory of nature, 2nd edn. Springer, New York

Pickett STA, Parker VT, Fiedler PL (1992) The new paradigm in ecology: implications for conservation biology above the species level. In: Fiedler PL, Jain K (eds) Conservation biology: the theory and practice of nature conservation, preservation, and management. Chapman and Hall, New York, pp 65–88

Redman C, Grove JM, Kuby L (2004) Integrating social science into the Long-Term Ecological Research (LTER) Network: social dimensions of ecological change and ecological dimensions of social change. Ecosystems (N Y, Print) 7:161–171 doi:10.1007/s10021-003-0215-z

Russell EWB (1997) People and the land through time. Yale University Press, New Haven

Schnore LF (1958) Social morphology and human ecology. Am J Sociol 63:620–624 629–634

Stearns F (1970) Urban ecology today. Science 170:1006–1007 doi:10.1126/science.170.3961.1006

Tansley AG (1922) The new psychology and its relation to life, 6th Impression. Dodd, Mead and Co., New York

Tansley AG (1935) The use and abuse of vegetational concepts and terms. Ecology 16:284–307 doi:10.2307/1930070

Turner WR, Nakamura T, Dinetti M (2004) Global urbanization and the separation of humans from nature. Bioscience 54:585–590 doi:10.1641/0006-3568(2004)054[0585:GUATSO]2.0.CO;2

United Nations Population Fund (2007) State of world population 2007: unleashing the potential of urban growth. United Nations Population Fund, New York

von Bertalanffy L (1968) General system theory: foundations, development, applications. George Braziller, New York

Wu J, Loucks OL (1995) From balance of nature to hierarchical patch dynamics: a paradigm shift in ecology. Q Rev Biol 70:439–466 doi:10.1086/419172