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Estimating Land Prices and Opportunity Costs of Conservation in a Megadiversity Country

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Abstract

We used data on 174 land purchases to estimate two aspects of opportunity costs across Western Cape Province, South Africa; (i) that of complete loss (acquisition cost), and (ii) and partial loss of benefits of land ownership, the latter due to biodiversity-friendly management on potentially arable private land. Observed land prices varied by more than four orders of magnitude (from $US 15.ha-1 to 178,000.ha-1 per unit area of farmland). Mean annual precipitation, percentage of untransformed land, property area, and topographic diversity were the most significant predictors of land price (R2 =0.67). Modelled acquisition costs were highest in vegetation types previously classified (based on biological importance and degree of conversion) as Critically Endangered. Our upper estimate of the annual opportunity costs of retaining remaining habitat patches ranged from negative to US$ 8,300.ha-1.yr-1 (mean $US 56.ha-1.yr-1, expressed per unit area of remaining natural vegetation). They were again highest in Critically Endangered (mean of $US 90.ha-1.yr-1) and lowest in the Least Threatened vegetation types ($US 40.ha-1.yr-1).

Keywords: land price, opportunity cost, vegetation types, biodiversity conservation, Western Cape

1. Introduction

Successful biodiversity conservation interventions depend on the availability of reliable information on both their benefits and costs (Balmford et al., 2003, Naidoo and Ricketts, 2006, Naidoo et al., 2006). However, data on conservation costs are scarce. In their absence, planners are often obliged to use poor proxies of cost, such as the area of the land under consideration. This paper considers two particularly poorly studied aspects of opportunity cost: (I) purchase/acquisition costs (the cost of complete loss of the benefits of landownership); and (ii) opportunity cost to landowners of biodiversity-friendly land management on private land (the cost of partial loss of benefits of land ownership). We illustrate how these costs can be estimated reasonably quickly and cheaply in areas with well functioning land markets.

Several authors have highlighted the substantial costs of effective biodiversity conservation, and the wide global and regional variation in management costs. The different conservation cost components include management, land purchase and opportunity costs. To date, few studies of the conservation costs have included land purchase/acquisition costs, and fewer still have considered opportunity costs of conservation on private land.

Two main approaches guide studies that estimate the opportunity costs of biodiversity conservation. The first involves the use of income values, such as potential net returns (per area.yr-1) from the most profitable alternative land use. The second approach involves estimating the land acquisition (purchase) costs or, the difference in the price of land under uses that are more or less favourable to conservation. Here, it is assumed that the sale value of a parcel of land is equal to the discounted flow of net revenue that the parcel is expected to generate into the future i.e. its Net Present Value.

In our study, we investigated variation in prices of farmland- a proxy for acquisition costs- across Western Cape Province, South Africa. We then used these to explore variation in opportunity costs of partial loss of benefits to landowners arising from a switch in land use management in potentially arable land across vegetation types of varying conservation priority. The Western Cape is an area of global importance for biodiversity: it contains most of one of 34 global hotspots - the Cape Floristic Region (CFR) - and much of a second – the Succulent Karoo. For the CFR, management and transaction costs are known; the management costs of a representative system of conservation areas for the entire CFR is estimated at $US 45.5 million.yr-1, discounted over a 20-year horizon, plus an additional annual maintenance cost of $US 29.6 million. These figures compare favourably to the US $1,100 million.yr-1 estimated benefits from the CFR's terrestrial ecosystem goods and services.

Here we focus entirely on agricultural land, and exclude other forms of land use. We seek to answer the following questions:

1. How much do land prices vary across a representative sample of farms in the Western Cape?
2. Which factors predict this variation in land price, and how?
3. To what extent can these factors be used to predict land prices, hence estimate acquisition costs across the Western Cape?
4. How do predicted land prices (acquisition costs) and opportunity costs (partial loss of benefits of landownership) vary across vegetation types, which differ in conservation priority?

2. Materials & Methods

Study area

The study area comprises the Western Cape Province, an area of 129,370 km2, which includes most of the Cape Floristic Region (Fig. 1a). The CFR has attracted global attention due to its high floristic endemism, and high levels of threats to its biodiversity from expansion of intensive agriculture, urbanisation, and invasive alien vegetations .

Gathering data on land price

We built our dataset from a variety of sources (Table 1), and included all properties for which we knew:

1. Identity of the property (name or unique identification number);
2. Size of the property (the total area of the land parcel);
3. The value of the property estimated from the sale price (amount paid for an agricultural property in a completed transaction) or listed price (the price requested for a property on the market). All sales were assumed to have been undertaken in the open market;
4. Year of sale. Pre-1995 sales were excluded because of the reforms in land policies instituted by the post-apartheid government in 1994;
5. Percentage of land transformation as estimated from a GIS layer .

We excluded properties if: (1) they could not be accurately located; (2) they were donations for conservation; (3) they were not bona fide market transactions (e.g. family exchanges); (4) they less than 10 ha (farming is considered to be un-economical below 10 ha [M. Botha, ReMax Properties, pers.comm.], or; (5) In the Estate Agents dataset (Table 1), there was considerable discrepancy between the property area as reported by the estate agents and the area in the GIS database (>500 ha or >100% of reported area). The final dataset comprised 174 farms. All the properties were spatially geo-referenced on a digitised 1:50,000 map (Directorate of Surveys & Mapping, SA) using names and/or unique property (ERF) numbers.

All datasets gave information on sale price with the exception of the estate agents', which, for 27 properties gave information only on listed price. We predicted the equivalent sale price for these properties based on the relationship between listed and sale price of 25 properties as recorded in the Cape Property Services dataset:

$$\text{Sale price} = 0.9784 \times \text{Listed price} \quad (R2 = 0.99,\ n=25)$$

All analyses were based on sale price and the data processed using Arcview GIS 3.2 software (ESRI, Redlands, California).

Standardising land price

We used the 1995 - 2002 and the 2003 - 2004 South African GDP deflator to standardize all land purchase prices to year 2000. We chose year 2000 as the base year because it had the highest number of property sales in our final dataset, and because it is the base year for national accounts estimates at constant prices. We expressed land prices in South African Rand per hectare of farmland (R.ha-1) and in US $.ha-1, using the exchange rate of 1st July 2000 (US$ 1=ZAR 6.79).

Spatial predictors

We conducted a literature review, expert consultations, and interviews with commercial estate agents and identified 20 potential predictors which we thought might influence agricultural property prices: mean annual precipitation (Fig. 1b); altitude; topographic diversity (surface area divided by the planimetric area); proximity to coastline, major and all roads, rivers, and urban centres; mean agricultural land capability; mean crop production potential for different crops (lupens, lucern, wheat, oat, barley and wine); property area; percentage of untransformed land (i.e. natural vegetation: Fig. 1b); human population density in the surrounding area (based on 1996 census); vegetation groups; and geological groups. We could not generate sufficient data on improvements to farms (buildings and other infrastructure) for the study area.

We obtained all the spatial layers from the South African National Biodiversity Institute , with the exception of agricultural land capability and crop production potential that were provided by the Agricultural Research Council (ARC, Stellenbosch), and population density provided by Statistics South Africa (StatsSA). The land capability layer classifies land based on its overall suitability for ecologically sustainable use for crops, grazing, woodland and wildlife. For the last two predictors, we reclassified the original 120 vegetation types into 20 groups based on a set of biogeographic features, and also reclassified the original geology layer from 54 geological types to 15 geological groups based on soil types and fertility.

Statistical analysis

We carried out a preliminary statistical analysis to quantify univariate correlations among potential predictors and excluded mean crop production potential of oat and barley because they were 99% correlated to mean crop production potential for wheat. We then used a stepwise Generalized Linear Model (GLM) in S-PLUS (S-Plus 2000 version, Mathsoft Inc.) to predict land price using 18 of the predictors listed above (Table 2). Land prices were log10-transformed to fit a normal distribution. The model was calibrated using 121 randomly selected properties and validated on 53 properties. From the calibration data set, an initial model was produced by selecting variables on the basis of R2 values and Akaike's Information Criteria (AIC). The use of stepwise regression reduces collinearity amongst the variables. We then excluded one predictor at a time (the last predictor entered in the initial model) and tested model performance on the validation data set. Due to possible over-fitting in the initial model, models with fewer variables could lead to a higher R2 in the validation data set. We retained the model with the highest R2 in the validation data set (Table 3), and then used this final model to predict land price for 30,150 cadastres across the Western Cape Province.

Estimating opportunity cost for landowners partial loss of benefits of landownership

In our study area, livestock and crop production are the two main land uses that could conflict with conservation. Estimating the foregone profit from limiting livestock production involves quantifying potential losses that could be incurred from stock reduction. Our land price model was not suitable for that purpose, so we restricted our analysis to crop-suitable areas.

We considered potentially arable land as defined by the agricultural land capability surface. We selected all 12,278 cadastres – with some remaining natural vegetation – and with a land capability index between 1 (land suitable for irrigated crops) and 6 (land marginally suitable for crops). We assumed that conservation of the remaining natural vegetation on private land could be undertaken voluntarily by landowners, or through legal restrictions. We therefore estimated the cost of partial loss of benefits of landownership to landowners of retaining remaining natural areas within each cadastre. We did this by calculating the difference between the predicted current land price (i.e. with natural vegetation retained) and the predicted land price if all remaining natural habitat were to be fully converted to agriculture, minus the estimated costs of conversion (Sinden, 2004):

$$\text{Opportunity Cost} = \left[\frac{\text{NPV}}{\text{Area}}\right] - \text{Conversion Cost}$$

Where;

$$\text{NPV} = (\text{LVF - LVP})$$

Area refers to the farmland portion consisting of natural vegetation; LVF refers to the estimated price of the farm if it is 100% transformed, and LVP refers to the estimated price of farm at the present level of transformation. We used a discount rate of 8% to annualise the opportunity cost figures.

Conversion cost comprises of on-farm costs of vegetation clearing, soil ripping and labour. We estimated the maximum and minimum took the mean cost of conversion as $US 74.ha^{-1} of remaining natural vegetation.

This method can generate negative opportunity cost values (where our model estimates that unconverted land cost more to convert than it would yield following conversion); this situation arose for one cadastre. Note that because non – converted land is in reality likely to be less productive than already converted land (but by unknown amount), our approach probably overestimates the opportunity costs of non – conversion. No data was available at a spatial scale fine enough to capture within-farm variations in crop suitability.

The cost of complete (acquisition costs) and partial loss of benefits of land ownership in relation to biodiversity conservation priorities

To explore the relationship between opportunity cost and conservation priority, we assigned our farms to one of four conservation priority classes based on their predominant vegetation type (Table 4). These classes; Critically Endangered (CE), Endangered (EN), Vulnerable (VU) and Least Threatened (LT) reflect national biodiversity targets for each vegetation type, and the extent to which they have been transformed .

We divided the sum of the predicted land prices for all 30,102 cadastres assigned to a given vegetation type by their total area to calculate mean land price per hectare of farmland for that vegetation type, and then calculated the area-weighted mean price per hectare of farmland for all the vegetation types in a given priority class. Similar calculations were done for estimating the mean cost of partial loss of benefits of landownership (opportunity cost)/ha of remaining natural vegetation.

3. Results

Variation in land price

Our dataset revealed very substantial variation in land prices across Western Cape, spanning more than four orders of magnitude (from $US 15.ha-1 to 178 000.ha-1 of farmland) (Fig. 1a). This striking variation was not the result of bias in our sample: the frequency distribution of property sales in our final dataset was remarkably similar to that for all agricultural properties listed in a reference dataset, the Farmer's Weekly (n=529 farms). The modal band for land prices was between $US 101 and 1000.ha-1 of farmland (Fig. 2).

Land price model

The best model for predicting land price included four predictors: mean annual precipitation; percentage of untransformed land; property area; and topographic diversity (R^2 = 0.66 and 0.67 for the calibration and validation data sets respectively; Table 3). We checked that land prices did not vary systematically across our nine data sources (by entering source as a further term in the GLM), but found no effect.

We then explored the partial effects of the model predictors by plotting residual land prices against each predictor. Residual land prices were positively associated with mean annual precipitation (Fig. 3a), and negatively related to the percentage of untransformed land (Fig. 3b). After accounting for the association with both mean annual precipitation and percentage of untransformed land, lower prices were paid per hectare of farmland for larger land parcels (Fig. 3c). Finally, we observed a negative association between residual land prices and topographic diversity of farms; rugged land was relatively cheap (Fig. 3d).

Estimating the opportunity cost of outright land purchase (acquisition cost)

To estimate the land purchase (acquisition) cost, we extrapolated the predicted land price for each cadastre to generate a land price map for the province (Fig. 4a).

Areas of high conservation priority have high acquisition costs. The mean predicted land price was $US 1,160.ha-1 of farmland for Critically Endangered (CE) vegetation types, $US 970.ha-1 for Endangered (EN) vegetation types, $US 490.ha-1 for Vulnerable (VU) vegetation types, and $US 220.ha-1 for Least Threatened (LT) vegetation types. Surprisingly, even within each priority class, there was considerable variation; Land prices ranged from $US 590 to 5,600.ha-1 of farmland within CE vegetation types, from $US 260 to 9,000.ha-1 of farmland within EN vegetation types, from $US 126 to 2,300.ha-1 of farmland within VU vegetation types, and from $US 37 to 9,130.ha-1 of farmland within the LT vegetation types.

Estimating opportunity cost of retaining natural vegetation on private land

The mean estimated opportunity cost per hectare of retaining the remaining natural vegetation was $US 56.ha-[1].yr-1. However, this masked very substantial variation across the province, with costs per unit area for individual cadastres ranging from negative cost to $US 8,300.ha-1.yr-1. More than 90% of the cadastres had a predicted mean opportunity cost of less than $US 500.ha-1.yr-1 (Fig. 4b).

The highest opportunity costs are incurred in CE vegetation types (mean of $US 90.ha-1 of remaining natural vegetation/yr). EN vegetation types incur a mean opportunity cost equivalent to $US 70.ha-1.yr-1, VU vegetation types, $US 60.ha-1.yr-1, and LT vegetation types, $US 40.ha-1 of remaining natural vegetation/yr (Fig. 5). Considerable variation was found among vegetation types of the same class; for example opportunity cost for CE vegetation types ranged from $US 52 to 554.ha-1.yr-1, (Fig. 5).

4. Discussion

Variation in land prices and opportunity costs of vegetation retention on private land

Our analyses have yielded two main results. Firstly, we found enormous variation – of more than four orders of magnitude – in observed land prices (from $US 15 to 178 000.ha-1 of farm land: Fig 1a) and predicted land prices (acquisition costs: Fig.4a) across the Western Cape. Similar variation applied to our estimated opportunity cost of retaining natural vegetation of private land (from negative cost to 8 300.ha-1 of remaining natural vegetation/yr: Fig 4b). Secondly, both acquisition and opportunity cost of vegetation retention on private land co-varied positively with conservation priority; both were highest within Critically Endangered, and lowest within Least Threatened vegetation types.

Three important sets of caveats should be considered. Firstly, while our model of land price was based on intuitively sensible predictors and had reasonable predictive power (similar to that reported by, its application for conservation planning effectively assumes that the current price of land captures the expected NPV of future benefits from that land. While this is true in well functioning land markets, rigidities in the South African land market may make this assumption untenable; compulsory land acquisition may inflate land prices beyond our current estimates. Secondly, our model does not take into account the dynamics in the land markets, and other factors such as the expansion of markets e.g. for wine, creating pressure to convert land to viticulture; and the enactment of new land use legislations e.g. National Environmental Management: Biodiversity Act, that could impact on conservation outcomes.

Third, our method assumes that non-converted land has the potential upon conversion to be as profitable as converted land (under similar environmental conditions). This assumption may be wrong; hence our estimates of absolute cost should be treated with caution. Nevertheless, we believe the extent and pattern of variation we found still hold.

Given the wide variations in management costs, our findings are not entirely surprising, but they are nevertheless striking; opportunity costs (like other costs) are highest in areas of high conservation priority because these areas are characterised by multiple socio-economic pressures. This variation has crucial implications for conservation planning and practice.

Application to conservation planning and policy

In most conservation planning exercises, decisions on the allocation of resources are made purely on biological criteria, ignoring socio-economic constraints. However, variability in economic factors can be just as important as ecological variability for conserving biodiversity efficiently and effectively. That is certainly true in the Western Cape, where we found that the variations in opportunity costs are enormous (Fig. 4), where costs co-vary positively with conservation priority identified on the basis of biological criteria (Fig. 5). Most surprisingly, even within high conservation priority areas (such as CE vegetation types), within-class variations in opportunity costs are considerable. These findings suggest that explicitly incorporating (rather than ignoring) such cost variation could contribute substantially to refining of conservation priorities as a first step towards efficiency. The second step involves investigating the extent to which addressing costs changes priorities i.e. determining the efficiency gains on no-cost and cost accounted scenarios, for which studies are now underway in the CFR.

Lastly, moving from planning to implementation, our results can be useful in two ways. First, the land acquisition costs surface (Fig 4a) is useful in identifying opportunities for strategic expansion of reserves between and within-conservation priority classes given a limited budget. Second, our estimation of opportunity cost for landowners of retaining natural vegetation on private land (Fig. 4b) can inform the development of proposed off-reserve conservation mechanisms, including conservation easements and payments for biodiversity services. Our results can be used to determine land owners payment level that is at par with the opportunity costs of compliance in a payment for biodiversity scheme, with the variations in costs, which we uncovered, reflected on variable levels of payments. These mechanisms have already been initiated to encourage landowners to protect Critically Endangered vegetation types (M. Botha, Botanical Society of South Africa. Pers. comm.). Our study forms an initial first step towards the integration of economic costs into conservation planning in the study area, with a potential for replication in other African countries to help increase cost-effectiveness of conservation interventions.

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Tables

Table 1. List of datasets on land purchases.

Source	Spatial Locality	Period	Original Size	No Used
National Dataset				
1. Farmer's Weekly Journal	Farm Name	2003-2004	529	61
2. SANParks[a]	Farm Name & ERF No	1998-2003	34	17
3. WWF-SA	Farm Name & ERF No	1968-2002	94	19
Provincial Dataset				
1. Estate Agents	Farm Name	2004	50	35
2. Western Cape Department of Agriculture	Farm Name & ERF No	2001-2004	68	18
3. Cape Property Services[b]	Farm Name & ERF No	1995-2004	408	1
Local Dataset				
1. FFI[c]	Farm Name	1997-2002	16	10
2. Parker, R MSc Project	Farm Name		40	9
3. Landowners	Farm Name & ERF No		4	4
Total sample size (n)				174

[a] *South Africa National Parks Authority*
[b] *Most of the CPS data were excluded because of the reasons explained in page 7. The dataset also contained information on non-agricultural properties (commercial, residential and other property types).*
[c] *Fauna and Flora International.*

Table 2. Variables used in the model to predict land prices in Western Cape Province, South Africa.

Variable[a]	Units	Group	Entire Study Area (n=30150)			
			Mean	Std Dev	Min	Max
MAP	mm/yr	climate	349.08	196.83	33.90	2036.8
ALT	meters	topography	351.13	309.91	1.10	2096.60
ROUGHNESS		topography	106.04	8.75	100.00	244.88
DCOAST	meters	spatial	512.34	451.14	0.00	2652.0
DROAD1	meters	spatial	98.69	120.39	0.00	1126.0
DROAD12	meters	spatial	10.82	18.78	0.00	204.00
DRIVERS	meters	spatial	11.93	19.76	0.00	213.00
DURBAN	meters	spatial	101.77	98.71	0.00	716.00
LANDCAP	score (1-9)	production	5.72	1.49	3.00	8.00
LUPENS	tons/ha	production	0.95	0.84	0.00	3.7
LUCERN	tons/ha	production	13.47	5.64	0.00	22.80
WHEAT	tons/ha	production	2.27	1.56	0.00	6.00
WINE	tons/ha	production	3.93	3.29	0.00	15.90
AREA	ha	farm size	421.51	921.77	10	40072.50
NATVEG	percentage	land use	54	41	0.00	100
POPDEN	log (people/QDS)		3.72	0.85	1.40	6.10
VEGGROUP	20 categories	vegetation				
GEOL.FERT	15 categories	geology				

[a] MAP = mean annual precipitation; ALT = altitude above sea level; ROUGHNESS = topographic diversity; DCOAST = minimum distance from the coastline; DROAD1 = distance to the nearest major road; DROAD12 = distance to the nearest minor or major road; DRIVERS = distance to the nearest river; DURBAN = distance to the nearest urban center; LANDCAP = land potential based on geo-physical and climatic variables; LUPENS = mean potential lupens production; LUCERN = mean potential lucern production; WHEAT = mean potential wheat production; WINE = mean potential dry wine production; AREA = total area of farm; POPDEN = mean population density; VEGGROUP = dominant vegetation group; GEOGROUP = dominant geological group.

Table 3. Stepwise Generalised Linear Model showing the steps, co-efficient values to reflect the statistical effects for the predictors, residual deviance and Akaike's Information Criteria (AIC)

	Model[a] + Step	DF	Resid.Dev	Co-efficient Values	AIC[b]
			105.45		-19.26
1	MAP	1	65.93	0.001923	-75.97
2	+ NATVEG	1	50.33	-0.546204	-107.70
3	+ AREA	1	43.98	-0.348359	-122.57
4	+ ROUGHNESS	1	41.12	-0.019553	-128.99

[a] variables were mean annual precipitation (MAP); percentage of untransformed land (NATVEG); area of property (AREA); and topographic diversity (ROUGHNESS)
[b] Akaike's Information Criteria

Table 4. Number of vegetation types in potentially arable land in Western Cape in each of the four conservation priority classes as categorised by the South African National Spatial Biodiversity Assessment

Priority Class for Vegetation Conservation	No. Of Vegetation Types
Critically Endangered (CE)	13
Endangered (EN)	23
Vulnerable (VU)	8
Least Threatened (LT)	12
Total	**56**

Figures

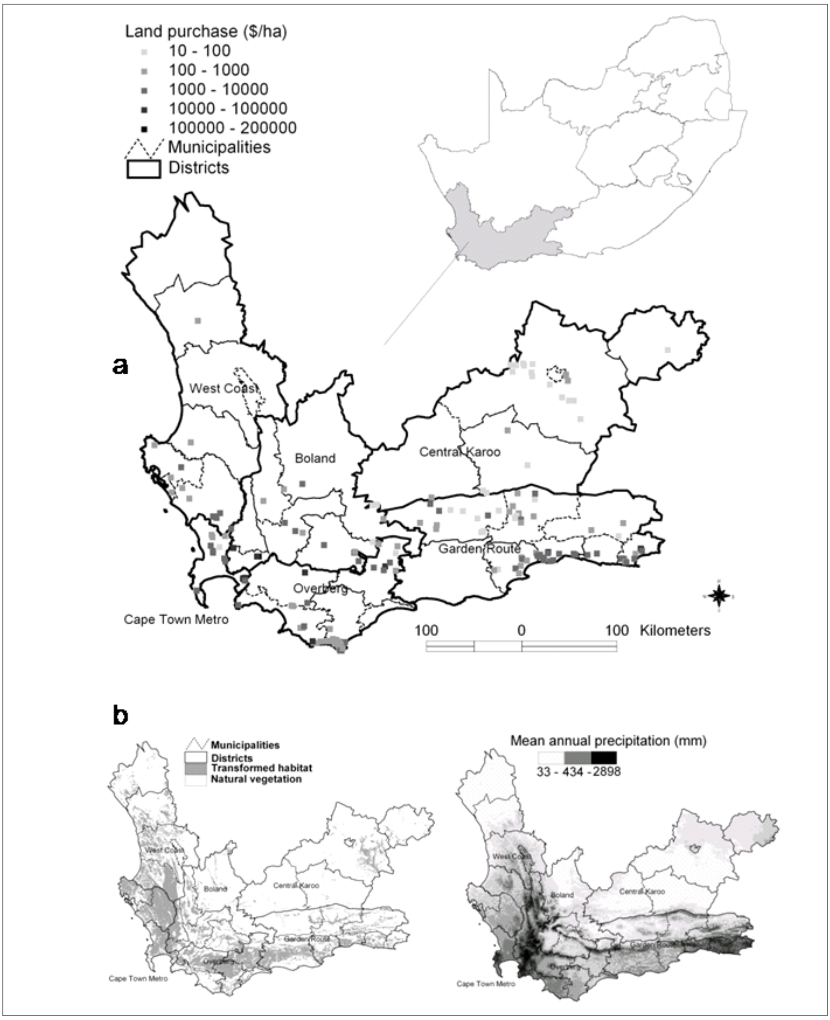

Figure 1: Study area showing a) district boundaries and spatial variation in observed land prices ($US.ha-1); and b) land transformation and mean annual precipitation.

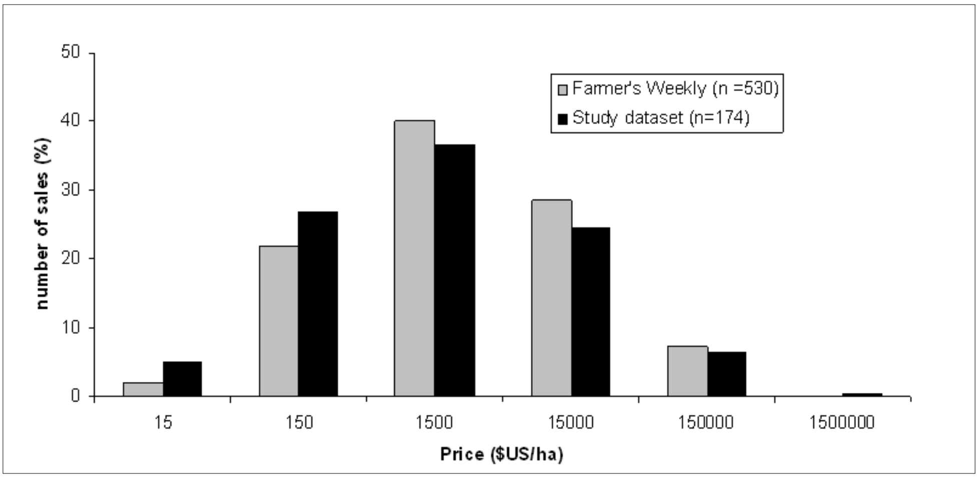

Figure 2. Frequency distribution of property sale price ($US.ha-1) for study dataset and Farmer's Weekly dataset (used as a Reference dataset).

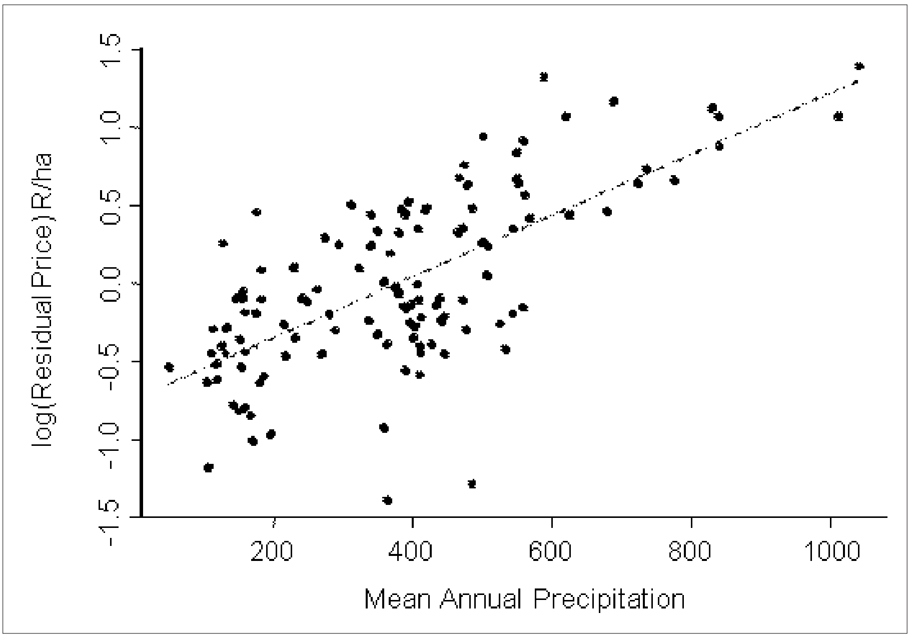

Figure 3a. Residual land prices ($US.ha-1) in relation to mean annual precipitation.

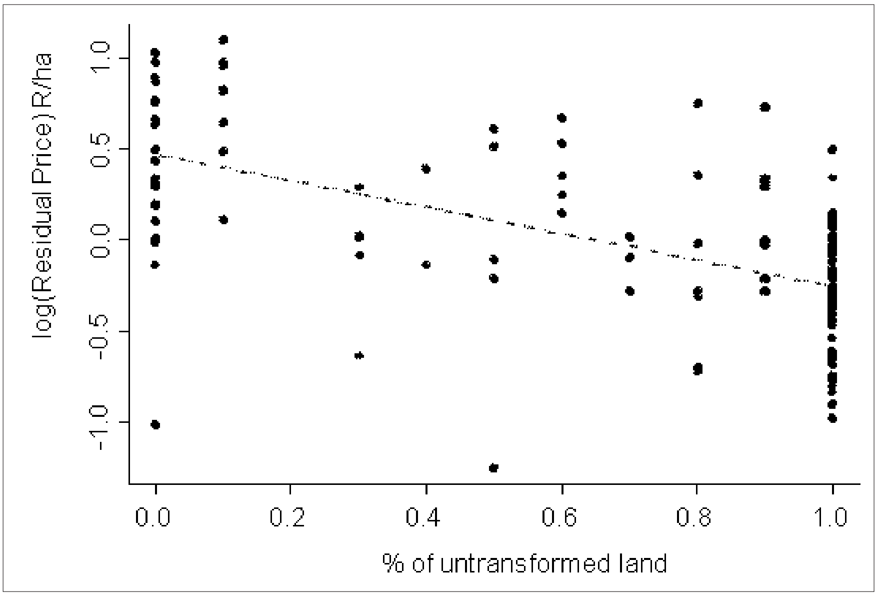

Figure 3b. Residual land prices ($US.ha-[1]) in relation to the percentage of untransformed land

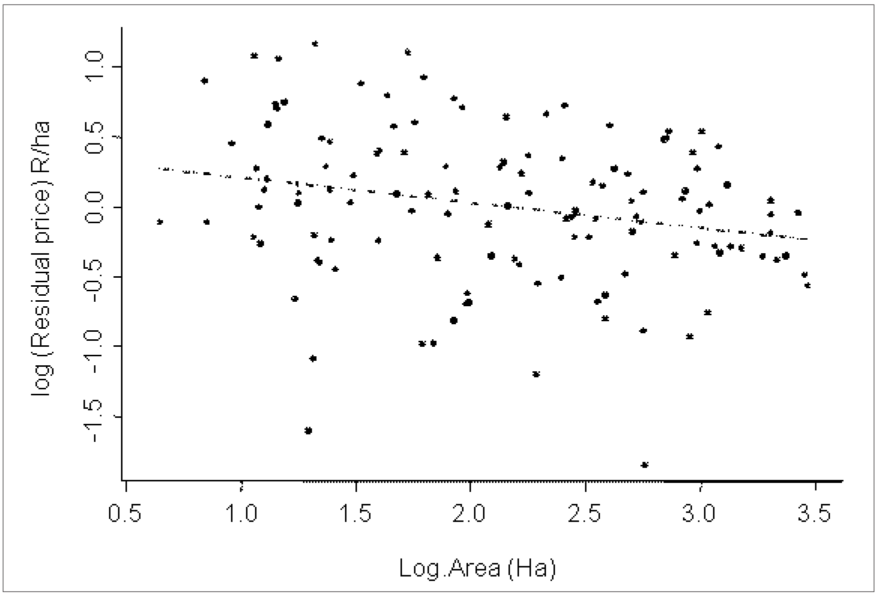

Figure 3c. Residual land prices ($US.ha-[1]) in relation to property area

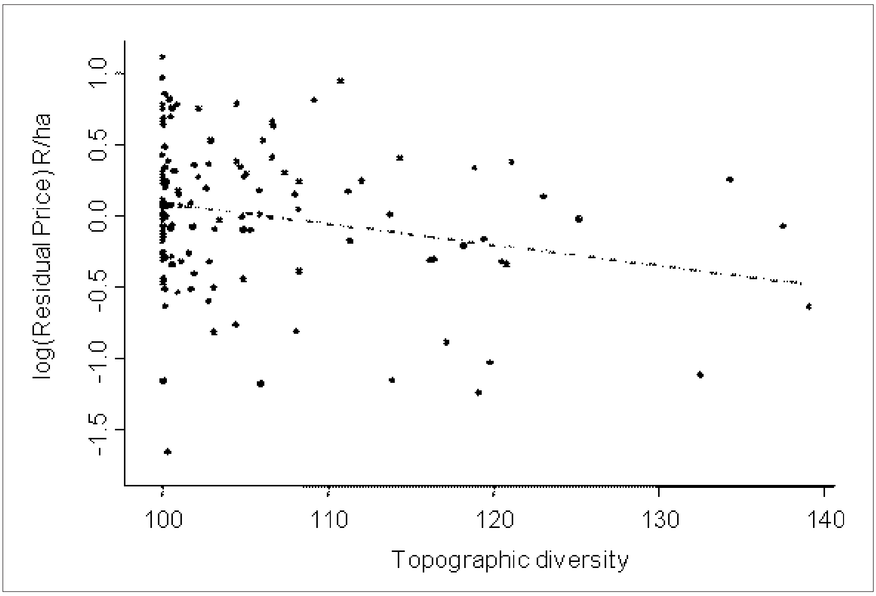

Figure 3d. Residual land prices ($US.ha-[1]) in relation to topographic diversity

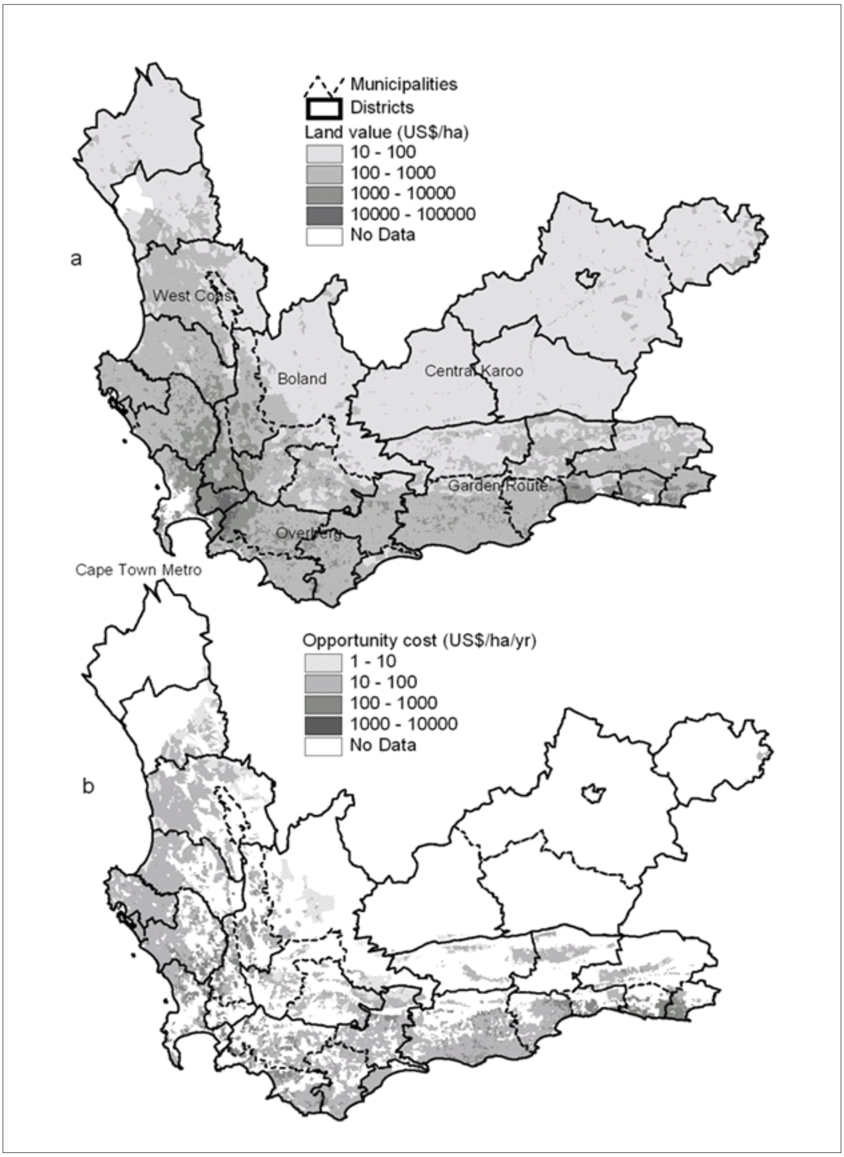

Figure 4. Predicted surface of a) land prices in ($US.ha-1) as a proxy for acquisition costs (total loss of benefits of landownership), and b) opportunity costs of retaining natural vegetation on private land in ($US.ha-[1].yr-[1]) (partial loss of benefits of land ownership)

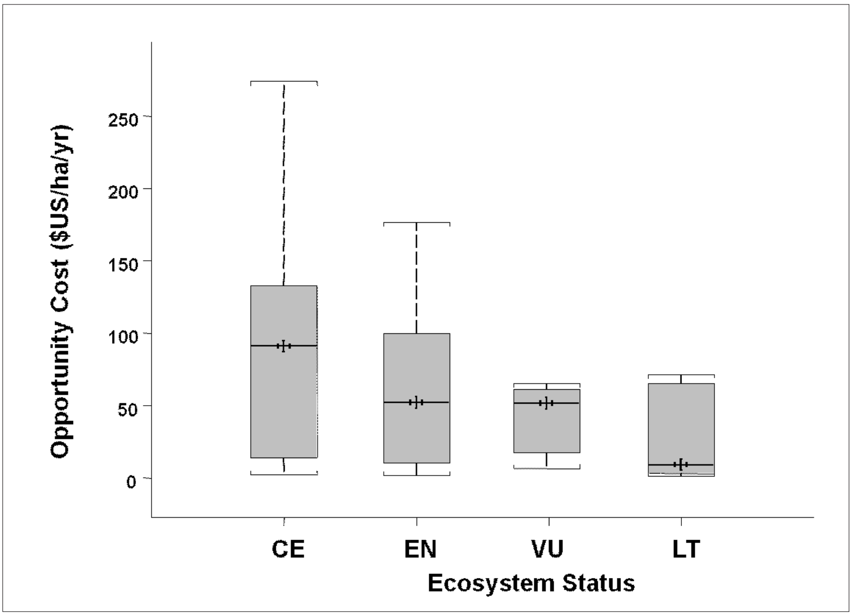

Figure 5. Opportunity cost ($US.ha^{-1} of remaining natural vegetation per year) showing upper 90 percentile, lower 10 percentile and mean per priority class of the four vegetation types (CE-Critically Endangered; EN-Endangered; VU-Vulnerable; and LT-Least Threatened) in Western Cape Province.

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