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The Financial Costs of Ecologically Nonsustainable Farming Practices in a Semiarid System

Margot C. Herling,[1] Clement F. Cupido,[2] Patrick J. O'Farrell,[1,3] and Lozelle Du Plessis[2]

Abstract

Nonsustainable ostrich farming practices have degraded large areas of the Little Karoo, a semiarid region in South Africa. The Little Karoo lies within the Succulent Karoo biome, a recognized biodiversity hotspot. A financial feasibility analysis was undertaken from a private landowner's perspective to examine the costs and benefits of rehabilitating degraded areas thereby allowing farmers to shift their production focus from ostrich to sheep farming, a financially stable and relatively conservation-compatible land use. Our aim was to raise awareness, at a private landowner level, to the opportunity costs incurred through unsustainable land use practices. We calculated and contrasted net present values for rehabilitation and no rehabilitation scenarios and investigated model sensitivities relating to seed costs, seedling survival and ostrich product prices. Rehabilitation was not found to be financially feasible for private landholders over 20 years. Seedling survival and associated seed costs were found to have strong controlling effects. Third parties need to contribute both financially and in terms of research outputs if sustainable land use practices are to be achieved in this area. This study elucidates the true costs associated with the unsustainable practice of ostrich farming and sounds a cautionary warning.

Key words: **conservation incentives, conservation on private land, financial feasibility analysis, net present values, seed costs, seedling survival.**

Introduction

Land use practices generating products closely linked to fashion and tastes often require rapid shifts as the demand for these goods changes. However, many human activities including agriculture reduce the capacity of ecosystems to benefit people by degrading ecosystems (Webb 1996; Matson et al. 1997). Management actions including restoration and rehabilitation are often required to reestablish a productive state and facilitate this shift in production focus (Hobbs & Norton 1996; Webb 1996; McDonald 2000; Hobbs & Harris 2001). Logically, the costs associated with rehabilitation and restoration strategies should influence land use practice decisions. In reality, these costs are poorly estimated and recorded and are rarely factored into production decisions (Milton 2001; Choi 2004). Case studies, which highlight local-level rehabilitation costs associated with production shifts, are needed in order to expedite the move toward sustainable land use. This is particularly important in arid areas, where costs and risks associated with rehabilitation are believed to be greater than in more mesic environments, as well as in areas of conservation importance (Milton 2001).

[1] Natural Resources and the Environment, CSIR, PO Box 320, Stellenbosch 7599, South Africa
[2] Western Cape Department of Agriculture, Private Bag X1, Elsenburg 7607, South Africa
[3] Address correspondence to P. J. O'Farrell, email pofarrell@csir.co.za

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Our study explored the restoration costs associated with shifting production focus from ostrich production, an unsustainable degrading land use practice, to sheep production, a relatively conservation-compatible land use. The study took place in the Little Karoo region of South Africa, which falls within the Succulent Karoo biome (Milton et al. 1997). This biome is internationally recognized as being one of only two biodiversity hotspots found in arid regions (Mittermeier et al. 2004) due to its high levels of plant endemism and its extensive transformation, estimated as at least 70% (Myers et al. 2000). Ostrich farming as it has been practiced here, with large concentrations of birds confined to relatively small camps averaging around 300 ha, has caused severe transformation and degradation of the vegetation of this region (Hoffman 1996; Cupido 2005). Much of this degradation is attributable to the active, territorial behavior and trampling effects of ostriches that lead to soil compaction, the removal of the biological soil crust (Cupido 2005), which increases the risk of soil erosion by wind (Belnap 2001), destruction of sensitive plants, and loss of biodiversity (Lombard & Wolf 2004; Cupido 2005). Ostriches receive full rations of supplementary feed, predominantly lucerne, which sustains these high numbers. Farmers are therefore only dependent on the space component of the carrier or habitat function of ecosystems, as defined by De Groot (2006), and are not dependent on the natural vegetation or related goods and services for ostrich production.

Ostrich farming has been practiced in the region for more than 150 years, but in the 2000 years prior to this, sheep and cattle production was the dominant agricultural activity (Pollock 1974; Burman 1981; Shearing & Van Heerden 1994). The ostrich industry has experienced much volatility attributable to changes in fashion and tastes. The collapse of the feather industry in the early 1900s demonstrated this association. Recent volatility within the industry is attributable to outbreaks of Crimea Congo Fever, Newcastles disease, and Avian flu resulting export bans, as well as increased local and international competition. Agriculture is still the single largest employer in the region, employing 27% of the labor force, most of which are workers in the ostrich industry (Anonymous 2002, 2003).

It was the intention of this study to create awareness around true costs or opportunity costs of keeping ostriches and the time taken to recover financial costs associated with a rehabilitation exercise required for a shift in land use activities. Rehabilitation of the natural vegetation from a degraded ostrich farming state to a condition where it could support mammalian livestock is seen as the most feasible and less financially volatile, alternative land use that would have both conservation and social welfare benefits. Our findings indicate that rehabilitation was prohibitively expensive for an individual over the medium term of 20 years, only becoming feasible over a longer time period.

Methods

Study Area

This study was carried out in the magisterial district of Oudtshoorn in the Little Karoo (Fig. 1). The mean annual rainfall is approximately 250 mm with peaks in autumn (March to May) and spring (August to October). The Little Karoo has eight major vegetation types, of which "Gannaveld" is the most common on lowland areas where the majority of ostrich farming takes place (Vlok et al. 2005). This area has a recommended grazing capacity of 60 ha/large stock unit (LSU), which is relatively low for raising mammalian livestock. Evidence from historical records indicates that the Oudtshoorn agricultural district has been heavily overstocked by cattle, horses, donkeys, sheep, goats, and ostriches (Dean & Milton 2003). Virtually no areas of pristine Gannaveld remain in this district (Thompson et al. 2005).

Gannaveld is usually found on deep, loamy, and saline soils and on wide-open plains in valley bottoms with slopes from 6 to 18° (Anonymous 1999). This vegetation unit is characterized by the shrubs, Gannabos (*Salsola* spp.) and Kriedoring (*Lycium* spp.) and is described as rich in shrub and succulent species (Vlok et al. 2005). In well-managed vegetation, palatable shrubs such as *Eriocephalus* spp and *Tripteris sinuatum* are expected to be present (Joubert et al. 1969; Vlok et al. 2005). In heavily selectively overgrazed and eroded vegetation, unpalatable plants are common (Milton & Dean 1990; Fuls 1992), and mat-forming succulents, which are resistant to trampling, such as *Malephora lutea* and *Ruschia impressa* or ephemerals, tend to dominate the vegetation (Acocks 1988). These hardy succulents serve as pioneers, as they establish more easily in open eroded sites than shrubs (Yeaton & Esler 1990).

We selected one ostrich farm dominated by Gannaveld, which was considered to be representative of a degraded site associated with ostrich farming, given plant species composition and evidence of trampling and erosion. The farm had three camps, each approximately 300 ha, all of

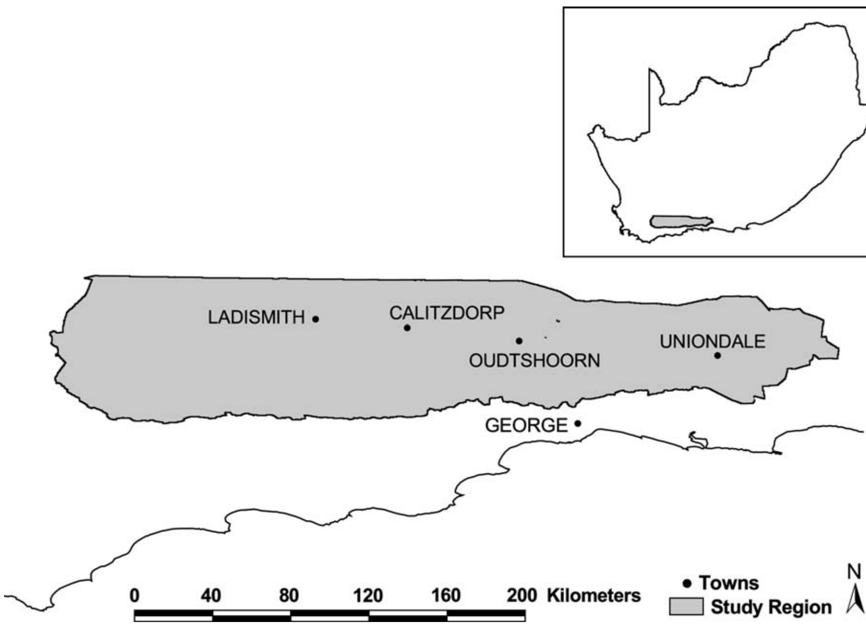

Figure 1. Map showing the Little Karoo study area location (shaded) in South Africa (insert) and the major towns within this region.

which had been used for extensive farming of breeding birds in the past. Camp 1 was the most degraded of the three camps and was used annually for ostrich breeding pair production without the recommended 2-year resting period. Camps 2 and 3 had been lying fallow for two decades.

Calculating Grazing Capacity

A descending point method was used to estimate the plant canopy cover and the botanical species composition by recording 1,000 strikes at 1-m intervals in each of the three camps (Roux 1963). The opinions of experts from botanical and agricultural fields were used to derive palatability values of plants recorded at the study site in conjunction with Van Breda et al. (1990). The grazing capacity was assessed using a technique developed by Bayer et al. (1992) for the three camps. This method disregards unpalatable plants and uses three categories of palatability, that is, less palatable, palatable, and highly palatable plants. The cover densities of these three categories are weighted by 20, 50, and 90%, respectively, based on production utilization to obtain a value for digestible product, which is calculated as follows:

$$\begin{aligned}&\text{Digestible product}\\&= (\%\text{ cover of highly palatable species} \times 90\%)\\&\quad + (\%\text{cover of palatable species} \times 50\%)\\&\quad + (\%\text{cover of less palatable species} \times 20\%)\end{aligned}$$

Grazing capacity values were obtained using the following equations:

$$\begin{aligned}&\text{Potential Production} = \text{MAR} \times \text{rain-use efficiency}\\&\quad (4.0 \pm 0.3 \text{ kg dry matter per hectare}),\end{aligned}$$

where MAR is mean annual rainfall (Le Houerou et al. 1988).

$$\text{Production } = \frac{\text{Digestible Product}}{100 \times \text{ Potential Production}} \quad (\text{kg/ha DMP/annum}),$$

where DMP is the dry matter production.

$$\begin{aligned}&\text{Grazing capacity (ha/LSU/annum)}\\&= \left(\frac{650}{\text{Production}}\right) \times 6.67,\end{aligned}$$

where 650 is equivalent to the annual dry matter requirement of a 60-kg Dorper sheep, and 6.67 is the figure used to convert from LSU to small stock units (SSU) (1 LSU = 6.67 SSU).

The additional plant cover required to increase the actual grazing capacity to the recommended grazing capacity for sheep and the number of seeds that would need to be sown to attain this recommended grazing capacity was then determined. This was calculated using one highly palatable species, *T. sinuatum* (Asteraceae), found naturally within the study area and one of the few species for which biological data exist.

Financial Modeling

A financial feasibility model was developed to compare the costs and benefits of improving or rehabilitating grazing capacity to this recommended level based on the following assumptions:

- The method of rehabilitation was the seeding of palatable plants at the start of the cool season with minimum disturbance of the vegetation by means of tilling (Milton 1995).
- The rainfall in the area was adequate to allow for the success of the rehabilitation process. Twenty to thirty millimeters of rainfall would be needed for successful germination during March to June and a further 10–20 mm for seedling survival during July to October (Wiegand et al. 1995).
- The survival rate of seeds sown that reached adulthood was 0.096%. This was based on studies conducted by Witbooi (2002) and Ghirmai (2004) on *T. sinuatum* on old fields.
- The vegetation would be rested for 3 years after rehabilitation before any livestock was introduced (Snyman 2003).
- Dorper sheep were used as the best alternative land use. The sheep were introduced into the vegetation in year 4. Initially, sheep were only stocked at 50% of the recommended stocking rate up to year 8; thereafter, the stocking rate was increased by 5% per annum until an 80% stocking rate was reached. The stocking rate was kept at this level to accommodate for drought years.
- Income from Dorper sheep was assumed to accrue based on a 2-year cycle.

The costs and benefits of rehabilitating Gannaveld for the case study were calculated for two scenarios, namely:

1. No rehabilitation intervention in camps 2 and 3 (these remain unutilized), whereas camp 1 continues to be used for ostriches.
2. Camps 2 and 3 are rehabilitated to their recommended grazing capacity of 60 ha/LSU and the land use changes to livestock grazing, whereas camp 1 continues to be used for ostriches.

Only the direct monetary values associated with lost or improved grazing capacity and the gross profits earned from ostrich farming were included (Blignaut & Lumby 2004). The valuation techniques used were based on the opportunity cost and the replacement cost approaches. A hedonic price approach could not be used because there are no farms or land units in a pristine state available for comparison with degraded areas within the study area (Thompson et al. 2005).

The opportunity cost approach estimates the value lost or gained from the difference in current and recommended grazing capacity. In a broad sense, it refers to the foregone net income benefit that could have been accrued from the next best alternative that has been lost due to the current use of a resource (Blignaut & Lumby 2004). The gross margin earned per SSU was R160.73 in 2003 (Western Cape Department of Agriculture 2003) (average daily exchange rate for 2004: R1 = \$0.16 [Oanda 2006]). This translated into a value of R162.95 per SSU in 2004 or R1 086.40 per LSU (where 1 LSU = 6.67 SSU). The change in income due to a change in the carrying capacity was calculated as follows:

$$Y_i = \left(\frac{V}{G} - \frac{V}{G_i}\right) \times S_i \times \left(1 + \frac{r}{100}\right)^{i-1}$$

where Y_i is the opportunity cost (or the income) from livestock in year i ($i = 1,\ldots,20$) (Rands), V is the gross margin of Dorper sheep in terms of LSU (Rands), G is the recommended grazing capacity (ha/LSU), G_i is the grazing capacity in year i (ha/LSU), S_i is the stocking rate in year i (ha/LSU), and r is the inflation rate (%). An inflation rate of 3.9%, the average annual growth in the consumer price index (the CPIX excluding interest rates on mortgage bonds) inflation rate for 2005 was used for all calculations, excluding the initial 2004 time step where an inflation rate of 4.3% was used (Statistics SA 2006).

The replacement cost approach measures the value of Gannaveld through the direct costs of rehabilitating it (Holl & Howarth 2000). The method considers the cost of replacing or restoring an aspect of environmental quality if it has been or will be destroyed or damaged (Blignaut & Lumby 2004). The rehabilitation costs included the cost of tiling, sowing seeds, and hiring labor. Tilling costs were based on those estimated by Mackay and Pennefather (2005). The cost of seeds was R60 per kg. This was after government subsidization (J.C. Botha 2006, Worcester Veld Reserve, South Africa, personal communication). The number of seeds in a kilogram varied based on the size of the seeds harvested. A scenario approach was developed to clarify the implication of this effect. A high-, average-, and low-cost scenario was adopted based on the average number of seeds per kilogram. Here, high cost referred to the costs associated with the lowest number of seeds in a kilogram, that is, 60,000 seeds per kg (Milton 2003), medium cost to the costs associated with 109,890 seeds per kg (Milton & Dean 1990), and low cost referred to costs associated with 137,500 seeds per kg (Heydenrych et al. 2000). Labor costs were R4.47 per hour (minimum hourly wage rate) from 1 March 2004 to 28 February 2005 (Department of Labour 2002). Rehabilitation costs were depreciated over 10 years.

The gross margin derived from an ostrich breeding flock was used as the income earned on camp 1, equaling R180 018 per annum, derived from the Western Cape Department of Agriculture (2003). It was assumed that the breeding flock consisted of 146 birds with a male–female ratio of 38:62 (approximately two males to every three females). Income was earned from the sale of day-old chicks, feathers, and whole eggshells. The assumptions were that each female lays 47 eggs per annum with a 60% hatching rate, and chicks were marketable at 27 days old. Thirty percent of the unhatched eggs were assumed to be available for sale as eggshells.

The net present value (NPV) was then calculated for each scenario over 20 years, using the following equation (adapted from Dixon et al. 1994):

$$\mathrm{NPV} = \sum_{i=1}^{20} \frac{B_i - C_i}{(1 + \frac{d}{100})^{i-1}}$$

where NPV is the net present value over 20 years (Rands), B_i is the benefit in year i (Rands), C_i is the cost in year i (Rands), and d is the discount rate (%). A discount rate of 7.81% was used based on the 12-year or longer government bond index on 10 November 2005 (Business Day 2005). The Department of Agriculture uses real interest rates (current lending rates adjusted for inflation) when working with medium- to long-term projects. For this reason, this discount rate used reflects the real circumstances faced by farmers, where no subsidies are given and farmers need to bear the cost of rehabilitation. Furthermore, the effect of a lower discount rate of 4% was tested to assess whether the future value of rehabilitation and costs and benefits of the various scenarios would be adversely affected by a higher value placed on future years. A zero or positive NPV would indicate that a scenario is financially viable.

In addition, the NPV into perpetuity was calculated to indicate the lifelong value of rehabilitation as follows:

$$\mathrm{NPV}_p = \frac{\mathrm{PV}_{20}}{\frac{d-r}{100}}$$

where NPV_p is the NPV into perpetuity (Rands), PV_{20} is the present value in the twentieth year (Rands), d is the discount rate (%), and r is the inflation rate (%).

A sensitivity analysis was conducted to assess the sensitivity of the rehabilitation scenarios to changes in income, seed cost, and the survival rate of seeds. They represent both optimistic and pessimistic future conditions for the region and possible effects of rehabilitation advances. These sensitivity analyses are listed below:

- the income received from ostrich products decreased by 20% and the seed cost increased by 10%;
- the income received from ostrich products increased by 20% and the seed cost decreased by 10%; and
- the survival rate of the seeds sown increased by 10%.

Table 1. Vegetation cover (%) in three camps before rehabilitation and 4 years after rehabilitation action for three categories of palatability.

	Highly Palatable	*Palatable*	*Less Palatable*
Camp 1			
Initial cover	0	2.4	7.2
Camp 2			
Initial cover	0	1.8	23.4
After rehabilitation	2.9	1.8	23.4
Camp 3			
Initial cover	0	0.5	14.9
After rehabilitation	5.7	0.5	14.9

Results

Grazing Capacity

A total of 31 plant species were recorded in the study area, comprised of 19 unpalatable, 5 less palatable, and 7 palatable plants. The vegetation cover in all camps was high and attributed to the presence of the less palatable mat-forming plants *Ruschia impressa* and *Drosanthemum lique*. The estimated grazing capacities before rehabilitation for camps 1, 2, and 3 were 164 ha/LSU, 75 ha/LSU, and 134 ha/LSU, whereas the mean vegetation cover for each of these camps was 47, 75, and 65%, respectively. Table 1 shows the percentage cover values according to palatability for all camps, before and after rehabilitation. Before rehabilitation, the vegetation cover of highly palatable and palatable plants was less than 2.5% of the total cover. After rehabilitation, this was expected to increase up to a maximum of 6.2% (Table 1). The number of *Tripteris sinuatum* individuals required to reach the recommended grazing capacity within camps 2 and 3 was 9,667 and 19,000 plants, respectively.

Financial Costs and Benefits

The costs of seeds needed to rehabilitate the camps to acceptable levels of grazing capacity ranged from R4 393 to R10 066 per ha in camp 2 and R8 643 to R19 785 per ha in camp 3, based on three different estimations of average number of seeds per kilogram (Fig. 2; Milton & Dean 1990; Heydenrych et al. 2000; Milton 2003).

Under scenario 1, all present values were positive (Table 2). For scenario 2, the present values in years 1–10 were negative and from year 11, the present values were positive (Table 3). The positive present values for scenario 2 from year 11 onward are directly related to the large rehabilitation costs no longer being included in these calculations from this point onward. Therefore, from year 11 onward, the benefits of rehabilitation outweigh the costs for the total farmed area of 900 ha. This was found to be true for all sensitivity analyses.

Table 4 presents a summary of the NPVs calculated for each scenario for the first 20 years and the number of years taken to achieve a positive NPV, modeled under high, medium, and low seed costs. Positive NPVs were found for scenario 1. The NPVs over 20 years were negative for all other rehabilitation scenarios, excluding sensitivity 2 under low seed cost conditions. The most financially viable scenario for rehabilitation was sensitivity 2, where the total NPVs were R3 858,878 and R3 106,217 under low and average seed cost conditions, respectively.

With a discount rate of 4%, on average, the NPV becomes positive within 30 years under all scenarios and

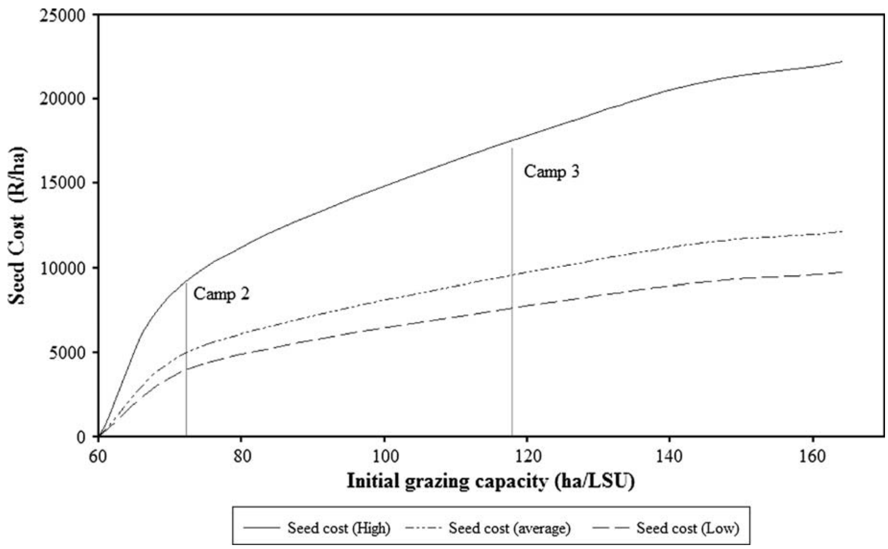

Figure 2. Relationship between initial grazing capacity and cost of seeds per hectare required to rehabilitate the area to an acceptable level for three different seed number estimates. Calculations based on Ghirmai (2004), Heydenrych et al. (2000), Milton (2003), Milton and Dean (1990), and Witbooi (2002).

Table 2. Scenario 1: The benefits of ostrich farming compared to the opportunity costs of not rehabilitating (2004 Rands).

	Benefits	*Costs*			
Year	*Income From Ostriches*	*Opportunity Cost (Camp 1)*	*Opportunity Cost (Camp 2)*	*Opportunity Cost (Camp 3)*	*NPV*
1	180,018	2,846	903	2,537	173,732
10	254,013	4,016	1,275	3,579	124,633
11	263,919	4,172	1,324	3,719	120,118
15	307,563	4,862	1,543	4,334	103,633
16	319,558	5,052	1,603	4,503	99,878
20	372,401	5,887	1,869	5,247	86,171

sensitivities with low and average seed costs (except sensitivity 1, where this happens at 43 and 54 years for low and average seed costs, respectively). Under high seed costs, the NPV becomes positive between 33 and 99 years. The difference between the years with a 4 and 8% discount rate ranges between 1 and 79 years, with a tendency for relatively high years (under the 8% discount rate) to have dramatic drops while low values have marginal decreases (Table 4).

Discussion

This study highlights, in concurrence with other studies (Milton et al. 2003), that financial and technical factors hinder effective restoration of degraded areas. The shift from ostrich production to livestock production, and more conservation-compatible and sustainable land use through the rehabilitation of degraded Gannaveld, was not found to be financially feasible for private landholders over a 20-year period. Rehabilitation costs are restrictively high compared with the comparatively low benefits that accrued from small stock farming, given the low recommended stocking rates for the vegetation type.

The model was specifically developed from a private landholder perspective, incorporating both technologies and product prices available to them. It demonstrates the sensitivity of seed costs and seedling survival to the feasibility of rehabilitation efforts. With lower seed costs, rehabilitation becomes more feasible in the long term, as costs are linked to the availability and supply of seed. Previous studies indicate that this lack of availability of indigenous seeds of palatable plants has hampered previous restoration efforts (Esler & Kellner 2001).

Rehabilitation cost is also shown to be dependent on the degree of degradation, with camp 3 costing roughly twice as much to rehabilitate than camp 2. Esler and Kellner (2001) also found rehabilitation costs to be directly related to degradation levels. Their costs varied between R150/ha and R1 322/ha, which are substantially lower than our predicted costs. This is attributable to different species and survival rates used in these two analyses. Seedling survival rates have a direct effect on costs and in turn are

Table 3. Costs and benefits for scenario 2—rehabilitation of camps 2 and 3 (2004 Rands).

					Rehabilitation Cost (Camp 2)			*Rehabilitation Cost (Camp 3)*			*Present Value*		
Year	*Income From Ostriches*	*Increased Grazing (Camp 2)*	*Increased Grazing (Camp 3)*	*Opportunity Cost (Camp 1)*	*High*	*Average*	*Low*	*High*	*Average*	*Low*	*(High)*	*(Average)*	*(Low)*
1	180,018	0	0	2,846	305,894	168,789	135,679	597,454	327,980	262,905	−726,176	−319,597	−221,412
10	254,013	876	2,461	4,016	431,629	238,168	191,449	843,032	462,794	370,970	−519,252	−227,578	−157,142
11	263,919	993	2,789	4,172							124,280	124,280	124,280
15	307,563	1,543	4,334	4,862							107,737	107,737	107,737
16	319,558	1,603	4,503	5,052							103,833	103,833	103,833
20	372,401	1,869	5,247	5,887							89,583	89,583	89,583

Table 4. NPVs after 20 years and the number of years before a positive NPV is achieved for scenario 1 and 2 and sensitivity 1–3.

	NPV After 20 yr			*Number of Years to Achieve Positive NPV*		
	High	*Average*	*Low*	*High*	*Average*	*Low*
Discount rate = 7.81%						
Scenario 1		2,502,876			Immediate	
Scenario 2	−5,112,715	−1,649,668	−813,378	Never achieved	52	32
Sensitivity 1	−6,962,933	−3,153,582	−2,233,662	Never achieved	Never achieved	Never achieved
Sensitivity 2	−3,262,497	−145,755	606,906	112	22	16
Sensitivity 3	−4,419,274	−1,271,049	−510,785	Never achieved	41	27
Discount rate = 4%						
Scenario 1		3,443,088			Immediate	
Scenario 2	−5,438,402	−1,390,163	−412,555	52	28	23
Sensitivity 1	−7,826,014	−3,372,951	−2,297,582	99	54	43
Sensitivity 2	−3,050,790	592,625	1,472,472	33	17	15
Sensitivity 3	−4,627,782	−947,565	−58,830	47	26	21

linked to the level of degradation. Costs similar to those presented by Esler and Kellner (2001) would only be achievable with a 3% seedling survival rate. Beukes and Cowling (2003) found *Tripteris sinuatum* to have very poor survival rates of less than 0.2%, and rates were strongly correlated with soil moisture. Ostriches trampling is expected to cause increased run-off and reduced infiltration (Cupido 2005). This demonstrates the need to factor in the degree of degradation when planning and assessing the viability for rehabilitation.

Model seed costs are directly related to the number and size of seeds found in a kilogram. The greater the number of large heavy seeds in a bag, the fewer seeds per kg, resulting in increased modeled costs of rehabilitation. However, larger seeds may be more viable and fewer would be required, implying that modeled costs may be slightly inflated. Halpern (2005) experimenting with *Lupinus perennis* seeds demonstrated this link between seed size and fitness. Our model showed that increasing seedling survival rates of 0.096% by 10% reduced the time taken to become financially viable by 11 years under average seed costs and 5 years under low seed costs.

There are a number of key variables that would improve the financial viability of rehabilitation for the private landowner. These include the reduction in the cost of seeds, decreases in the gross margin of ostrich products, increases in the gross margin of alternative land uses such as sheep farming, and the improved survival rate of seedlings (Milton 1994). The comparison the model presents is somewhat skewed as the Dorper sheep in camps 2 and 3 are maintained within the recommended stocking rate, whereas ostrich stocking rates are kept constantly at 6.16 ha/LSU. Although this is currently a financially viable enterprise, it is one that will ultimately lead to the severe degradation of the natural vegetation. This will result in a loss of a number of ecosystem services. Within the study area, these are likely to include soil stability, soil retention, flood prevention, and tourism. However, services such as carbon sequestration are not likely to play a major role, given plant species composition of this vegetation type.

If sustainable land use is to be promoted, the necessary conditions for this need to be created. This could include incentives, payments, punitive actions, and statutory requirements. Studies which identify ecosystems services and or natural capital (Ekins et al. 2003) at a local level and elucidating their benefits to farmers (e.g., O'Farrell et al. 2007) may incentivize farmers to rehabilitate their land (Hobbs & Harris 2001). There are a variety of fiscal and monetary incentives that have been suggested to promote conservation-compatible land use practices including tax incentives, subsidies, legislation, grants, and payments (Balmford et al. 2002; Tilman et al. 2002; Pence et al. 2003). Frazee et al. (2003) demonstrated that this type of approach may provide a cheaper means of ensuring conservation over the establishment of formal reserves. Although our study is focused at a farm scale, considering ecosystem services and natural capital generated at the vegetation-type scale would be a useful next step in determining the social benefits derived from sustainable management or conservation at this vegetation-type scale. Given the high levels of biodiversity and severe level of transformation and degradation of Gannaveld, it should be treated as critical natural capital (De Groot et al. 2003) requiring protection and restoration. This study presents a stark contrast to the economic value of natural capital as presented by Farley and Gaddis (2007), which increases exponentially in value with approaching scarcity. Clearly, the private benefits of degradation come at a cost or a loss to the broader public, and this is a complex intuitional issue that we need to start grappling with. Private and public benefits need to be weighed up against one another in determining ultimately who pays for rehabilitation and restoration actions. Making payments for ecosystem services could potentially reward sustainable land use and could pay for restoration actions (Wunder 2005), provided a mechanistic understanding of the functioning of these services was in place. However, the effectiveness of this approach and the ease of implementation are still unclear (Landell-Mills & Porras 2002), and our understanding of the ecology of ecosystem services is rudimentary at best (Kremen 2005). Conservation of Agricultural Resources Act 43 of 1983 is the primary statute governing agricultural resource use (Glazewski 2000). This Act provides detailed prescriptions of stocking rates according to mapped areas for ostriches and for the delegation to agricultural authorities to assess and implement these measures. Poor implementation of this legislation by authorities renders these institutional mechanisms currently ineffective in controlling this unsustainable land use practice. Improving the implementation of legislation and extension services to farmers would provide vital first steps in halting landscape degradation. Additional statutory requirements could also be placed on unsustainable farming activities, such as those pertaining to other industries, for example, the mining industry, where an agreed-upon restoration goal is established prior to the commencement of mining activity (Hobbs & Harris 2001; Carrick & Krüger 2007). In this example, the South African Mineral and Petroleum Resources Development Act 28 of 2002 requires that monetary deposits are held by the state for the express purpose of restoring the land surface to its natural state, once mining operations are completed and before mine closure is granted.

In addition to these options, there needs to be investment in seed production, where an expansion in this industry would serve to reduce current costs. Further research in rehabilitation techniques and in particular how to promote seedling survival would further improve rehabilitation potential. The Little Karoo is suited to large-scale extensive livestock farming such as that practiced by indigenous pastoralists in this area for around 2,000 years (Smith 1999). Current farm sizes further restrict the shift toward livestock farming.

Although the shift to livestock grazing at recommended rates could work in tandem with conservation, our methodology of increasing grazing capacity is based on tilling and seeding highly palatable species, which is in itself a questionable practice toward a "conservation" end. Alternative methods of seed sowing would be preferential, possibly by hand; however, this would increase restoration costs. This would require a trade-off between more time required sowing seeds or more seed required to ensure success as we know that different treatments have different seedling success rates (Beukes & Cowling 2003). Restoration methods of this nature would offer direct benefits to local communities in the form of employment creation (Cairns 1993).

Cupido (2005) found that more than 50% of Little Karoo farmers are willing to rehabilitate their vegetation. However, forcing farmers to rehabilitate could lead to changes in land use away from farming and increased unemployment in the area and could have detrimental effects on the local economy. Willingness is essential if rehabilitation efforts are to succeed. Rehabilitating vegetation to a level recommended for livestock production would pose a financial risk to farmers, given the possibility of low rainfall after sowing, seed viability, and the low plant survival rates. A further factor amplifying this financial risk is the potential threat of Avian flu and price variability typical of ostrich production. Due to economies of scale, small-scale farmers are financially constrained and unlikely to be able to invest in rehabilitation. These factors would most certainly affect their degree of willingness.

Conclusion

Our data indicate that rehabilitation of Gannaveld vegetation on the succulent karoo biome, after unsustainable ostrich farming, is costly and not financially feasible over a period less than 20 years, largely due to low seedling survival rates of *Tripteris sinuatum*. Given these costs, and the conservation importance of the region, conservation initiatives should be targeted at making farmers aware of the irreversibility of ostrich farming. Various strategies, possible incentives, payments, punitive actions, and even statutory requirements, need to be considered in discouraging free-range ostrich farming at overstocked rates. Actions that force private individuals to rehabilitate vegetation for a change in land use are likely to result in a shift away from agriculture, which will in turn impact on farm workers and the rural poor. The broader implications of this study are that serious degradation in arid systems should be prevented because with present technology and knowledge relating to seedling survival and establishment, it is nearly impossible to restore on a financially viable basis.

Implications for Practice

- A multidisciplinary approach, which couples ecological with social research, provides a clearer understanding of the constraints governing rehabilitation actions and the setting of feasible and achievable rehabilitation goals.
- Rehabilitation practices can be restrictively expensive, particularly in semiarid environments, due to seedling survival rates. We need investment in research focused on improving seedling viability and decreasing seed costs.
- The restrictive costs of rehabilitation should be used to demonstrate the potential irreversibility of land use decisions to private landholders, administrators, and government officials, providing a clear deterrent to the adoption of unsustainable land use practices and decisions.
- Third-party interventions are required if landholder willingness to rehabilitate is to be capitalized upon. Payments for ecosystem services offer potential opportunities to bridge the divide between private and public costs and benefits.

- Conducting a financial feasibility analysis that examines the costs and benefits of a rehabilitation action, from a private landholder perspective, is a good starting point in any rehabilitation exercise. If rehabilitation is financially feasible at this scale, this may negate the need for further investigation into broader scale ecosystems services, beneficiaries, and the payments for these services.

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