Bio-Inspired Cadastral Boundary Design

Rohan BENNETT, Australia, Jaap ZEVENBERGEN, Netherlands

Key words: bio-mimicry, land administration, cadastral boundaries

SUMMARY

This paper argues that the principles of bio-mimicry can be used to establish an alternative approach to constructing cadastral boundaries. Existing approaches are often built purely on the principles of geodesy: fixed bearings and distances, often with little or no relationship to surrounding ecological or biological phenomena, prescribe borders and enclose areas. Limitations are evident when sustainable approaches to managing natural and urban environments are sought. Meanwhile, new geospatial technologies enable alternate methods for demarcating, surveying and recording natural phenomena than previously possible: the opportunity now exists to use biological and ecological principles in boundary design. This paper outlines the theoretical and methodological underpinnings for such work. Additionally, it describes the potential the long-term impacts: innovative boundary options that better support sustainability objectives.

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1. INTRODUCTION

Conventional property boundaries often ignore underlying biological and ecological systems. The approach undermines natural processes and often results in unsustainable ecosystems. Ecological and biological systems actually provide blueprints for creating boundary systems that are more in tune with the environment.

This paper aims to explore this hypothesis in more detail and argues for the importance of further research in the area. First, problems relating to conventional boundary systems and ecosystems are discussed. Subsequently, areas of potential work are identified. The theoretical and methodological underpinnings for such work are proposed: biomimicry design principles lie at the heart of the approach. Finally, the potential outcomes of such work are discussed from a number of perspectives. The paper concludes with a summary of contents.

2. THE PROBLEM: CADASTRES AND UNDERMINED ECOSYSTEMS

The conventional boundary systems of human populations undermine balanced ecosystems in three distinct ways. First (1), they ignore or weaken systems in surrounding natural environments (Bennett et al, 2010; Kloppenburg, 2004; Benyus, 2002; Altieri, 1999; 1983; Jackson, 1980; McHarg, 1969). Second (2), establishment and maintenance are often economically expensive (Baldwin, 1998; Dale and McLaughlin, 1999; Deininger, 2003). Third (3), very specific social norms must exist to ensure their recognition (Buckley and Kalarickal, 2006; Payne, 2001). To restore balance in ecological systems, these problems with conventional boundaries require attention.

Conventional boundary systems are primarily products of the agricultural revolution (Ting and Williamson, 1999). Barriers, either physical or invisible, supported by changed institutional norms served to alienate and protect crops from outside parties and threats. These barriers were documented in registers and cadastral maps and are commonly referred to as land parcels or properties. Two main systems emerged (Dale and McLaughlin, 1999): 'fixed' systems with very accurately demarcated, surveyed and recorded boundaries; and 'general' systems with physical presence and more approximate definition. Prevalence of the systems accelerated during Europe's enclosure movements and parallel pervasion of modern capitalism around the 16th century (Larsson, 1991). Colonization, and more recently globalization, saw the approaches adopted variously in most country contexts (Williamson et al, 2010). Recognition of the problems inherent in conventional boundary systems only emerged in the final decades of the 20th century.

The first problem, ecological ignorance, emerges because in conventional boundary systems the science of geodesy dominates over biology, geology, and ecology. Geometry is used to delineate physical space, not the natural boundaries inherent to biological and ecological systems. The oft sharp edges and corners of geodetic boundary systems disregard nature's predisposition for gradual transitions: natural processes at scales beyond a human delineated space are ignored or obstructed (Pimm, 1991; McHarg, 1971). The consequence has been system breakdown of natural processes. In agricultural settings, human delineated spaces are often developed as monocultures of single crops or single uses (Benyus, 2002). In natural contexts, these immature Type I systems are shown to be unsustainable and give way to more biologically diverse Type III environments (Allenby and Cooper, 1994). Although, it should be noted that nonequilibrium ecological systems also exist (Rohde, 2006; Walker, 1997; Sullivan, 1996).

The second problem, economic expense, emerges because the processes of establishing and maintaining conventional boundary systems are generally costly: adjudication, demarcation, surveying, and recordation activities can require significant resources (Henssen, 2010; Dale and Mclaughlin, 1999; Larsson, 1991). The four sub activities usually exhibit high levels of complexity, can be time consuming, and require availability of expert-labor and geo-ICT.

The third problem, the need for very specific social norms, arises because conventional boundary systems being artefacts of highly specific human constructs regarding the relationship between humans and land (c.f. De Soto, 2000; North and Thomas, 1973). These constructs, or norms- the on ground markers, maps, and registers- are primarily artefacts of agricultural and latter capitalist practices. Despite their dominance in many parts of the world, the norms still do not prevail in many human contexts (Ostrom, 1990). Consequently, the application of conventional boundary systems creates conflict between humans, and between humans and their ecologies.

Combined, the three problems undermine a balanced relationship between ecosystems and their human participants. Various lines of research attempt to resolve the specific problems. Work on rapid and low cost boundary establishment and recording processes focuses on the second problem (e.g. Griffith-Charles, 2011; FIG, 2010; RICS, 2011; Pirti et al, 2009; Fourie, 1995). At its core, this work tends to revolve around application of emerging geospatial technologies to surveying and recordation activities. Meanwhile, another body of work focuses on institutional development and alternative tenure models as a means to solve the third problem (e.g. Arko-Adjei, 2011; UN-Habitat, 2008; De Soto, 2000). For now, solutions to the first problem, the tendency for conventional systems to ignore underlying natural systems, are undeveloped. Whilst policies promoting synergies between natural and built environments are endorsed, for example the Pan-European Ecological Network (CoE, 2012), tools for operationalizing such policies are still limited. Scientific works demonstrating the interaction between human boundary activities and surrounding ecologies processes are already evident (c.f. van Gils and Loza Armand Ugon, 2006; van Gils et al, 2006; Ngene et al, 2010; van Gils, and Kayijamahe, 2010; Pittiglio et al, 2012), however, such lessons still require translation into cadastral boundary design options.

3. BIO-INSPIRED BOUNDARIES: A POTENTIAL SOLUTION

The first problem, ecological ignorance, is largely untouched in land administration circles. There lies the opportunity to develop an alternative set of boundary systems, ones that are sympathetic and opportunistic towards natural or existing biological and ecological systems, rather than being purely reliant on geodetic principles. More specifically, there is the need to: 1) articulate the requirements of contemporary cadastral boundary systems; 2) identify, catalogue, and select biological or ecological processes with viability in cadastral boundary design; 3) translate the lessons from the most viable approaches into requirement specifications for cadastral boundaries; 4) explore, examine, and select geospatial technologies that support the adjudication, demarcation, surveying, and recording of the biological and ecological boundary systems in practice; 5) design a framework of boundary options that fuses biological, ecological, and geospatial subsystems; and 6) evaluate and refine the new approaches in a number of contexts.

Achieving such objectives would fundamentally involve design research. Design research utilizes the scientific method to conceptualize, build and test something- as opposed to performing an experiment, observational study, modelling exercise, or comparative study. Design theories cut across many disciplines: there exists no standardized approach, although general principles are evident (e.g. TRIZ algorithm (Altshuller, 1999)).

Biomimicry is one subset of design approaches; however, arguably it is more a design philosophy than a rigorously defined process in itself. Early inspiration can be found in McHarg's (1969) seminal text Design with Nature, whilst Benyus (2002), Kelly (1994), and McDonough and Braungart (2002), amongst others, articulate the guiding philosophy: principles inherent in nature should be used to inform the design process. A scientific foundation was provided by Passino (2005). In all cases, a strand of biological science is fused with a design approach and the principles from another disciplinary area, for example, architecture or agriculture. At a generic level, most approaches involve: 1) identifying a function to be performed, 2) 'biologizing' the question, 3) finding natures best practice, and 4) translating those best practices into buildable things (c.f. www.biomimicry.net).

As no specific biomimetic approach is yet evident in the realm of human boundary design, any design process would need to borrow from related disciplines where methodologies are already more established. These include electrical or energy engineering, civil engineering, and architecture- all typically associated with the 'built environment' to which geodesy is often linked. Typically, these approaches are conceptualized as iterative design spirals, design curves or trajectories. Activities often run in parallel and are oft repeated: iterative cycles are common and include problem redefinition; repeat translation or 'biologization' of the problem; reinvestigation and observation of nature's strategies; recurring abstraction and application of the natural strategies on the problem domain; and recurring evaluation, revaluation, and synthesizing (Haastrich, 2007). To further the dialogue on bio-inspired cadastral boundary design- these design methodologies need to be further developed.

4. THE POTENTIAL IMPACT OF BIO-INSPIRED CADASTRAL BOUNDARIES

Bio-inspired boundaries have potential impacts from social, economic, and environmental perspectives. They may also have an impact on the scientific and research landscape across multiple disciplines.

Socially, the approaches may prove useful in contexts where customary boundary solutions are sought, such as the pastoralist approaches evident in both eastern and western parts of Sub-Saharan Africa, or the communal approaches to land access displayed by many indigenous groupings. Implementation will support tenure reconciliation in areas of conflict.

Economically, the bio-inspired approaches are likely to result in lower cost, more rapidly deployed, and more fit-for-purpose boundary systems. This will reduce the sometimes significant costs of human boundary design and implementation. The designs will promote pragmatic and innovative land and natural resource management and may lead to further economic opportunities for both private and public sectors.

From the environmental perspective, global and local level policies relating to climate change response, food security, and natural resource conflict could make direct reference to the outputs. As suggested, bio-inspired boundaries can support operationalization of policies frameworks such as endorsed by Pan-European Ecological Network (PEEN) that aim to reconcile nature policies, land use planning and urban development. Developments on this front would lead to practical changes in boundary creation within the region, and thus support sustainability in multiple human contexts, including both urban and agricultural settings.

From a science and research perspective, building on the shift in human boundary studies from the observational research paradigm to the design paradigm (Cagdas and Stubjkaer, 2009; 2011), the incorporation of biomimetric design principles can be seen as reasoned extension to human boundary design science. Such designs would introduce new concepts to geodesy, encourage multidisciplinary approaches, and promote new links between geodesists, biologists, and ecologists. Conventional boundary methods will be supplemented, and potentially superseded, by the new biomimetric approaches for solving the boundary problem. The innovation would inspire modifications to core curriculum design in geodetic and surveying courses.

Also within the specialist area, bio-inspired designs will inspire new opportunities for geodesy and geospatial technology application- these will be required to support the surveying and recordation of any new eco or bio-inspired boundary approaches. For example, could thermal, NIR, or other types of earth observation sensors play a role in boundary surveying if boundary demarcation approaches are fundamentally biological in nature? Or, what geospatial tools are available to support bounding an area of protected, but moving marine species. Developments on this front would lead to changes in boundary creation in practice, and thus support sustainability in multiple human contexts, including both urban and agricultural settings.

Beyond the specialist area of cadastral boundary design, bio-inspired boundary designs would provide useful inputs for the disciplines of civil engineering, spatial planning, architecture, natural resource management, and public administration. These areas already maintain their own strands of biomimetric design research. All aim at developing more sustainable approaches to manage the interaction between ecological systems and human participants. An example in the European context is the Pan-European Ecological Network (PEEN). Endorsed in 1995 by 54 European countries during the 3rd Environment for Europe Ministerial Conference, it aims to better synthesize existing nature policies, land use planning, and urban development. The boundary approaches suggested here would enhance these initiatives and thus support more balanced ecosystem design and management.

5. CONCLUSION

This paper is built from the simple argument that the principles of biomimicry can be used to establish an alternative approach to constructing cadastral boundaries. Ecological and biological systems actually provide blueprints for creating boundary systems that are more in tune with the environment. Existing approaches are often built purely on the principles of geodesy: fixed bearings and distances, often with little or no relationship to surrounding ecological or biological phenomena, prescribe borders and enclose areas.The approach undermines natural processes and often results in unsustainable ecosystems. Limitations are evident when sustainable approaches to managing natural and urban environments are sought. New geospatial technologies enable alternate methods for demarcating, surveying and recording natural phenomena than previously possible: the opportunity now exists to use biological and ecological principles in boundary design. This paper outlined the theoretical and methodological underpinnings for such work. It described the potential the long-term impacts: innovative boundary options that better support sustainability objectives.

ACKNOWLEDGEMENT

The authors would like to acknowledge the support from colleagues at the UNU School for Land Administration, University of Twente, Netherlands in the development of this paper.

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BIOGRAPHICAL NOTES (PRESENTER)

Prof.dr Jaap Zevenbergen is a professor of land administration systems at ITC, University of Twente, and before was a staff member of Delft University of Technology. Prof.dr. Zevenbergen maintains over twenty years of teaching, research, and consulting experience in the domain of registration and administration of rights restrictions and responsibilities related to land and real estate.

CONTACTS

Dr. Rohan Bennett
University of Twente (ITC Faculty)
P.O. Box 217, 7500 AE
Enschede
NETHERLANDS
+31 (0) 534 874 339
r.m.bennett@utwente.nl
http://www.itc.nl/about_itc/resumes/bennett.aspx

Prof. Jaap Zevenbergen
University of Twente (ITC Faculty)
P.O. Box 217, 7500 AE
Enschede
NETHERLANDS
+31 (0) 534 874 351
Zevenbergen@itc.nl
http://www.itc.nl/about_itc/resumes/zevenbergen.aspx