The conservation costs and economic benefits of using biodiversity offsets to meet international targets for protected area expansion

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SUPPLEMENTARY MATERIAL S1 Calculating offset multipliers based on the relationship between biodiversity target, current protection levels and habitat intactness

The draft South African biodiversity offset policy aims to ensure the no net loss of biodiversity in each ecosystem against a benchmark defined by the ecosystem-specific biodiversity target.

This multiplier, *m*, is calculated as:

$$m = \left[\frac{I - P}{(I - P) - (B - P)}\right] - 1$$

where *I* is the percentage of intact habitat, *P* is the percentage currently protected and *B* is the ecosystem-specific biodiversity target. From this equation it is clear that multipliers become impractically high for ecosystems that are poorly protected and have been transformed extensively (Fig. S1).

Multipliers calculated in this way represent the bare minimum offsetting ratio. In practice, multipliers would be higher to incorporate the risks involved with offset failure, the uncertainty in underlying datasets and spatial concentration of important biodiversity features.

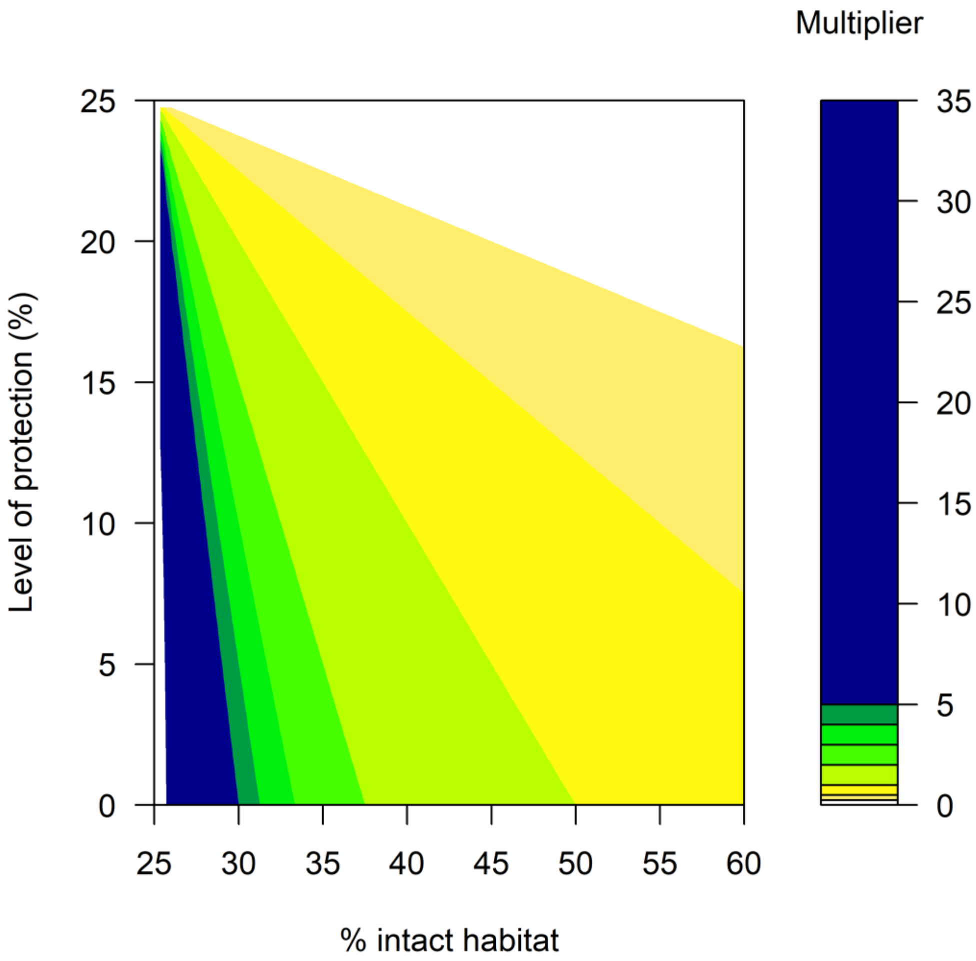

FIG. S1 The biodiversity offset multiplier (i.e. the ratio of area lost to transformation and the area to be protected, represented by the colour ramp) for hypothetical ecosystems with biodiversity targets of 25% and varying combinations of current protection and intact habitat.

Supplementary Material S2 Quantifying the economic gross value-added factor cost from transforming land

We obtained national spatial data on the gross value-added factor cost (GVA, Naudé et al. 2007), which is an estimate of revenue from regional economic activity as updated in 2011. GVA data were compiled for 6,717 homogeneous socio-economic units known as mesozones, with one GVA unit representing ZAR 1,000,000 (c. USD 70,000 in 2016). These mesozones are planning units (each c. 50 km^2) delineated by the South African Council for Scientific and Industrial Research. For our study we considered economic revenue generated by three sectors only: (1) Agriculture and forestry, (2) mining and quarrying and (3) electricity, gas and water supply. These three sectors were expected to be more closely linked to land transformation compared to, for example, manufacturing or retail.

The GVA of each ecosystem type was quantified as the sum of the GVA from all the mesozones within it. The total economic value was then divided by the area of the ecosystem type to determine the value per km^2. As the GVA data were based on actualvalues rather than forecasts of economic potential, we regressed the GVA per km^2 of each ecosystem type against the proportion of intact natural habitat (Fig. S2). We assumed that more heavily transformed ecosystem types would have yielded higher economic revenue.

Prior to regression, GVA per km^2 was log transformed. We examined five relationships in the data (*lm* and *nls* commands in the *stats* package) using *R v. 3.1.2* (R Development Core Team 2014) (Table S1). Although the exponential and asymptotic exponential models fit the data equally well (ΔAIC = 0.78), we used the asymptotic function in our simulations because we assumed that the most lucrative portions of an ecosystem would be developed for economic gain first and that subsequent developments would be relegated to marginal areas that offer considerably fewer economic returns. Hence, the asymptotic function represents this assumption more closely.

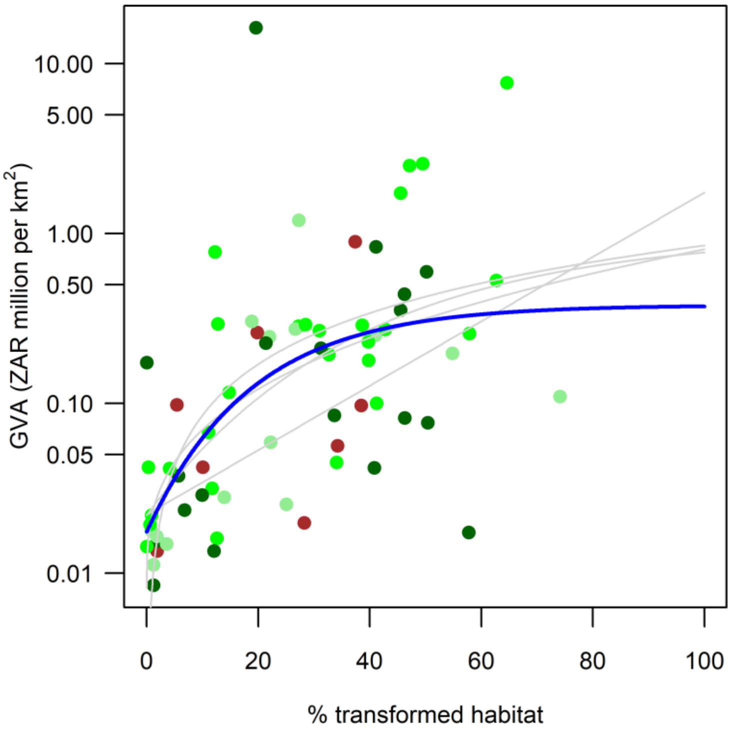

FIG. S2 The relationship between log-transformed GVA and the percentage of intact habitat. Each point represents a specific ecosystem and is coloured based on the bioregion in which it is nested. The blue line is the predicted asymptotic exponential relationship used to predict GVA in subsequent simulation and the grey line shows the relationships for the four other models fitted to the data.

TABLE S1 The five models used to predict the relationship between log-transformed GVA as the dependent variable and the percentage of intact habitat as the independent variable.

Model	Equation	Parameter estimates			AIC	ΔAIC
		α	β	γ		
Exponential	$y = \alpha . e^{\beta . x}$	−3.822	−0.027		235.83	
Asymptotic exponential	$y = \alpha + (\beta - \alpha)e^{-e^{\gamma}x}$	−0.973	−3.071	-0.053	236.61	0.78
Power	$y = \alpha . x^{\beta}$	−4.803	0.331		237.25	1.42
Linear	$y = \alpha + \beta . x$	−3.395	0.047		240.25	4.42
Logarithmic	$y = a + \log(x)$	−4.769			261.92	26.09

SUPPLEMENTARY MATERIAL S3 The monetary value of ecosystem services for each of the 72 ecosystem types in the South African grassland biome.

Previous research quantified the monetary value of ecosystem services in South Africa's grassland biome in the order of ZAR 29,000 per km^2 in 2006 (De Wit & Blignaut, 2006). This is equivalent to ZAR 37,962.43 per km^2 in 2011 monetary units (the same year as the GVA data). These original values were derived by dividing estimates of total monetary value by the original extent of the biome, so we assumed a linear relationship between the value of ecosystem services and the percentage of habitat remaining in each ecosystem type. Thus, if 50% of an ecosystem type had been transformed, we assumed that the economic value of ecosystems services would also be halved (i.e. ZAR 18,981.22 per km^2). This is clearly an oversimplification, but even coarse estimates can be useful for understanding the broad constraints of proposed policies (Costanza et al., 2014).

For each ecosystem type, we added the monetary value of ecosystem services to the GVA to denote the total economic value and analysed the data using the same approach as using only GVA data in the main manuscript.

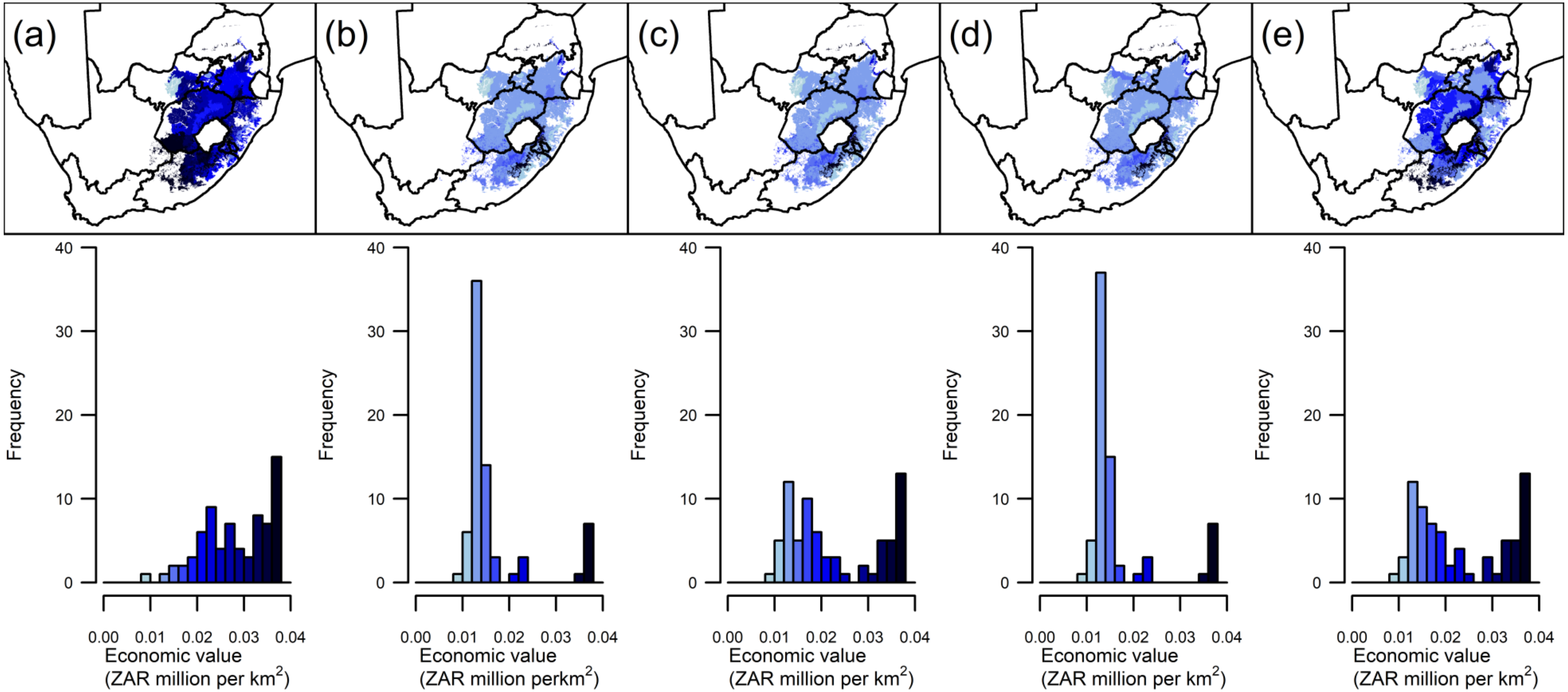

FIG. S3 The monetary value of ecosystems services for each of the 72 ecosystem types in the South African grassland biome (a) as modelled for the current situation, and simulated for (b) Scenario 1, (c) Scenario 2, (d) Scenario 3 and (e) Scenario 4.

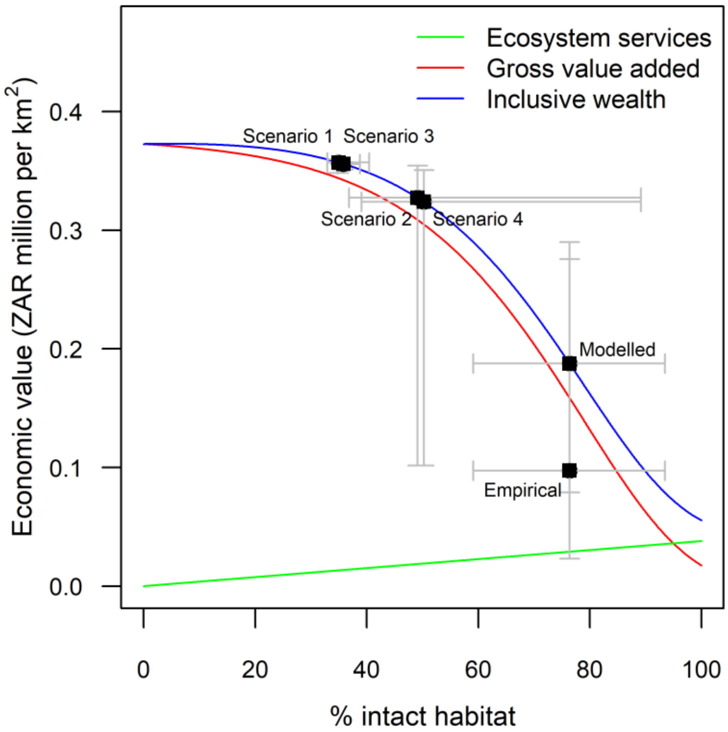

FIG. S4 The relationship between the median percentage of intact habitat and the modelled economic value for the current situation (both empirical and modelled) in the 72 ecosystem types in the South African grassland biome, as well as the four simulated scenarios. Lines represent the modelled relationship between intact habitat and ecosystem services, gross value-added factor cost and total economic value (inclusive wealth). Error bars denote the 25th and 75th percentiles.

References

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