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Perspective

Spatial theory in early conservation design: examples from Aldo Leopold's work

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Abstract

Aldo Leopold is well known in North America as a conservationist, author, and promoter of the Land Ethic. Although Leopold's work is rarely included in the realm of landscape ecology, he left several illustrations of an early spatial theory for conservation. While European geographer Troll published the term 'landscape ecology' in 1939, Leopold was discovering the role of spatial configuration in European working landscapes, and began to apply the landscape ecology concepts to wildlife management and cooperative conservation in the US. With his own spatial language he wrote, mapped, and applied elements of pattern, process, and connectedness in the landscape. In this perspective piece I use three examples from Leopold's work to demonstrate his contribution to spatial theory in early conservation design. First, this paper deciphers spatial elements conveyed through Leopold's writing, drawing, and teaching in the early 1930s. Second, I re-interpret Leopold's observations of the spatial design of remises from his visit to Silesia, Europe. Third, I show how the lessons from Silesia were applied to a landscape in Wisconsin, USA, involving both farmers and townspeople in cooperative implementation of a remise system. Collectively, a new perspective emerges on the early dialogue of landscape ecology and conservation across continents.

Introduction

The spatially explicit nature of wildlife habitat, and its application to management and land conservation is evident in several works by North American conservationist Aldo Leopold from the 1930s and 1940s. With a master's degree in Forestry from Yale in 1909, Leopold began his career with the US Forest Service in Arizona and New Mexico and was instrumental in establishing the Gila Wilderness Area. In 1924 Leopold transferred to the US Forest Products Laboratory in Madison, Wisconsin, USA, but resigned four years later to write and consult. The University of Wisconsin-Madison appointed Leopold to head the institution's first wildlife management program in 1933 (Meine 1988). Wisconsin is a Midwestern state between lakes Superior and Michigan, and the cities of Minneapolis-Saint Paul and Chicago.

While the conservation idea in America was brought to public awareness at the turn of the century with Theodore Roosevelt's ideas for ″conservation through wise use″ (Morris 2001), by the 1930s Leopold was calling for application of the ideals and the science; i.e., applied conservation. This was the juncture at which Leopold developed his own techniques for game protection, compiled into the well-used text for wildlife studies, *Game Management* (Leopold 1933). The 1930s was a time of intellectual development for Leopold, as he first applied the lessons learned during his work with the US Forest Service in the Southwestern US, and during the time he conducted game surveys for the Sporting Arms and Ammunition Manufacturers' Institute. As a University of Wisconsin professor, Leopold and his students began to experiment with tangible conservation techniques that integrated spatial thinking. Although theories of landscape ecology had been developing in Europe for the past decade, motivated by German bio-geographer Carl Troll and the new possibilities of aerial photography (Schreiber 1990; Turner et al. 2001), there was not yet a firm theoretical basis for an 'ecology of landscapes' in North America (Sanderson and Harris 2000; Zonneveld 1995).

In this paper I illustrate the contributions of Aldo Leopold's work to spatial thinking in nature conservation and applied landscape ecology. Although several books analyze Leopold's work and writings, little attention is drawn to his consideration of spatial relationships on landscapes. Likewise, few landscape ecology texts cite Leopold as a major contributor to development of the field (see for example Forman and Godron 1986, Sanderson and Harris 2000, Turner et al. 2001). Using a selection of Leopold's writings and diagrams, I draw parallels to contemporary concepts in landscape ecology, show how he applied these concepts to a Wisconsin landscape, and offer thoughts on the significance of his spatial work to our field.

Leopold's spatial language

The theoretical foundation for Leopold's spatial premises are best articulated in his chapter on Game Range (Leopold 1933, Chapter V), in relation to the home range of species. Three key spatial concepts are brought out explicitly in this chapter: composition, interspersion, and edge. Using habitat requirements of deer and quail, Leopold explained,

> …each species has its own particular set of environmental requirements, that there is usually a critical season during which each of these is most deficient, and that the probability of surviving this critical season depends on the availability of certain particular kinds of vegetation, topography, or soil, which are usually associated with certain vegetative types. In other words, a game range, to support a given species, must have a certain *composition* in which the essential environmental types are represented. (Leopold 1933, p. 127)

Therefore, composition, or the mix of environmental types within a landscape was the first element he considered. But Leopold also knew that the juxtaposition of types influenced wildlife movements:

> The game must usually be able to reach each of the essential types each day. The maximum population of any given piece of land depends, therefore, not only on its environmental types or composition, but also on the *interspersion* of these types in relation to the cruising radius of the species. *Composition and interspersion are thus the two principal determinants of potential abundance on game range* (emphasis added). (Leopold 1933, p. 128–29)

Already in the 1930s the new Wisconsin professor was developing a theoretical basis for 'land ecology,' in which he implicitly employed elements of landscape structure to study and teach the complex interactions between species and the natural and cultural landscapes (Flader and Callicott 1991, p. 303). The interspersion theory, for example, was clarified by a pair of diagrams in the *Game Management* chapter that illustrate alternative arrangements of four equal area cover types in a landscape, and the hypothesized effect on quail populations (Figure 1). These diagrams typify figures one might find in an issue of this journal that illustrate theoretical, simplified land cover distribution in relation to some ecological process. Leopold's understanding went beyond a static role of landscape structure in game distribution: he also recognized that there is variability in the compositional needs and the effects of interspersion depending on the resolution of units, or, ″the refinement and accuracy to which the types are defined″ (Leopold 1933, p. 129), as well as quality, seasonality, and regional context. But for the purpose of presenting principles, rather than detailed biology, he used the simple classification of four cover types.

The illustration of *interspersion* leads to the concept of *edge*. The landscape in Figure 1B, for example, has five times more edge than the landscape in Figure 1A. The juxtaposition of the four types – in patches as we would say today – results in differing levels of interspersion of the types, and varying amounts of edge between types. The linear length of edges is ″a matter of geometry, proportional to the degree of interspersion″ (Leopold 1933, p. 131). Leopold asserted that game is a phenomenon of edges – occurring where the types of food and cover come together, and that this phenomenon is obvious to any hunter or woodsman who has followed quail, rabbit, deer, wild turkey, or other species. The reason for this phenomenon, Leopold theorized, is related to ″the desirability of *simultaneous access* to more than one environmental type, or the *greater richness* of border vegetation, or both″ (Leopold 1933, p. 131). Whether or not Leopold's argument on the relationship between edge and game density holds up under contemporary theory, the point is that he *had* an argument that tied spatial configuration of the landscape to wildlife movement and density, which could be im-

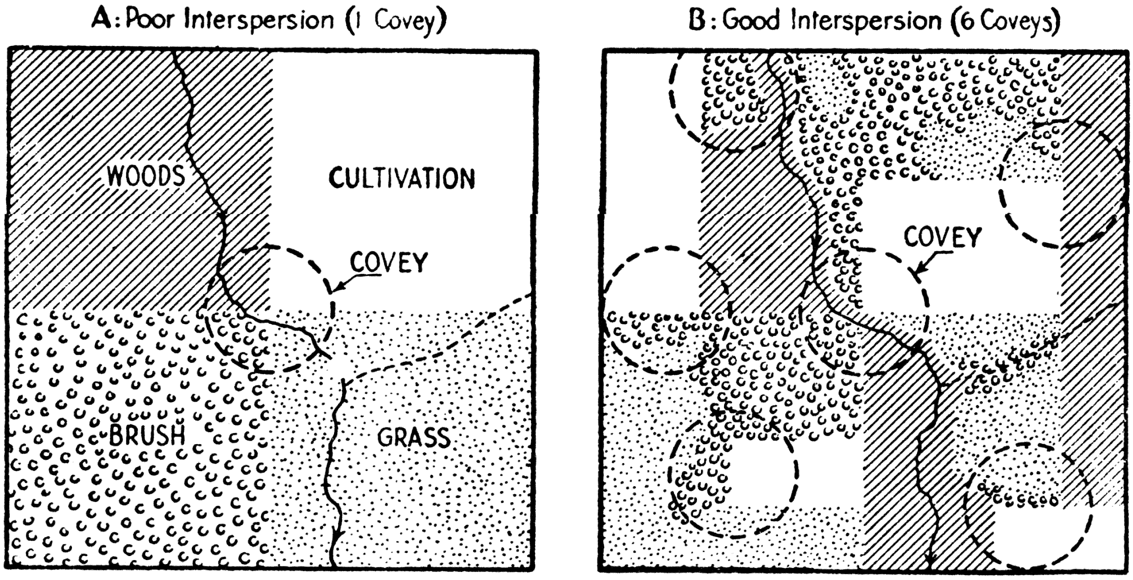

Figure 1. Leopold illustrated the concept of *interspersion* through this pair of diagrams, which he labeled, ″Interspersion of Types – Relation to Mobility and Density of Quail.″ Diagram A represented ″poor interspersion (1 covey);″ diagram B represented ″good interspersion (6 coveys).″ Note that both A and B have the same types and same total area of each. Published in Chapter V, 'Game Range' of *Game Management* (Leopold 1933, p. 130). (Permission granted by the Aldo Leopold Foundation, Baraboo, Wisconsin.)

proved upon by future scholars (Guthery and Bingham 1992). Also, Leopold did not simplify this relationship into an assertion that more edge equals more game. His observations led him to realize that the relationship between edge and density was more complex than a simple formula. For example, he observed that edge effects are most prevalent in game species of low mobility and high type requirements, but not so attractive to mobile, one-type game like geese, buffalo, antelope, plover, or sea-ducks (Leopold 1933, p. 131). In fact, he suggested that the requirements for forest interior species, in terms of edge, were the reverse of those for farmland game. These observations led to Leopold's relational model between game and landscape pattern:

> Carrying capacity in species of high type requirements and low radius varies directly with the interspersion of the types, which is proportional to the sum of the type peripheries. Such game is an ″edge effect.″ (Leopold 1933, p. 135)

From this model, Leopold suggested a classification of game species with respect to their cruising radius and range, or landscape structure requirements. For example, deer, ruffed grouse, and wild turkey, classified as 'Forest and Range Game' he argued, thrive best on forest land (as the matrix) with only partial interspersion of cultivation (patches). In essence, he made a classification by species of habitat/range needs for particular land cover types as matrix or patch, and the level of patchiness within the matrix.

So Leopold provided at least three terms: composition, interspersion, and edge; with illustrative explanations that easily relate to, or are used in, contemporary landscape ecology theory and application. Indirectly we can relate the contemporary term, 'patch' to Leopold's use of the words 'covert' and 'type'. I have selected additional concepts from *Game Management* that are distinctly spatial in nature and suggest related terms used today (Table 1).

Visualizing and mapping spatial concepts

Leopold's insistence on the use of maps or spatial diagrams is another example of his contribution to spatial approaches in ecology. In a recent meeting with Nina Leopold Bradley, I asked about her father's propensity for maps and diagrams. She said most definitely, her father was always sketching and drawing the lay of the land. She readily pulled from a file of Leopold's records of his Sand County property in central Wisconsin, several hand drawn maps of the

Table 1. Relationship of Leopold's spatial terms from *Game Management* to contemporary landscape ecology concepts; see also inter-patch distance discussed in text.

Leopold Term	Definition from *Game Management* (Leopold 1933)	Related contemporary concepts/terms	Definition (Turner et al. 2001)
Composition	Not defined explicitly but suggested as the mix of environmental types on a particular landscape/range	Heterogeneity	Quality or state of consisting of dissimilar elements, as with mixed habitats or cover types occurring on a landscape
Cover	Vegetative or other shelter for game	Cover type	Category within a classification scheme defined by the user that distinguishes among the different habitats, ecosystems, or vegetation types on a landscape
Covert	A geographic unit of game cover	Patch	Surface area that differs from its surroundings in nature or appearance
Cruising radius	The distance between locations at which an individual animal is found at various hours of the day, or at various seasons, or during various years.	–	Related concepts are used, but not defined here; e.g., dispersal distance, foraging range, etc.
Edge	Not defined explicitly, but occurs where they types of food and cover needed by game species come together	Edge	…length of adjacency between cover types
Interspersion	The degree to which environmental types are intermingled or interspersed on a game range.	Configuration	Specific arrangement of spatial elements; also spatial, or patch structure
Mobility	The tendency of the individual animal to change location during the day, or as between seasons or years.	Connectivity	Relates to: spatial continuity of a habitat or cover type across a landscape
Game range	Not defined explicitly, but suggests a piece of land suitable for a given species of game; includes food and cover.	Landscape	Area that is spatially heterogeneous in at least one factor of interest
–	Optimum range composition	Matrix	Background cover type in a landscape
Remise	European term for an artificially established game bird covert. Sometimes includes food as well	–	Relates indirectly to patch, corridor, matrix, habitat

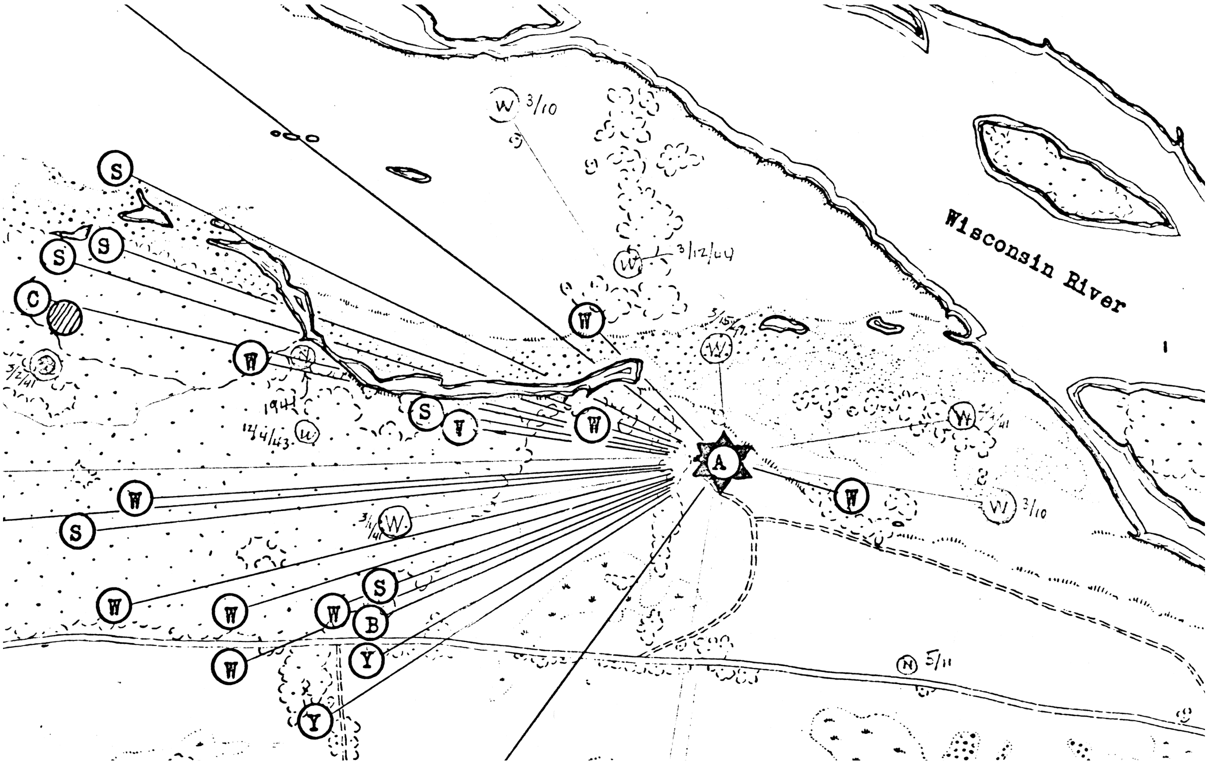

Figure 2. From the files of the Bradley Study Center, courtesy of the Aldo Leopold Foundation, Baraboo, Wisconsin. This clipped map shows ″Range of Chicadees banded in winter at Station A (Leopold Shack, Sauk Co., Wis.),″ no date. Circled letters indicate: seen, banded: S-summer, W-winter, N-nesting, Y-with young; or seen, caught: B-banded at substation B, hatched circle – unbanded.

area around Leopold's family cabin, known as the Shack (Figure 2). One of the later chapters in *Game Management* is devoted to his technique for mapping. To explain the purpose or benefit of making maps, Leopold mentioned the largely ″mapless early literature of game,″ and said,

> Facts concerning game distribution, behavior, history, and management can often be accumulated on maps or tables to better advantage than in notes. Provided the symbols and format be adequate, maps and tables are easier visualized, analyzed, and reproduced than notes. (Leopold 1933 p. 374)

He went on to point out how field workers often accumulate so many notes, over such a long time that they can't adequately analyze or manage them. To create a game map, Leopold suggested himself that one acquire the best possible base map available – often using the local plat maps, which show parcel ownership. But he, like Troll, was also intrigued by the power of aerial photogrpahy, especially when no good base map was available.

> Aerial maps are coming into widespread use for many purposes. The cost is high, especially for small jobs, but their wealth of detail makes them especially valuable for game work. (Leopold 1933, p. 375)

Leopold described a method for creating a cover type map by traversing a landscape to enter cover types, census figures, banding returns, or similar data on a pre-existing base. At every 1/8 mile (0.20 km), the cruiser would stop, scale off the distance on the map, and ″sketch in the objects nearby which are pertinent″ (Leopold 1933, p. 375). Using the Riley tract that will be discussed in the next section, for example, Leopold created a simple type map for a 1500-acre (607 ha) tract. Detail was added to a local parcel map base by cruising and required two days of field work (Figure 3).

In teaching as well, Leopold regularly used visual aides – sketches, diagrams, and maps especially – in the form of mimeographed handouts to assist students' understanding. The illustrations helped him portray basic ecological concepts. For example, Rob-

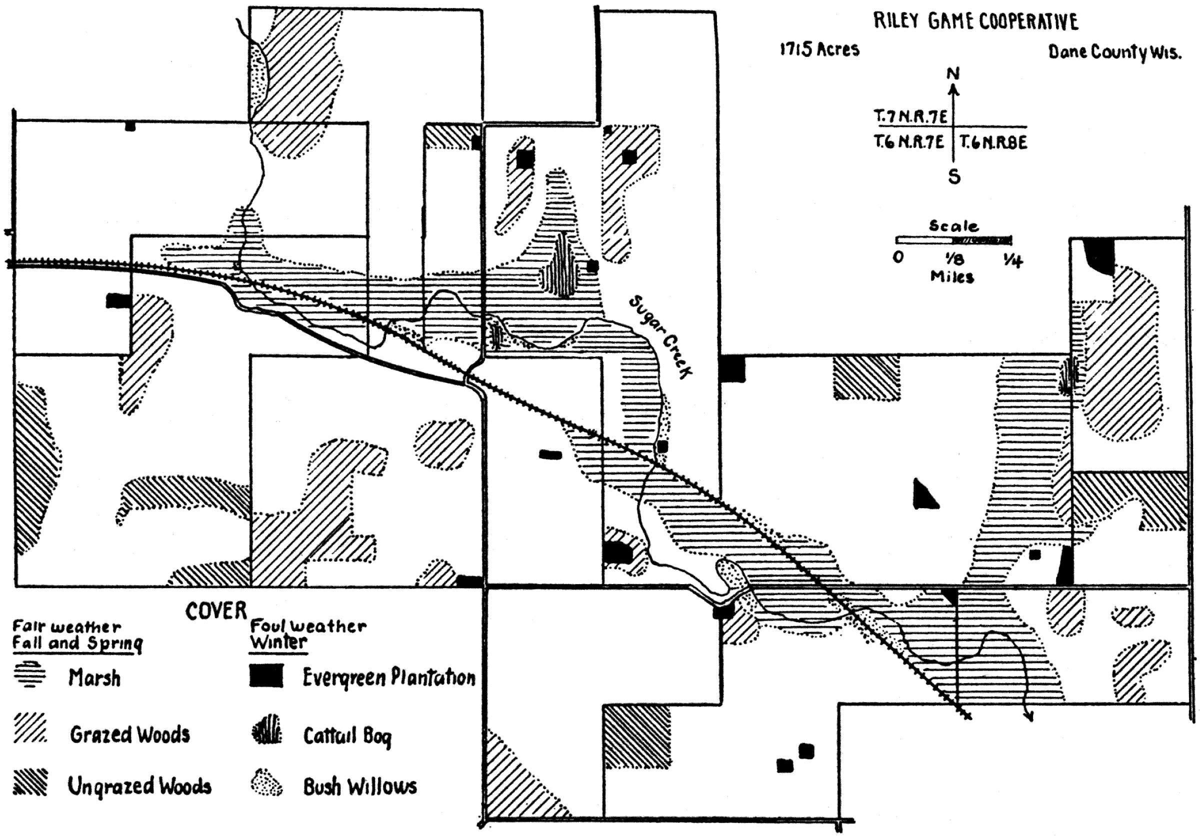

Figure 3. Cover map of Riley Game Cooperative, simplified for reproduction from a detailed cover map in the Leopold-Riley archives, Department of Wildlife Ecology Library, University of Wisconsin-Madison. Black patches indicate pine plantings, or remises for foul weather cover.

ert McCabe, a graduate student of Leopold's at the University of Wisconsin described a particular handout that Leopold had used to illustrate the seasonal movements of a covey of quail, and thus to outline conceptual seasonal and annual home ranges (Figure 4, McCabe 1987). Leopold was not interested in precision as much as he was in providing a picture of bobwhite quail movements that matched his field observations and that adequately illustrated the home range concept. As McCabe suggests, with today's computer modeling capabilities, home ranges have become more mathematical than biological in meaning. ″The simplistic diagram in Leopold's notes of 1937 may yet be clearer and more biologically meaningful than sophisticated computer assessments″ (McCabe 1987, p. 60).

Case studies from Silesia and the Riley Game Cooperative

Consider Leopold's use of a spatial language for two geographically distant landscapes: the region of Silesia in Germany and Czechoslovakia, and the area of Riley, Wisconsin, USA – just west of his post at the University in Madison. The observations and recordings that Leopold made during his four months of study in Silesia in 1935 may have had direct impacts on his later spatial 'designs' for game management in the Riley Game Cooperative.

'Farm Game Management in Silesia' was published in *American Wildlife* in 1936, and was reproduced in the edited book, *For the Health of the Land* (Callicott and Freyfogle 1999). In this article Leopold described how farmers in Silesia managed their lands to promote game along with other crops. He remarked on their practice of breaking up large cultivated fields with 'remises': small coverts of mixed

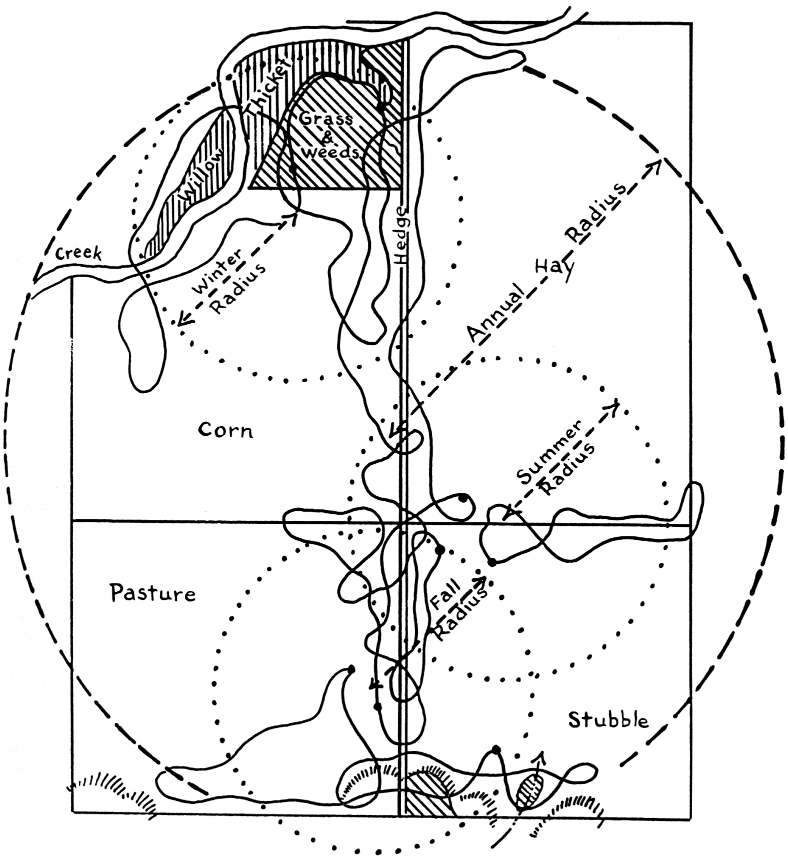

Figure 4. Sample teaching illustration Leopold used to show the concept of home range relative to a quail covey to his Wildlife Ecology class at the University of Wisconsin. Reprinted from a mimeographed handout in McCabe (1987).

trees planted just for game. Although the Silesian plain was similar in climate to the upper Midwestern United States, it was even more intensively cultivated, with very little timber except in the remises. Still, most Silesian farms often had a few acres for wildlife remises. As Leopold explored and wrote,

> Where, in such a highly cultivated landscape, shall one find shelter for game? The answer is the remise – a small concentrated spot of cover planted especially for pheasants, but used also by hares and roes.
>
> A typical remise covers an acre or two, and consists of an outer belt of hedged Norway spruce, next a belt of taller unhedged spruce, then a belt of alder, and finally a central core of hardwoods, or – if on wet land – willows and cane (phragmites). Figure 1 shows the design and operation of a typical remise. (Callicott and Freyfogle 1999, p. 58), (Figure 5a).

Thus we have an illustration, both narrative and graphic, of a typical spatial configuration for remises within a farmland matrix. Leopold explained the remise system at different scales. In addition to describing the configuration of a single remise, he also observed how a system of remises could work within a large property or estate.

> The best remise system I examined had ten cover units on an estate of 780 acres, or one per 80 acres. On this estate the area in remises, park, and food patches was 8 per cent of the total. The average size of a remise was 2 acres. The average distance between remises was a long pheasant flight, i.e., about one-third mile. Figure 2 shows a typical estate in relation to its remise system. (Callicott and Freyfogle 1999, p. 59), (Figure 5b).

Considering a remise, as Leopold used the term, equivalent to a high quality patch, these descriptions and diagrams show an understanding of landscape composition, patch size, number of patches, and proportion to matrix area. In fact in the description above, Leopold introduces a measure of inter-patch distance – the distance of a long pheasant flight. He was collecting concepts for a science of land ecology (Zonneveld 1995). The way in which Leopold told the reader about the form of wildlife cover in Silesia suggests that he was trying to capture what he had seen and learned during his study abroad, and was ready to test it on Wisconsin landscapes.

The Riley Game Cooperative, co-founded by Aldo Leopold and landowner/farmer Reuben J. Paulson, was a voluntary arrangement for city-dwelling hunters and rural farmers in rural Wisconsin to collectively manage a tract of farmland for game, with the farmers providing the land and grain, and the hunters providing the cash for improvements and stocking. With Leopold's tie to the University, a research component also emerged and wildlife management graduate students involved themselves in the cooperative – collecting data and helping members with labor. The cooperative idea was initiated as Leopold looked for a place to try game management practices, while Paulson and other farmers sought relief from trespassing hunters. The paper, 'History of the Riley Game Cooperative, 1931–1939' was published in the *Journal of Wildlife Management* (1940) (Callicott and Freyfogle 1999). It was Leopold's reflection on the first nine years of the game cooperative, and his documentation of applied remise system design/land management learned during his time in Silesia.

The landscape of the Riley area in the early 1930s, situated at the base of a terminal moraine, was comprised mostly of grazed pasture, cropland, and farmsteads. The Sugar River and the Chicago and Northwestern Railroad tracks cut across the cooperative reserve. Springs, marshes, isolated woodlots, and odd-shaped corners were the few uncultivated lands in the area. These fragments held remnants of the original prairie, savanna, or wet meadow vegetation. Leopold had identified two major ecological problems for the Riley area: the gradual transfer of fertility from upland to bottoms by erosion, and the gradual elimination of cover by grazing. The loss of cover was happening in woodlots that were cut and then grazed, and in the marshes that were plowed with each succeeding drought. Even the fencerows were at risk during the tough years. The railroad right-of-way, on the other hand, was protected from annual clearing and burning and provided some of the best cover in the Riley area, Leopold remarked.

With the land so intensively used, the Riley Cooperative goals initially were to increase game quickly by winter feeding and restocking. But as a community and university project, the goals soon grew to include improvements for many species of wildlife, and longer-term efforts centered around planting cover – in other words, developing a remise system. Leopold wanted to show that the downward trend of wildlife in these lands could be reversed by the combined efforts of farmers and sportsmen, without a lot of money, land, or oversight. He had found a place to apply and test the ideas of European remises in intensively used landscapes, and he had found a community-based mechanism to implement those ideas cooperatively. Members had a mutual interest in improving wildlife and conserving the land.

The cover assessment of Riley in the 1930s suggested to Leopold that there was adequate 'fair-weather' cover for spring and fall use, such as tussock (*Carex*) marsh and small ungrazed woodlots with hazel (*Corylus americana*) and grey dogwood (*Cornus racemosa*). But the area was deficient in 'foul-weather' cover that would protect against deep snows and blizzards (Callicott and Freyfogle 1999, p. 181). These patches of cattail (*Typha latifolia*) and bush willow (*Salix sp.*), and fencerows of grape (*Vitis sp.*) tangles and plum (*Prunus sp.*) thickets amounted to only one percent of the area. Thus, the strategy was to double or triple the dense winter cover plantings. To decide what, where, and how to plant these, Leopold combined what he had learned in Silesia with trial and error. Although the first few years had significant seedling losses from drought and browsing, by 1938–39 the cooperative had successfully planted and replanted cover plantings sufficient to ″constitute a remise system which will double the area of foul-weather or true winter cover″ (Callicott and Freyfogle 1999, p. 182). Leopold footnoted his article on Silesia (in *American Wildlife*), and illustrated the 'cover pattern' in a map of the Riley Game Cooperative (Figure 3).

The Riley Game Cooperative persisted past Leopold's death well into the 1950s, while some members continued to hunt and feed game in the area even later. I have revisited the Riley area several times in the past year. Many physical landscape features can be identified from Leopold's descriptions and photographs, some perhaps in better condition (e.g., more cover) than in 1931 (Figure 6). The railroad corridor

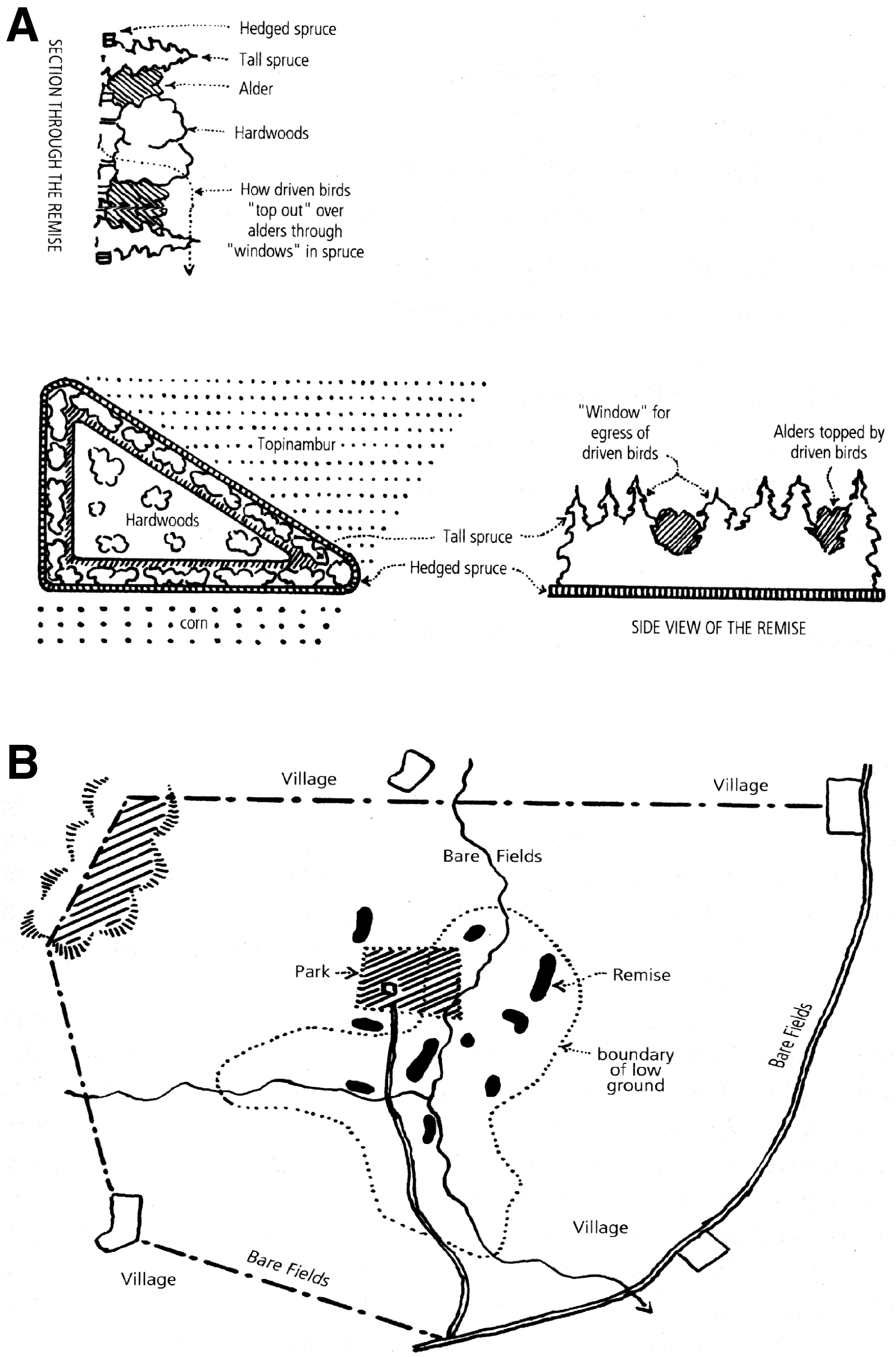

Figure 5. Illustrations used in Leopold's article, 'Farm Game Management in Silesia,' 1936 in *American Wildlife* to explore and describe the European remise system. a) ″Design and operation of a remise;″ b) ″Village map.″ Both reproduced from Callicott and Freyfogle 1999, pp. 58–59.

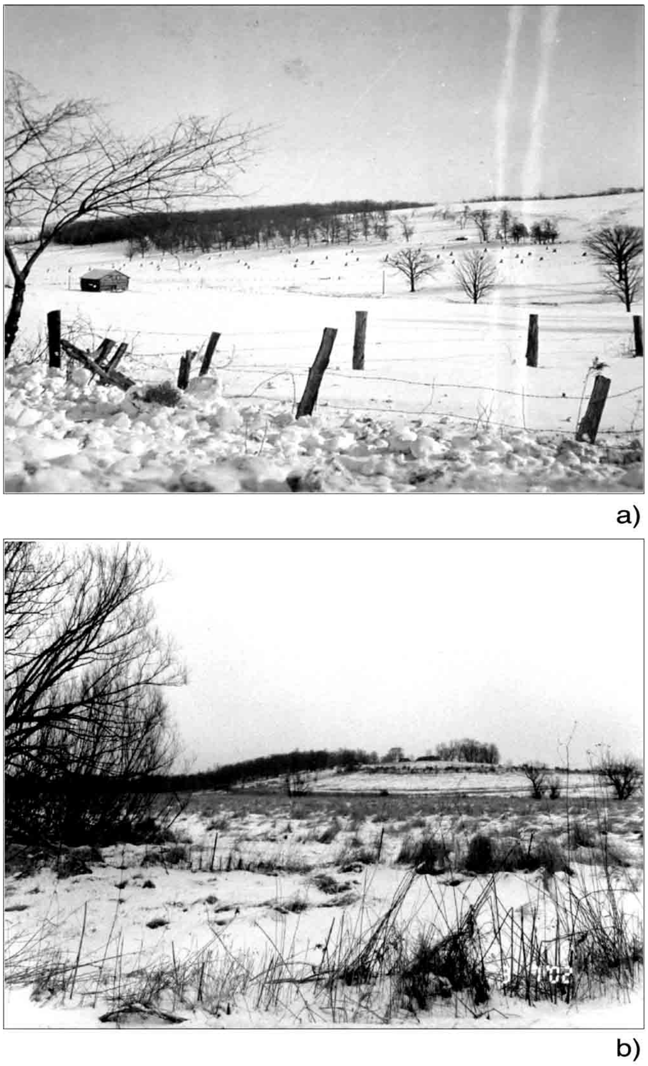

Figure 6. The Riley landscape; Dane Co. Wisconsin, US. a) ″Winter landscape near Riley. Note lack of cover. Feb. 1940″ – caption and image from Leopold's photo albums, Leopold-Riley archives, Department of Wildlife Ecology Library, University of Wisconsin; the photo was likely taken from the railroad corridor on the west end of the Cooperative lands looking north; b) contemporary winter landscape near Riley, photograph by the author, March 2002, taken from the railroad corridor looking north (see Figure 3).

is now the Military Ridge state bicycle trail and many of the lower areas are no longer cultivated or grazed. Fencerows are still covered with grape tangles and plum trees, and atop the sandstone hills are several stately, but aging stands of pine planted by Leopold and members of the Cooperative (Figure 7). Although the urban fringe from Madison is pushing out toward Riley, there is probably more cover today than there was at the time Leopold and Paulson began the project. And, through efforts of local citizens and descendants of Coop members who remember the work of Leopold in the Riley area, the Game Cooperative lands are being considered for protection.

Conclusions and implications for landscape ecology

This paper traces just one line of Leopold's intellectual development, specifically the concepts and applications of *spatial* land ecology and conservation. My intent was to look at some of Leopold's ideas from the perspective of a landscape ecologist and convey

a)

b)

Figure 7. Evergreen plantings within the Riley Game Cooperative to improve foul-weather cover. a) ″Remis at Riley. 1/41″ – caption and image from Leopold's photo albums, Leopold-Riley archives, Department of Wildlife Ecology Library, University of Wisconsin-Madison; b) contemporary view of a remise planting. Photograph by the author, March 2002.

the ways he used, promoted, and applied spatial concepts. To do so, I considered the spatial language Leopold used in *Game Management*; his study of spatial design for conservation in Silesia; and his application and experimentation with similar concepts in a Wisconsin landscape. Leopold's work can remind us of the tools of observation and experimentation; and the value of on-the-ground trial and error experiments aimed at directly improving land conservation. Leopold was a solid record-keeper and scientist, but he was astute enough to see beyond the records and capture in his mind, his notebook, and his teachings the qualitative observations and lessons learned in the field. He had a profound talent for synthesizing multi-dimensional landscape understanding. Moreover, he applied his holistic sense of 'land ecology' toward collective, community-based, spatially-driven conservation design. ″Land ecology,″ Leopold said, ″is putting the sciences and arts together for the purpose of understanding our environment,″ (Flader and Callicott 1991, p. 303). Similarily, in *Land Ecology*, Zonneveld considers the term 'land' synonymous with 'landscape' in the sense of 'full system' (Zonneveld 1995, p. 9). Clearly Leopold is recognized for advancing an applied conservation practice, but he is only scarcely noted for this application in spatial context. Findings from this study suggest that Leopold was both a student of, and contributor to, the early 'land(scape) ecology' dialogue, as theories began to be transferred, tested, and applied to conservation on landscapes worldwide.

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References

Callicott J.B. and Freyfogle E.T. (eds) 1999. Aldo Leopold: For the Health of the Land. Island Press, Washington, DC, USA, 243 pp.

Flader S.L. and Callicott J.B. (eds) 1991. The River of the Mother of God and Other Essays by Aldo Leopold. University of Wisconsin Press, Madison, Wisconsin, USA, 384 pp.

Forman R.T.T. and Godron M. 1986. Landscape Ecology. John Wiley & Sons, New York, New York, USA, 619 pp.

Guthery F.S. and Bingham R.L. 1992. On Leopold's principle of edge. Wildlife Society Bulletin 20: 340–344.

Leopold A. 1933. Game Management. 1986 edn. University of Wisconsin Press, Madison, Wisconsin, USA, 481 pp.

McCabe R.A. 1987. Aldo Leopold, The Professor. Palmer Publications, Inc., Madison, Wisconsin, USA, 172 pp.

Meine C. 1988. Aldo Leopold: His Life and Work. University of Wisconsin Press, Madison, Wisconsin, USA, 638 pp.

Morris E. 2001. The Rise of Theodore Roosevelt. The Modern Library, New York, New York, USA, 920 pp.

Sanderson J. and Harris L.D. (eds) 2000. Landscape Ecology: A Top Down Approach. Lewis Publishers, Boca Raton, Florida, USA, 246 pp.

Schreiber K.F. 1990. The history of landscape ecology in Europe. In: Zonneveld I.S. and Forman R.T.T. (eds), Changing Landscapes: An Ecological Perspective. Springer-Verlag, New York, New York, USA, pp. 21–33.

Turner M.G., Gardner R.H. and O'Neill R.V. 2001. Landscape Ecology in Theory and Practice. Springer-Verlag, New York, New York, USA, 401 pp.

Zonneveld I.S. 1995. Land Ecology. SPB Academic Publishing, Amsterdam, The Netherlands, 199 pp.