LETTER

Temporal patterns in the size of conservation land transactions

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Abstract

The full or partial acquisition of land remains a predominant focus of terrestrial conservation strategies. Non-governmental organizations play an important role in habitat protection, yet few studies investigate their contribution to conservation investment. Here we examine temporal trends in the size of land transactions made by the world's largest land trust, The Nature Conservancy (TNC). We consider three dimensions of deal size (area, upfront cost, and relative cost per hectare) for two commonly used conservation approaches (fee simple acquisitions and conservation easements). Mean area of protected land parcels has been robust to the growing subdivision of properties for sale. Variation in the area and cost of transactions ranged between six and eight orders of magnitude, and increased through time as TNC undertook occasional large deals once established. Conservation planning approaches need to better account for the variation in deal sizes, and how this may change in response to dynamic budgets and priorities.

Introduction

Land acquisition is the cornerstone of terrestrial conservation strategies aimed at slowing persistent rates of habitat destruction and associated losses of biodiversity (Wilcove & Chen 1998; Ferraro & Kiss 2002). Current public sector investment falls substantially short of the expenditure required to protect habitats (Lerner *et al.* 2007) and non-governmental organizations (NGOs) have an important role to play in helping to address this deficit in investment (Albers & Ando 2003; Merenlender *et al.* 2004). However, habitat protection comes at a price and the conservation community is under increasing pressure to allocate limited financial resources effectively (James *et al.* 1999; Murdoch *et al.* 2007). Despite this, information regarding the strategic choices made by NGOs remains limited (but see Halpern *et al.* 2006; Lerner *et al.* 2007; Fishburn *et al.* 2009a, b).

In this article, we examine 50 years of land transactions made by The Nature Conservancy (TNC) across the United States. TNC is the largest environmentally oriented NGO in the United States, holding 20% of the overall sector's assets and managing 11% of total revenue (Straughan & Pollak 2008). Over the five decades TNC has been in operation, the organization has maintained a consistent conservation mission and homogeneous financial records of all land transactions; the temporal and spatial extent of the resulting data set is, therefore, unsurpassed.

We assess how the size of conservation investments has changed through time, focusing on three measures of deal size (area, upfront acquisition cost, and acquisition cost per hectare). Understanding the size of land transactions in terms of area remains one of the most fundamental questions in conservation planning. Since the late 1970s, when the "single large or several small" reserve selection debate came to the fore (Diamond 1975; Simberloff & Abele 1982), there has been much discussion regarding the optimal size of land parcels to be protected to maximize species richness (e.g., Pyke 1983) while sustaining minimum viable population sizes (e.g., Soulé 1987; Caughley 1994). More recently, research into maximizing the effectiveness of conservation efforts has focused on where protected areas should be located (Margules & Pressey 2000). Critically, the outcomes of such optimal reserve-site selection studies depend on the size of individual land parcels available for protection (Pressey *et al.* 1999; Warman *et al.* 2004). Since 1950, the size of rural land parcels in U.S. land markets has reduced due to the ongoing subdivision of properties for sale (Brown *et al.* 2004). Unless TNC has taken investment decisions that prioritized properties in a way that counteract this trend, the mean area of individual land transactions would be expected to have decreased through time.

In relation to the financial dimensions of deal size, there is a growing recognition that efficiency gains can be exploited by integrating spatially explicit land cost information into conservation planning (e.g., Ando *et al.* 1998; Naidoo *et al.* 2006). A change in the cost per hectare of properties protected by TNC through time could signal a move toward more strategic priority setting (Margules & Pressey 2000). The overall cost of land transactions is also important, especially when considering dynamic budget allocation decisions (Costello & Polasky 2004; Meir *et al.* 2004; Strange *et al.* 2006), as future options will become constrained if an organization commits to large individual deals.

We compare all three elements of deal size for two distinct approaches to land conservation: fee simple acquisitions and conservation easements. With fee simple acquisition, an organization takes ownership of a land parcel, whereas an easement is a voluntary agreement between a private landowner and an organization to restrict specific management rights on a parcel of land that are incompatible with conservation objectives (e.g., the right to clear-cut timber) (Merenlender *et al.* 2004; see Parker 2004 and Armsworth & Sanchirico 2008 for discussion on the comparative advantages of the two approaches). An improved understanding of the nature of properties available for protection via these two conservation approaches, and quantification of the relative costs involved, will help inform debates regarding what balance of investments is desirable in different socioeconomic and ecological contexts (Pence *et al.* 2003; Parker 2004; Murdoch *et al.* 2007; Armsworth & Sanchirico 2008; Nelson *et al.* 2008). Conservation planning strategies that incorporate such real-world information on opportunities and constraints are more likely to result in successful implementation (Knight *et al.* 2008).

Methods

Data collation

The TNC land transaction database comprised all deals made in the 48 contiguous states of the United States between 1954 and 2004. A "deal" was defined as the total area and cost invested in all subdivided land transactions of the same name, occurring within the same state and finalized within 1 month of each other. Only the upfront cost of acquisition was recorded within the database and thus the subsequent management costs for land parcels were not considered. In addition, inadequate spatial references for land parcels prevented us from identifying where transactions had been made to buffer previously protected sites. Nonetheless, this does not systematically bias our analyses as we are examining temporal, not spatial, patterns of investment. It should be noted, however, that the data set only represents the opportunities to protect land that were taken by TNC; we do not know what land parcels were considered by the organization but not acquired.

Six conservation investment data sets were constructed: the area (*Hectares*), cost (*Dollars*) and relative cost (*Dollars per Hectare*) of each deal were extracted from the database for both fee simple acquisitions and conservation easements. Deals relating to water rights (and therefore with an area of 0 ha) were excluded from the two area data sets, full donations were removed from the cost data sets, and both water rights and full donations were omitted from the relative cost data sets.

All financial data were standardized to 2004 to correct for inflation through time. Commonly, this would be achieved using price indices, such as the consumer price index (CPI). The CPI measures inflation based on the purchasing power of households by studying variation in the cost of a representative "basket" of consumer goods and services between time periods. Here we use the same principle to examine variability in the purchasing power of TNC, standardizing our financial data according to the more indicative change in price per hectare of farm real estate. This benchmark is more appropriate for our analyses and ensures that any changes detected in the cost of investments made by TNC occur over and above baseline trends in land price inflation. Historical land values were obtained from the U.S. Department of Agriculture's National Agricultural Statistics Service (USDA NASS) at the state-level, thereby allowing us to account more accurately for spatial variation in land markets across the United States at the same scale over which TNC operates (most land transactions are overseen by state chapters).

All data sets were log-transformed to meet assumptions of normality. This also guarantees that any increase in the variation in deal size is not simply a product of a multiplicative error structure.

Statistical inference

For each of the land conservation tools, associations between the three different measures of deal size (*Hectares*, *Dollars*, and *Dollars per Hectare*) were assessed using Spearman's rank correlation. Mann-Whitney U tests were used

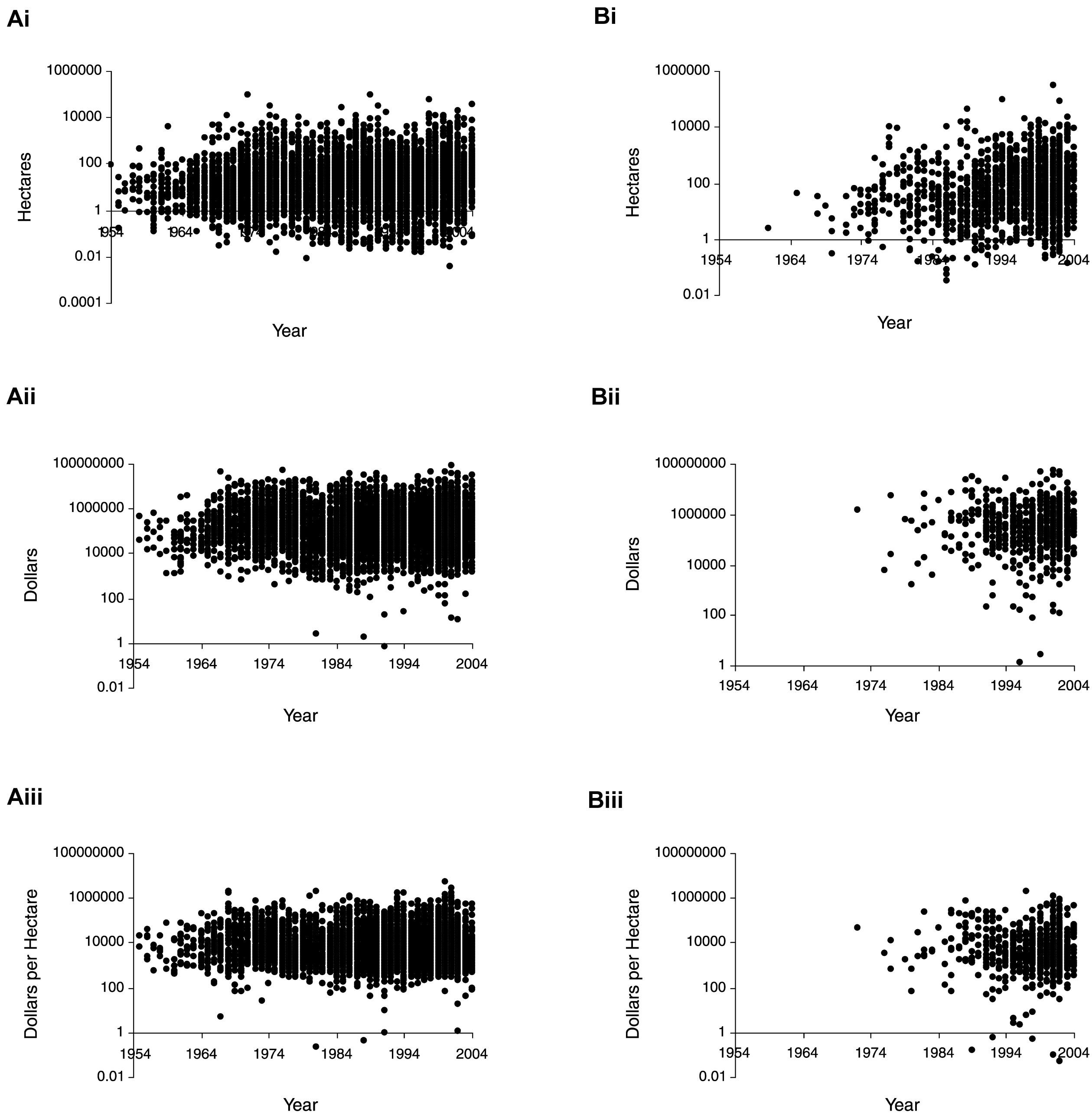

Figure 1 The size of individual deals, plotted on a logarithmic scale, through time for: (A) fee simple acquisitions and (B) conservation easements, measured by (i) area, (ii) cost, and (iii) relative cost per hectare.

to compare median deal sizes for fee simple acquisitions and conservation easements.

In all six investment data sets, the characteristic fan-shaped plot of individual deal sizes against year (Figure 1) indicated heteroscedasticity, which prevented us relying on simple linear regression to detect trends in the central tendency of deal size through time. Year-on-year changes in the annual variance for deal size were therefore examined using piecewise regression. For each data set, alternative two- and three-segment models were compared using information-theoretic methods. As sample sizes were less than 50, second-order Akaike Information Criterion (AIC*c*) values were used to control for the number of parameters and assess model parsimony. In all cases, a two-segment piecewise model was the most parsimonious descriptor of the relationship between annual

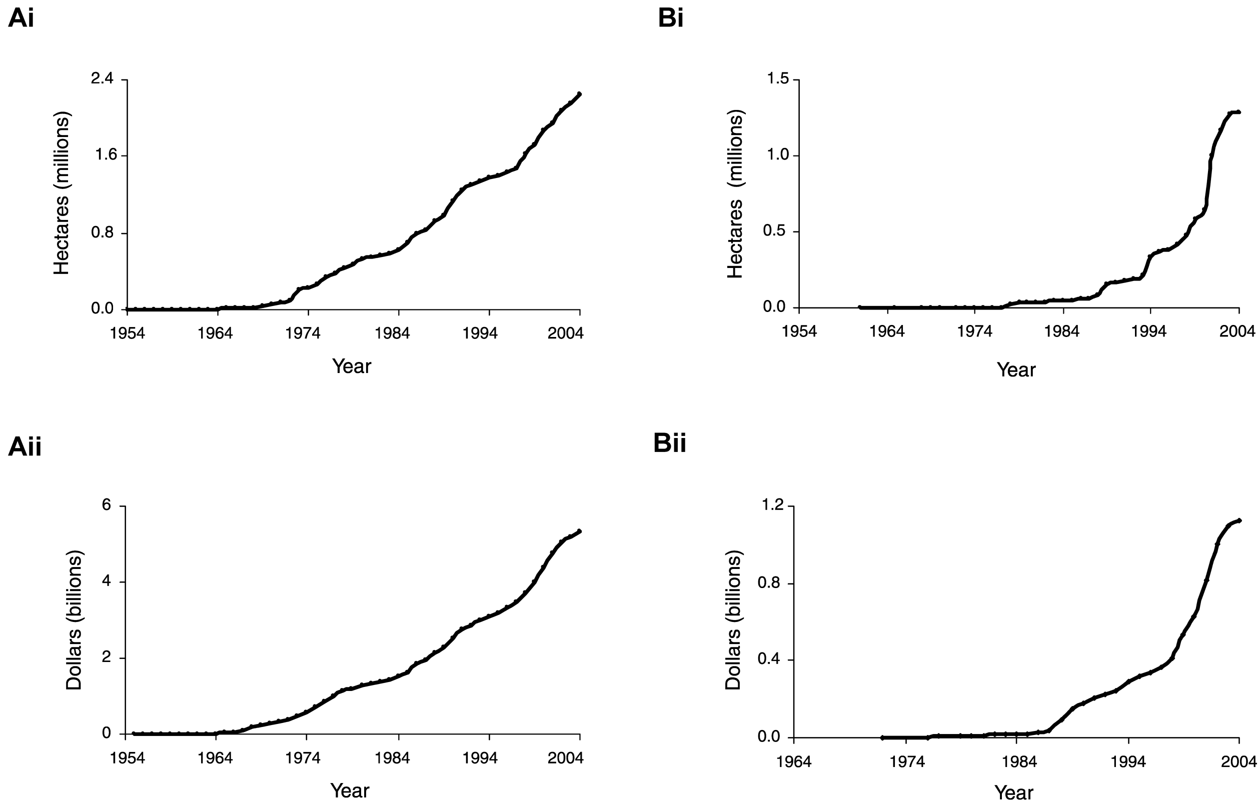

Figure 2 Cumulative patterns of deal size through time for: (A) fee simple acquisitions and (B) conservation easements, measured by (i) area and (ii) cost.

variance in deal size and time. Mann-Whitney U tests were used to confirm that the annual variances before the break point were smaller than those after. Finally, we examined trends in the central tendency of individual deal sizes using linear regression through the two time segments. Bias-corrected accelerated (BCa) 95% confidence intervals for the regression line slopes were bootstrapped based on 10,000 resampling events. All analyses were carried out in R (version 2.8.1, R Development Core Team 2008).

Results

Between 1954 and 2004, TNC made over 10,000 fee simple acquisitions, protecting in excess of 2.3 million hectares at an upfront cost of more than US$5.3 billion (Figure 2). In comparison, from 1961 and the introduction of conservation easements, TNC secured approximately 1,600 easement deals with a value of US$1 billion and coverage of 1.3 million hectares. The annual budget and total land area protected each year, for both fee simple acquisitions and conservation easements, has grown through time.

The area and cost of land transactions were correlated for both fee simple acquisitions and conservation easements (Figure S1), but leave much of the variation in the data unexplained (Table 1). Associations among other variables (e.g., hectares and relative cost per hectare), while present, are no stronger than would be expected given how the variables relate to one another.

The median cost per hectare for fee simple acquisitions was greater than that for easements by a factor of 1.2 (Figure 3; $z = -4.26$, $P < 0.001$). However, land parcels

Table 1 Correlation between different measures of deal size for fee simple acquisitions ($n = 7{,}115$) and conservation easements ($n = 733$)

		r_s	P
Fee	Hectares vs. dollars	0.71	<0.001
	Hectares vs. dollars per hectare	−0.49	0.496[a]
	Dollars vs. dollars per hectare	0.19	0.499[a]
Easements	Hectares vs. dollars	0.53	<0.001
	Hectares vs. dollars per hectare	−0.59	0.492[a]
	Dollars vs. dollars per hectare	0.29	0.502[a]

[a] Bootstrapped P values (based on 10,000 resampling events) are given for the correlations of hectares and dollars with dollars per hectare, due to the x and y values not being independent (Brett 2004).

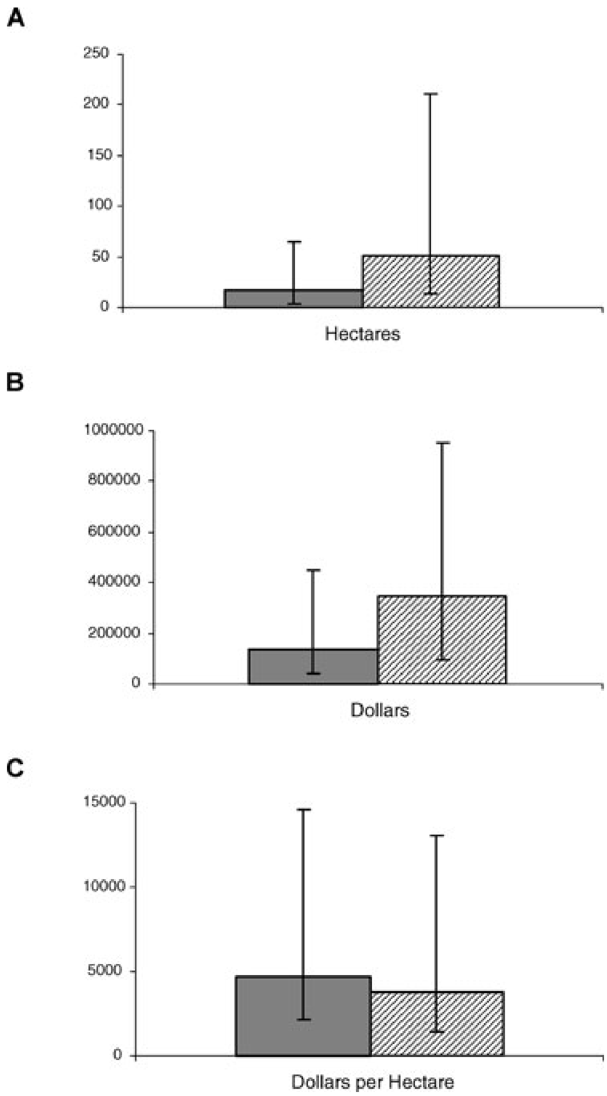

Figure 3 Comparison of median deal size for fee simple acquisitions (gray bars) and conservation easements (hatched bars), measured by (A) area, (B) cost, and (C) relative cost per hectare. Bars represent the interquartile range.

protected using easements were, on average, three-fold larger than those conserved by fee simple acquisition ($z = -19.55$, $P < 0.001$) and, when the two results are combined, the overall cost of an individual easement transaction was more than twice as large as that for a fee simple deal ($z = -11.25$, $P < 0.001$).

Over the 50-year study period, individual deal sizes exhibited considerable variation (Figures 1 and 3). The size of fee simple acquisitions differed by between six orders of magnitude for *Hectares* (range: 0.02–40,000) and eight orders for *Dollars* (range: 0.73–87 million). *Dollars per Hectare* (range: 0.22–5.5 million) varied by seven orders of magnitude. Similarly, the deal sizes for all three of the easement data sets differed by seven orders of magnitude (*Hectares*, range: 0.03–300,000; *Dollars*, range: 1.35–55 million; *Dollars per Hectare*, range: 0.08–1.8 million).

The break points generated by the two-segment piecewise models of annual variance of deal size through time were consistent for all three measures of investment for both fee simple acquisitions (range: 1967–1969) and easements (range: 1980–1986). Furthermore, for each data set, the annual variances for deal size were lower before the break point compared to those after (Figure 4), providing evidence that a time signal was indeed apparent. However, year-on-year changes in annual variance were harder to detect (Figure 4). A linear relationship of annual variance in deal size increasing over time was only evident for *Dollars per Hectare* for fee simple acquisitions in the segment prior to the break point (ß $= 0.17$ [SE $= 0.04$]; $F = 15.34$; $P = 0.001$; $R^2 = 0.53$), and for easements *Hectares*, both before (ß $= 0.49$ [SE $= 0.09$]; $F = 19.36$; $P = 0.002$; $R^2 = 0.67$) and after the break point (ß $= 0.10$; $F = 12.81$; $P = 0.002$; $R^2 = 0.33$).

When patterns in mean deal size through time were examined within segments, the size of individual deals increased for all of the fee simple acquisition data sets prior to each respective break point, as did *Hectares* for easements (Table 2). Correspondingly, the area protected in individual transactions also increased through time after the break point for both land conservation approaches. However, the models accounted for only between 0.4% and 24% of the variation in the data set segments, and the rate of increase in deal size was small in relation to the noise within the data sets.

Inspection of the *Hectares* and *Dollars* annual upper quartiles for fee simple transactions indicates that the increasing variability in deal size is a result of TNC investing in a growing number of relatively large land transactions (Figure S2). Nevertheless, the occurrence of these particularly large investments is not a standard practice and, consequently, does not drive sizeable increases in central tendency through time.

Discussion

Many theoretical studies have investigated how to optimize resource allocation for habitat conservation (see Margules & Pressey 2000; Naidoo *et al.* 2006 for examples), yet few studies have explored empirical patterns of investment made by conservation agencies or NGOs (but see Halpern *et al.* 2006; Lerner *et al.* 2007; Fishburn *et al.* 2009a, b). In this paper, we continue to bridge this knowledge gap between theoretical conservation

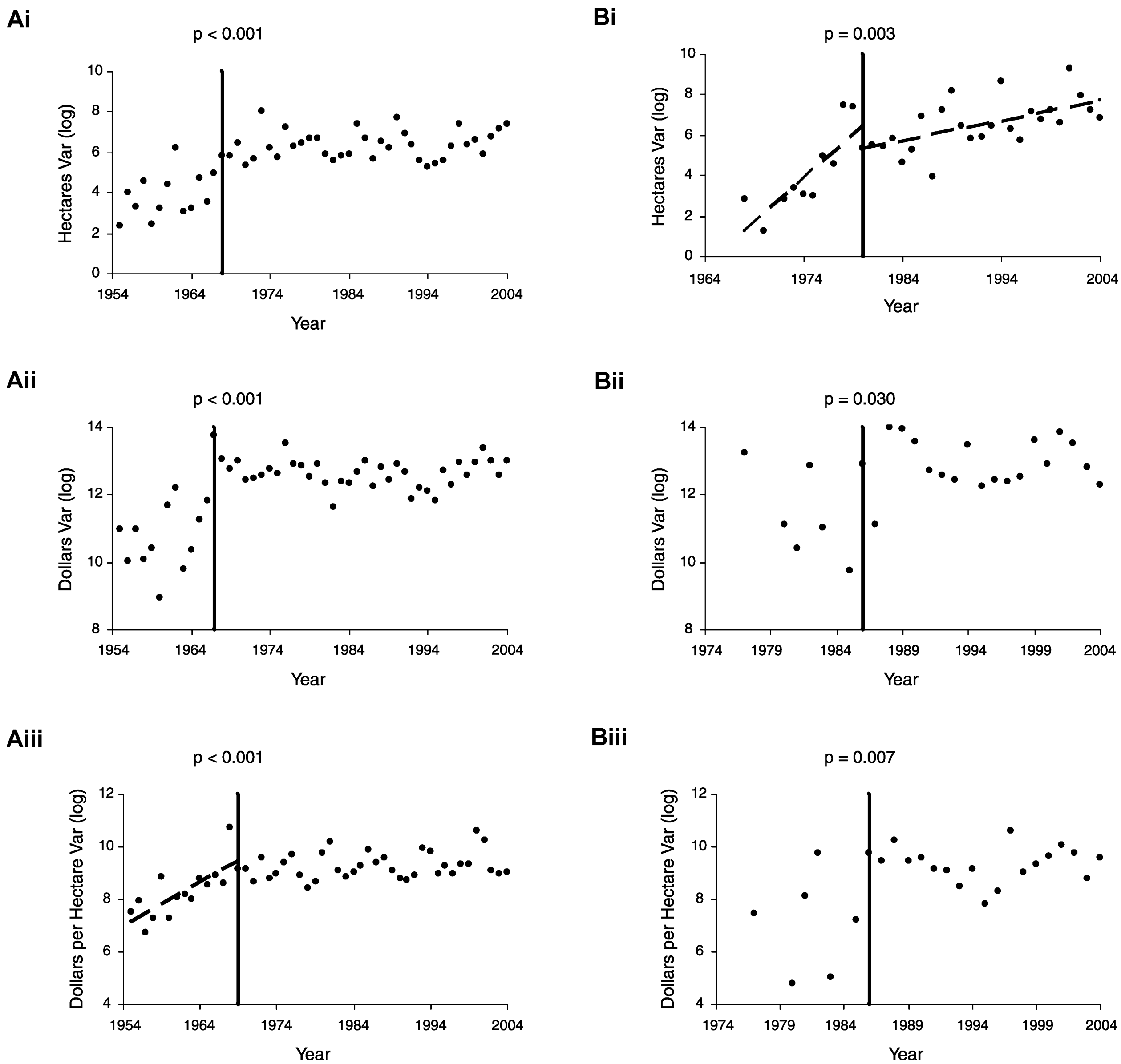

Figure 4 Annual variance for deal size through time for: (A) fee simple acquisitions and (B) conservation easements, measured by (i) area, (ii) cost, and (iii) relative cost per hectare. Solid lines indicate the break point generated by unconstrained two-segment piecewise regression models; dotted lines represent segment linear relationships; *P* values are given for Mann-Whitney U tests comparing median annual variances in deal size before and after the break point.

biology and on-the-ground practice by examining temporal trends in the size of land transactions made by the largest conservation NGO.

When deal sizes were compared between the different land conservation approaches, individual easements were three times larger in area and cost twice as much as fee simple acquisitions. However, fee simple deals were more expensive on a cost-per-hectare basis than easements. For both approaches, the area and cost of individual deals were correlated, but were not reliable surrogates for one another as much of the variability in the relationship was left unexplained.

Since 1954, the average area of TNC's fee simple acquisitions has risen, although the growth rate slowed after 1968. A similar pattern was observed for the size of easements, with a reduction in the rate of increase from 1980. This slight increase in the average area of deals through time has occurred despite a decrease in the size of rural

Table 2 Linear regression models for each data set before and after the break point determined by two-segment piecewise regression

	Break point year	Pre/post break segment	ß (SE)	R^2	F	P	Bootstrapped 95% confidence intervals
Fee hectares	1968	Pre	0.030 (0.012)	0.016	6.283	0.013	0.005–0.055
		Post	0.006 (0.001)	0.004	37.416	<0.001	0.005–0.009
Fee dollars	1967	Pre	0.043 (0.019)	0.032	5.210	0.024	0.008–0.085
		Post	0.002 (0.001)	0.000	3.376	0.066	−0.001–0.004
Fee dollars per hectare	1969	Pre	0.035 (0.015)	0.021	5.411	0.021	0.008–0.065
		Post	−0.001 (0.001)	0.000	2.418	0.120	−0.003–0.037
Easement hectares	1980	Pre	0.176 (0.039)	0.244	20.639	<0.001	0.102–0.273
		Post	0.028 (0.004)	0.03	47.467	<0.001	0.020–0.037
Easement dollars	1986	Pre	−0.036 (0.119)	0.007	0.090	0.769	−0.239–0.210
		Post	0.001 (0.008)	0.000	0.004	0.952	−0.015–0.016
Easement dollars per hectare	1986	Pre	0.006 (0.098)	0.000	0.004	0.950	−0.180–0.220
		Post	0.007 (0.008)	0.001	0.771	0.380	−0.024–0.011

land parcels available in U.S. land markets (Brown *et al.* 2004). Dissecting this divergence in more detail would require additional data on deals considered by TNC but not transacted.

The most striking discovery is the considerable variability in deal size across the 50-year period, ranging between six and eight orders of magnitude for both fee simple acquisitions and conservation easements. For example, variation in the cost per hectare of land protection is much greater than suggested in previous studies. Past estimates of per unit area costs have been derived from either local averages (e.g., the mean value of agricultural land within a U.S. county; Polasky *et al.* 2001) or observable land characteristics (e.g., soil productivity, elevation; Naidoo & Adamowicz 2006). The first of these methods cannot account for the fact that biodiversity depends on specific, not average, parcels of land. The second approach does not allow for the idiosyncratic nature of individual deals in land markets, where prices may reflect the opportunities, personal circumstances, and unobservable values of the vendor and buyer (Knight & Cowling 2007). Although some remote methods of estimating costs have generated reliable proxies for land values (e.g., Naidoo & Adamowicz 2006 achieved $R^2 = 0.89$ for actual versus modeled property prices across a 2,920 km^2 study area in Paraguay), others have been less successful (e.g., Jack *et al.* 2009 had an explanatory power of $R^2 = 0.08$ for estimates of short-term rental agreement costs in two Indonesian villages). Overall, such estimates have predicted the variation in the cost per hectare of conservation land transactions to be between two to four orders of magnitude (Ando *et al.* 1998; Naidoo *et al.* 2006), yet our findings demonstrate that the actual extent of the variation is much greater at seven orders of magnitude. Importantly, this means that the efficiency savings made possible by accounting for costs in conservation planning are likely to have been substantially underestimated.

TNC has become more willing to undertake occasional, particularly large land transactions as the organization has grown and realized that large landscapes are necessary for conserving many species and ecosystems. Interestingly, however, there has not been a systematic shift away from undertaking small deals as well, raising questions about whether it is efficient for one organization to fill both niches in the conservation market place. In addition, the ability of conservation organizations to undertake large investments once established is an important consideration for dynamic conservation planning studies (e.g., Costello & Polasky 2004; Meir *et al.* 2004; Murdoch *et al.* 2007).

Conservation practitioners and planners need to be cautious about how large protected areas will impact the surrounding landscape (Armsworth *et al.* 2006). "Leakage" can occur when conservation purchases push up surrounding land prices which, in turn, can potentially undermine conservation efforts by displacing development toward important habitats that remain unprotected (Armsworth *et al.* 2006; McDonald *et al.* 2007). To date, some have argued that the impact of such land market feedbacks are likely to be negligible due to the relatively small areas of land parcels protected by conservation organizations and agencies (Ando *et al.* 1998; Polasky 2006). However, we have shown that at least some conservation deals can be substantial in size.

TNC's willingness to undertake large land transactions has increased as the organization itself has grown. To determine whether growing rather than fixed annual budgets are the norm for conservation NGOs or something particular to TNC, we examined changes in expenditure between 2004 and 2007 of a randomly selected sample of 100 NGOs active in the biodiversity conservation sector and registered for tax purposes within the United States, using data collated from annual tax returns (available from www.guidestar.org and based on IRS 990 forms). The NGOs examined during this time frame had a positive growth rate (Wilcoxon signed rank test: $V = 3455$; $P < 0.001$) with an average increase of US$80,600 over the 3-year period after controlling for inflation. Similarly, there is evidence that expenditure is related to the number of years a NGO has been established (Figure S3). These results should be interpreted as preliminary, because we have not controlled for bias due to survivorship effects (Sutton 1997), but may reflect the ongoing expansion of the environmental nonprofit sector, which is growing faster than other nonprofit sectors and the economy at large (Harrison & Laincz 2008; Straughan & Pollak 2008).

Here we have illustrated that conservation practice is more influenced by internal (e.g., annual budgets) and external (e.g., size of available land parcels) constraints than is currently assumed by existing reserve-site selection tools. By incorporating such information into conservation planning approaches, they will become more indicative of how the business of conservation actually operates, better reflecting the trade-offs practitioners make between meeting conservation objectives, the relative level of protection afforded to a land parcel and the cost of protection.

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Supporting Information

Additional Supporting Information may be found in the online version of this article:

Figure S1 Correlation between the three different measures of deal size for: (a) fee simple acquisitions and (b) conservation easements.

Figure S2 Annual upper quartiles for deal size for fee simple acquisitions measured by: (i) area and (ii) cost. Solid lines indicate the break point generated by two-segment piecewise regression models.

Figure S3 Relationship between annual expenditure and the number of years a charity has been established for a random sample of 100 NGOs working in the biodiversity conservation sector that are registered for tax purposes in the United States. Linear regression: $ß = 0.14$ ($SE = 0.04$); $F = 15.48$; $P = 0.000$; $R^2 = 0.14$.

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