Ostrich farmer characteristics predict conservation opportunity

AUTHORS:
Anita Wheeler[1,2]
Andrew T. Knight[3,4,5]
Mark Difford[5]
Susanne Vetter[1]

AFFILIATIONS:
[1]Department of Botany, Rhodes University, Grahamstown, South Africa
[2]CapeNature, Gouritz Corridor, Oudtshoorn, South Africa
[3]Department of Life Sciences, Imperial College London, Ascot, United Kingdom
[4]ARC Centre of Excellence in Environmental Decisions, University of Queensland, Brisbane, Queensland, Australia
[5]Department of Botany, Nelson Mandela University, Port Elizabeth, South Africa

CORRESPONDENCE TO:
Susanne Vetter

EMAIL:
s.vetter@ru.ac.za

DATES:
Received: 30 Aug. 2018
Revised: 10 Dec. 2018
Accepted: 20 Dec. 2018
Published: 27 Mar. 2019

HOW TO CITE:
Wheeler A, Knight AT, Difford M, Vetter S. Ostrich farmer characteristics predict conservation opportunity. S Afr J Sci. 2019;115(3/4), Art. #5540, 8 pages. https://doi.org/10.17159/sajs.2019/5540

ARTICLE INCLUDES:
☒ Peer review
☒ Supplementary material

DATA AVAILABILITY:
☐ Open data set
☐ All data included
☒ On request from authors
☐ Not available
☐ Not applicable

EDITOR:
Teresa Coutinho

KEYWORDS:
agriculture; environmental management; environmental psychology; Little Karoo; South Africa

FUNDING:
National Lottery Distribution Trust Fund through the Ostrich Business Chamber's Biodiversity Management Project

Environmental sustainability rests on human choice and action. Understanding these may assist in determining the factors that predict or influence an individual's behaviour towards the environment. In South Africa, approximately 80% of the most threatened vegetation types are in the hands of the private agricultural community. In the Little Karoo, which is situated in the Succulent Karoo biodiversity hotspot, unsustainable land-use practices including ostrich flock breeding threaten this region's lowland biodiversity. We interviewed ostrich farmers in the Oudtshoorn Basin to quantify latent variables thought to represent components of conservation opportunity: environmental attitude, conservation knowledge, conservation behaviour, and willingness to collaborate with agricultural, environmental and conservation organisations. Three groups of land managers were identified: (1) younger land managers (<31 years' farming experience) with bigger farms (≥2050 ha) who had above-average scores for all four indicators, (2) older farmers (≥31 years' farming experience) who had above-average scores for environmental attitude and conservation knowledge, average scores for environmental attitude, but low willingness to collaborate, and (3) a large group of younger farmers (<31 years' farming experience) with smaller properties (<2050 ha) who had low to average scores for all four indicators. Farmers in the first two groups represent the best opportunities for conservation, although different strategies would have to be employed to engage them given the current low willingness to collaborate among older farmers. Land managers were more willing to collaborate with agricultural than conservation organisations, pointing to a need to involve agricultural organisations in championing more environmentally sustainable ostrich breeding practices.

Significance:

- Achievement of biodiversity conservation targets requires stewardship in production landscapes outside protected areas, which necessitates identification of farmers who present conservation opportunity, i.e. who are willing and able to participate in conservation.
- Plant biodiversity in the Little Karoo has been severely degraded through ostrich flock breeding, but ostrich farmers consider their practices to be ecologically sustainable.
- In the Little Karoo, land managers with more years of farming experience, and younger farmers with larger properties, represented the greatest opportunity for interventions to promote more biodiversity-friendly ostrich farming practices.

Introduction

Changing environmental behaviour

Sustainable development is driven by human choice and action. Changes in individual behaviour can contribute significantly to reduce human impacts on the environment.[1] Environmental impacts by agriculture are caused by the behaviour of a relatively low number of people, but with a high per capita impact. Changing farmer behaviour thus has the potential to have a substantial effect on the global environment, including a reduction in biodiversity losses. This approach requires an understanding of how farmers' attitudes and behaviours are interrelated, and what interventions are therefore most likely to be effective in changing farmers' behaviour.

To influence and change environmental behaviour, it is necessary to understand the factors that determine behaviour and how they interrelate. Several studies in the agricultural context[2-4] have examined the relationship between land managers' use of conservation practices that impact the environment and the personality characteristics of environmental attitude and moral reasoning about the environment. These studies suggest that farmers tend to be less concerned about the environment than other groups, because of the nature-exploitative character of most farming activities.

An individual's enduring disposition toward the environment is referred to as an environmental attitude[4] and can be a direct predictor of behavioural intention, which in turn is a key determinant of behaviour.[5,6] There are many environmental attitude measures available based on different conceptual frameworks, but there seems to be a consensus that environmental attitude is multidimensional and organised in a hierarchical fashion.[7] Commonly measured dimensions related to environmental attitude are conservation knowledge, conservation behaviour, willingness to participate and willingness to collaborate.[8]

Identifying human and social factors that directly influence environmental and conservation behaviour can support implementation of more biodiversity-friendly land management.[8,9] Studies of land manager characteristics that affect the adoption of conservation practices have, until recently, remained limited.[10,11] The last 10 years have seen an increase in research on factors that lead farmers to adopt (or fail to adopt) sustainable farming practices (including in Mexico[12], Italy[13], Brazil[14] and Ethiopia[11]) and water management (e.g. in Australia[15] and Finland[16]). Recent research has also examined factors that promote or limit farmers' adoption of practices that conserve biodiversity (e.g. in Ireland[17], Brazil[14] and Slovenia[18]). Given that meeting biodiversity conservation targets relies to a large extent on private landholders in production landscapes[9], more such research is needed, especially from biodiversity hotspots in less intensively studied parts of the world.

Biodiversity conservation in agricultural production landscapes

In South Africa, the conservation of threatened ecosystems now lies predominantly in the hands of private land managers[19] as approximately 80% (by area) of the most rare and threatened vegetation types occur in privately owned production landscapes. One of the first studies on how socio-economic, agro-physical, demographic and human behavioural factors affect conservation attitudes and behaviours was done in the Renosterveld on the West Coast of South Africa.[20,21] The authors concluded that for land managers who have to make a living from the land, the economic role of that land takes precedence over its aesthetic values. A study of the attitudes and behaviour of landholders toward the conservation of Renosterveld[22] showed that younger land managers were more willing to conserve, were not necessarily better educated, and owned larger farms (>500 ha) with greater extents of remnant Renosterveld (>300 ha) than those less willing to conserve. Attitudes toward Renosterveld were generally negative because it was not economically advantageous to retain it.[22] In the Little Karoo, farmers' attitudes towards existing conservation policies were most likely to be improved via the provision of extension services and the public recognition of their contribution to private conservation areas.[23] Personal interaction had a greater potential than any other method for persuading land managers to change behaviour, while restrictive legislation was found to have no decisive influence on conservation behaviour in the Renosterveld.[24,25]

In order to allocate scarce resources effectively to improve conservation behaviour among farmers, it is useful to identify farmers who present 'conservation opportunity', i.e. those who are willing and able to participate in conservation.[9] In South African grasslands, an interaction between attitudes towards the relative importance of conservation and levels of interest in wattled crane conservation was found to be the best predictor of conservation behaviour such as conservation-friendly habitat management.[26] Research in the Eastern Cape of South Africa mapped feasible opportunities for implementing effective conservation[9] and land restoration[8] actions on private land based on the land manager's knowledge, behaviour, willingness to participate and willingness to collaborate. The findings provide conservation and land management professionals direction on where and how implementation of local-scale conservation should be undertaken.

Aims and focus of this study

The Little Karoo is a semi-arid agricultural region within the Succulent Karoo biodiversity 'hotspot' of South Africa[27], but extensive grazing and browsing by domestic small stock, and especially ostriches, over the last 120 years has resulted in severe degradation of more than 50% of the region[28]. This degradation has led to a loss in productivity and biodiversity over large areas.[29,30]

Free-range ostrich farming has been the leading cause of land degradation in the Little Karoo, and the currently prevalent grazing systems and land management practices are ecologically unsustainable.[31] Recommended stocking rates are considered economically unsustainable by farmers and ecologically unsustainable by conservationists.[32] Whereas the dominant ostrich farming practice in other countries is pen breeding, which has a smaller footprint, ostrich farmers in the Little Karoo have not readily adopted this system. The reasons for this are unclear, and little is known about the environmental attitudes, knowledge and behaviours of ostrich farmers or their willingness to cooperate in farming practices that are more conservation-orientated.[33]

In this study, our aim was to develop an understanding of the attitudes and behaviour of ostrich land managers in the Little Karoo, and to identify factors that may positively influence a land manager's decision to conserve their natural environment. This is an important step in determining conservation opportunity, and towards developing implementation strategies for landscape conservation in the Little Karoo.[9]

The three specific aims were:

1. to document land managers' farming practices, environmental attitudes, levels of conservation knowledge, attitudes towards different types of conservation incentives, and willingness to collaborate with environmental organisations;
2. to explore the correlation and causal relationships between environmental attitude, conservation knowledge, conservation behaviour and willingness to collaborate; and
3. to identify attributes of farmers who display higher than average levels of conservation behaviour, and who are open to collaboration with organisations promoting conservation and sustainable agriculture.

Methods

Study area

The study was conducted in the Oudtshoorn Basin, a 10 163 km^2 area in the northeast of the Little Karoo which includes Oudtshoorn, the largest town. The Little Karoo is a semi-arid, inter-montane basin where three biodiversity hotspots (Cape Floristic Region, Maputaland-Pondoland-Albany and the Succulent Karoo) intersect.[29] The low-lying parts of the basin are dominated by dwarf shrublands associated with the Succulent Karoo biome.[28] Only 8.6% of undeveloped land remains intact, while 67.9% is moderately degraded and 23.5% severely degraded.[28] Ostrich farming is the largest contributor to the economy of the Little Karoo, and more than 80% of all South African ostrich farms are situated in this region.[31,34] All operating ostrich farms (256 at the time of the study) are registered with the South African Ostrich Business Chamber (SAOBC), the coordinating body for the ostrich industry.

Ostrich farming comprises several different production systems, of which all or a subset may be found on any particular farm in the study area. Breeding practices implemented by ostrich land managers include free-range flock breeding on natural land, intensive group breeding in small camps, and intensive pen breeding. Free-range flock breeding on natural land is the most environmentally destructive ostrich farming practice[31], whereas intensive pen breeding is considered to be a more ecologically and economically sustainable alternative because of its considerably smaller footprint[35].

Several biodiversity initiatives have been launched in the Western Cape following the development of fine-scale maps of Critical Biodiversity Areas. Critical Biodiversity Areas are terrestrial and aquatic features that must be kept in a natural state in order to retain a reasonable proportion of biodiversity pattern in an ecologically functional and resilient landscape and represent the most area-efficient option for meeting all stated biodiversity thresholds. Critical Biodiversity Areas form the basis for conservation initiatives in the Little Karoo.[36] The Ostrich Industry Biodiversity Management Project is a business and biodiversity initiative implemented by the SAOBC and its aim is to investigate and promote alternative ostrich farming practices in the Little Karoo.

Sample selection and data collection

The Oudtshoorn Basin was chosen because it has, since 1865, been the centre of the Little Karoo's ostrich industry.[28] All SAOBC registered ostrich farms within the Oudtshoorn Basin that were affected by the avian influenza outbreak in 2011 were identified. All ostriches on these farms were slaughtered by order of the South African Department of Agriculture, which provided data on ostrich numbers and densities.[33] We assumed that the farms that were affected by avian influenza represented a random sample of ostrich farms in the Oudtshoorn Basin, as viruses exist and flow through complex agri-food systems in a random fashion, making it impossible to predict the direction or speed of their movement through livestock farming regions.[37-39] From the affected ostrich farms, all those that occurred within the Little Karoo Critical Biodiversity Area map's critically endangered vegetation types were selected. Of the 41 affected registered ostrich farms in the Oudtshoorn Basin, 27 farms were situated within a Critical Biodiversity Area. This gave us a sample of 27 farms (10.5% of registered ostrich farms in the Oudtshoorn Basin) operated by 23 land managers, 22 of whom owned their farms.

A structured questionnaire (Supplementary appendix 1) was developed, based on earlier research.[9,22,31] This comprised a combination of quantitative, qualitative, closed- and open-ended questions. The questionnaire was tested in two pilot interviews with land managers not included in the sample. The questionnaire was developed in English and translated into Afrikaans, as most land managers in the Little Karoo are Afrikaans speaking. Face-to-face interviews were conducted with the 23 land managers on their farms between May and November 2012. Land managers were informed that interviews would be confidential, that they would remain anonymous, and that participation was voluntary. All land managers approached agreed to be interviewed.

We identified four dimensions hypothesised to comprise a land manager's conservation character[9,22], namely environmental attitudes (EA), conservation knowledge (CK), conservation behaviour (CB) and land manager willingness to collaborate (WC). The sections of the questionnaire that targeted EA and CB comprised 13 and 9 statements, respectively, with agreement or disagreement being recorded on a 5-point Likert scale. The section targeting CK assessed whether land managers knew about, or were aware of, biodiversity and conservation facts pertinent to the study area and to ostrich farming. Answers were scored using a scale consisting of 3-point Likert items (yes, unsure or no). The section targeting WC contained three subsections: (1) willingness to work with each of 24 land-management organisations (measured using a 5-point scale); (2) the degree of willingness to engage in conservation (agreement on a 5-point scale with seven statements regarding the landowner's role in conservation); and (3) the degree of interest in nine types of incentives for participating in conservation measures (measured using a 5-point scale).

The questionnaire was grouped into eight sections. The first section gathered background information on the land managers, including the number of years the land manager had been on the farm and the size of the farm. The next four sections of the questionnaire targeted the dimensions/constructs EA, CK, CB and WC, as described above. The sixth section comprised a range of closed- and open-ended questions about ostrich farming practices, including their spatial and temporal scale, and why land managers chose specific practices and avoided others. The seventh section comprised a range of closed- and open-ended questions about ostrich stocking rates, including land managers' flock breeding preferences, ostrich stocking rates on natural land, estimates of natural land stocking capacity, the perceived condition of their natural land, and their assessment of the profitability of the stocking rate of 22.8 ha/ostrich recommended by the Provincial Department of Agriculture. The final section of the questionnaire gathered demographic information, including age and level of education.

Data analysis

To refine, or sharpen, the scales that we used to measure the latent variables (LVs) of our study (i.e. the dimensions CB, CK, EA and WC), we relied mainly on classical test theory. Conceptually and mathematically, classical test theory is simpler than item response theory, and it is also better suited to small samples.[40] We assessed the internal consistency and dimensionality of our scales using Cronbach's alpha[41] (summarised by α), McDonald's hierarchical factor analysis[42] (summarised by the omega hierarchical coefficient ωh), and Revelle's item-cluster analysis[43] (summarised by the beta coefficient β). In addition to these classical test theory tools, we used Mokken scale analysis[44] and item-information curves from item response theory to help identify the most internally consistent and unidimensional set of items. The final scales were formed by eliminating items that reduced the measures of internal consistency and/or dimensionality to unacceptably poor values[9,43] (Table 1).

We explored relationships between the LVs and likely predictor variables (Supplementary table 1) using multivariate regression trees (MRT).[45] The method allows for the identification of groups of land managers who hold similar attitudes to conservation and whose conservation-related behaviour is similar, based on easy-to-obtain general characteristics such as the size of the farm and the number of years spent farming. The decision trees (or rules) that result from the analysis allow one to recast the results as a principal component analysis of instrumental variables, or redundancy analysis[46], where the instrumental variable is given by the MRT-determined combinations of the predictor variables[45]. The constrained principal components are linear combinations of the column-centred LVs (technically, response variables). The MRT analysis provides an F-test of the significance of the effect of the MRT-transformed predictors (or rules) on the transformed LVs, i.e. the constrained principal components. We conducted the test by regressing each constrained principal component on a three-level factor whose levels are given by the MRT-determined rules.

We also mined out a set of causal models relating the LVs to each other, using the PC algorithm of Spirtes et al.[47] To test the plausibility of the models, we used Shipley's *C*-test[48], and followed up by fitting a pair of partial least-squares path models to the best-fitting model to test model effects.

Analyses were done using R[49], supported by the contributed packages bnlearn[50] (for the causal model), semPLS[51] (for the partial least-squares path model), mvpart[45] (for the MRT and associated analyses), and multcomp[52] (for the post-hoc contrast analysis of the constrained principal components).

Table 1: Statistics on the reliability and dimensionality of the final scales to measure the four latent variables

Scale	RV[a]	Reliability[b]					Dimensionality[c]			
		α	λ6	ωt	MS	LC_R	*H*	*β*	ECV	ωh
Conservation behaviour (CB)	0.913	0.881	1.000	0.990	0.841	0.777	0.593	0.814	0.502	0.704
Conservation knowledge (CK)	0.806	0:849	1.000	0.999	0.655	0.763	0.553	0.631	0.563	0.710
Environmental attitude (EA)	0.838	0.905	0.979	0.991	0.904	0.835	0.653	0.785	0.655	0.839
Willingness to collaborate (WC) [C19]	0.846	0.945	1.000	0.984	0.926	0.900	0.671	0.841	0.632	0.783

[a]RV indexes the extent to which the matrix of scores of the sharpened scale matches or approximates that of the unsharpened scale.

[b]Reliability if the item is dropped. The first three indices derive from classical test theory, the last two from Mokken scale analysis (non-parametric item response theory): α is Cronbach's alpha; λ6 is the sixth of Guttman's coefficients; ωt is McDonald's total omega; MS is Molenaar and Sitjsma's coefficient of reliability; LC_R is coefficient of latent class reliability.

[c]Dimensionality if the item is dropped. H is Loevinger's coefficient of scale scalability (from Mokken scale analysis); β is Revelle's beta (from item-cluster analysis); ECV is Reise's explained common variance; ωh is McDonald's hierarchical omega.

Results

Land managers' attitudes, knowledge and behaviour

All 26 land managers were white men aged between 33 and 77 years, with the majority (61%) aged ≤50 years (Supplementary table 2). Farming experience ranged from less than 10 years to over 50 years, with the majority (74%) of respondents having farmed for between 11 years and 30 years. Farms ranged in size from <50 ha to 12 000 ha, with 48% being between 100 ha and 500 ha in size. Most (91%) land managers indicated that ostrich farming was their primary land-use activity. First-generation land managers comprised 22% of the sample, with the remainder representing a range from 2nd generation to 7th generation land managers; 65% of land managers had learnt how to farm ostriches from their fathers. Although 17% had no tertiary qualifications, 35% had a formal qualification in Agriculture.

Flock breeding was the most widespread breeding practice, implemented by 65% of land managers, primarily because it is less intensive and easier to manage than pen breeding, and was considered the most profitable practice. Only two (9%) respondents reported that they implemented flock breeding primarily for historical reasons, and because they were not interested in other practices. Other reasons included poor success with pen breeding and having access to sufficient natural land available for ostriches to roam. Camp size and the perceived carrying capacity of the land were the primary criteria (both 26%) given for deciding upon ostrich stocking densities.

Regarding ostrich stocking rates, two farmers (9%) thought that ostriches should not be kept on natural land because they cause excessive degradation. Two (9%) thought that low (11–50 ha/ostrich) stocking rates are ecologically appropriate, whereas one (4%) thought that moderate (11 and 20 ha/ostrich) stocking rates are ecologically appropriate. The remaining land managers either expressed no opinion (22%) or thought that a stocking rate of less than 10 ha/ostrich is sustainable (56%). The majority of land managers (87%) held that the recommended stocking rate of 22.8 ha/ostrich is 'very unprofitable'. The farms of 21 of the 23 land managers surveyed have flat areas or valleys where most ostrich farming activities take place. The vegetation of these areas was considered to be in good condition by all 21 land managers who use them.

Attitudes toward the environment (EA) were generally positive (Supplementary table 3). The majority of land managers 'agreed' or 'strongly agreed' (hereafter 'agreed') with several statements indicating pro-environmental attitudes, a sense of responsibility for the environment, and an interest in biodiversity stewardship. Most (96%) agreed with the statement that 'Protection of plants and animals that occur outside of protected reserves should be the responsibility of private landowners'.

Conservation knowledge was generally high (Supplementary table 4). Most respondents (74%) were aware that the vegetation of the Little Karoo is endangered and knew why the lower lying areas of the Little Karoo should be conserved. All but two were aware of the Ostrich Biodiversity Management Project, and of the stocking rates prescribed by the government, but more than half were unaware of the CapeNature Stewardship Programme.

Most land managers reported positive conservation behaviour (Supplementary table 5); 87% had instituted soil conservation measures for reducing soil erosion in the last 5 years, and 70% indicated that they had undertaken nature conservation activities such as surveys, restoration, and monitoring on their farms during that period. More than half (65%) thought it was necessary to have an environmental management plan for their farm, and most (91%) implemented healthy waste-management practices on their farms. Only 34% formally monitored the condition of their land, and 48% regularly attended conservation-related meetings.

When asked whether incentives would motivate them to promote conservation on their land, 95% of respondents agreed (Supplementary table 6). The majority of land managers indicated an interest in incentives (Supplementary table 7). A large proportion (48%) were not interested in public or community recognition for their conservation efforts. Those who responded positively to the incentives question were most interested in subsidy for conservation work (92%), assistance with fencing and land management (87%), assistance with farm environmental plans and maps (83%), law enforcement support (83%), access to scientific information and support (83%), and tax or rate rebates for conservation activities (78%).

Of the 24 organisations suggested in the questionnaire, land managers were most willing to collaborate with the National Department of Agriculture, Fisheries and Forestry (NDAFF), the South African Police Service (SAPS), a Farmers' Association (AgriKK), and neighbouring farmers (Supplementary table 8). The Wildlife and Environmental Society of South Africa (WESSA), Rhodes University, and local and district municipalities received the lowest willingness to collaborate scores. Many land managers had never heard of the conservation organisations WESSA (43%), the Gouritz Biosphere Reserve (22%), or the Cape Leopard Trust (22%).

Correlation and causal relationships between latent and ancillary variables

Relationships among the four latent variables (CB, CK, EA and WC), and between them and four key ancillary variables (Years Farming (YrF), Farm Size (FSz), Farmer Age (FAge), and Level of Education (LoE)), are shown in Supplementary figure 1. Conservation behaviour was positively correlated with EA ($p<0.001$) and CK ($p<0.01$), but only marginally with WC ($p=0.1$). A near-significant positive relationship ($p<0.1$) was found between CK and EA, but no significant relationships were found between CK and WC, or between CB and WC. Farmer age and YrF showed a strong positive correlation ($p<0.001$). There were near-significant ($p<0.1$) positive correlations between FAge and CB and CK (but not EA), and a near-significant negative correlation between YrF and WC ($p<0.1$). Farm size showed a weak positive relationship with CK ($p<0.1$). Level of Education was not significantly correlated with any other variable.

Both causal models (Figure 1) are plausible descriptions of causal relationships between the latent variables, based on Shipley's *C*-test ($C_{df=6}=2.947$, $p=0.815$ and $C_{df=8}=7.756$, $p=0.458$). The model shown in Figure 1a fits the observed data marginally better than does the model shown in Figure 1b, based on the log-likelihood (−90.525 versus −90.539). The two models differ in how they describe the causal relationship between CB and EA, with CB being a determinant of EA in the model shown in Figure 1a and the opposite being the case in the other model. Relationships that are common to both models are, firstly, that CK has no causal effect on CB, EA or WC. Secondly, and likewise, WC has no effect on CB, CK or EA. Finally, both models indicate that CK is a consequence of CB, rather than it influencing, or being a cause of, CB.

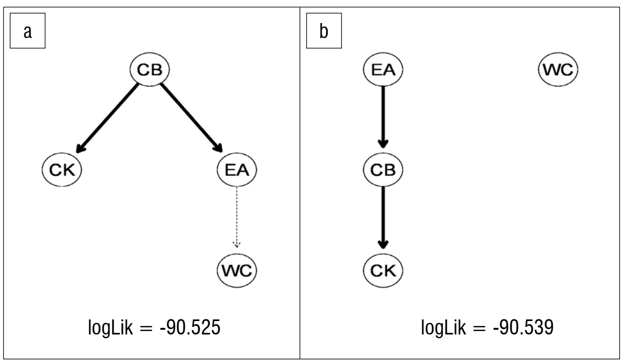

Figure 1: Causal models of the latent variables. The weights of the paths are proportional to the degree of confidence in the path, based on a Monte-Carlo simulation analysis (800 000 permutations). All effects are positive, and both models are plausible descriptions of causal influences based on Shipley's *C*-test (see the text).

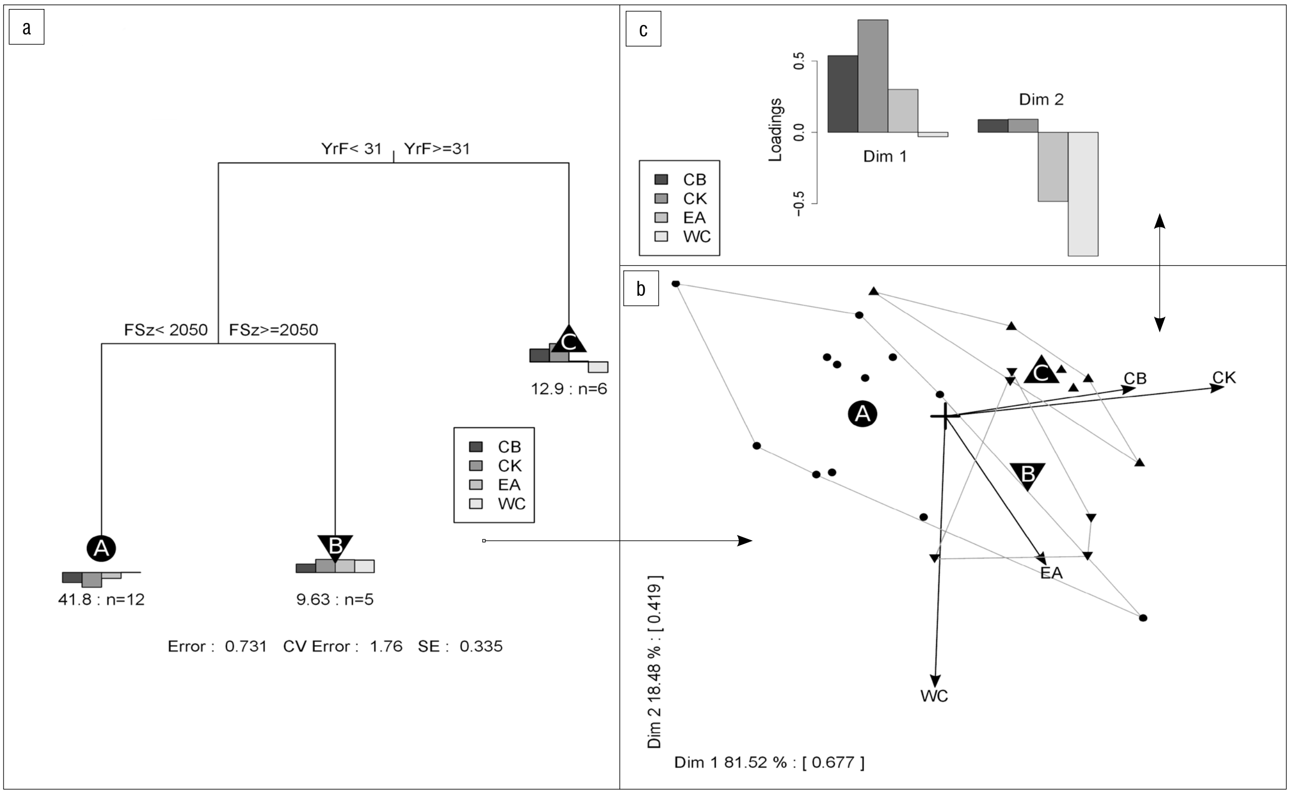

Figure 2: (a) Multivariate regression tree (MRT) of the predictors of the latent variables (LVs). The model has an approximate R^2 of 0.2698, meaning it explains approximately 26.98% of the variance of the LVs. Bars show deviations from the grand mean of each scale. (b) Distance (i.e. row-preserving) biplot of the constrained principal component analysis on instrumental variables (PCAIV). The origin of the biplot represents the average position. Convex hulls delimit each group and the big points within each hull show the centroid (or MRT-predicted mean) of each group. An estimate of respondents' individual-level scores on the LVs may be derived by orthogonally projecting the small points onto the vectors of the LVs. The values in square brackets after the variance explained by each dimension are interset correlations, the correlation between respondents' scores on each dimension and the LVs. (c) Variable loadings on dimensions 1 and 2 of the PCAIV shown in (b).

Predicting conservation opportunity from farmer attributes

A MRT showed that there were three groups of land managers based on their scores for the four LVs (Figure 2a). The three groups were defined by the number of years they had been farming (YrF) and by farm size (FSz). Land managers with 30 or fewer years of farming experience were split into two groups. The first group (Group A in Figure 2) of 12 land managers manage smaller farms (<2050 ha). They have below-average scores for EA, AB and CK, and have average scores for WC. The second group (Group B) comprised five land managers whose farms are large (≥2050 ha) and who have above average scores for all four LVs. Scores for CB and CK were highest in land managers (n=6) who had farmed for ≥31 years (Group C in Figure 2). Their EA scores were average and their WC scores were the lowest of the three groups. This group represents more experienced and knowledgeable land managers who show little willingness to collaborate with a wide range of institutions. Parametric and non-parametric omnibus tests reject the null hypothesis that there are no differences between the grand means of the three groups (parametric test: ρ=0.0061; non-parametric test: ρ=0.0045), although the effect size was relatively small (26.98% variance explained).

Figure 2b illustrates relationships between the MRT-determined groups and the LVs in greater detail, on a component-by-component basis. The first dimension explained 81.52% of the total variation and is highly significant ($F_{[df=2,20]}$=8.48, p=0.0022). It is mainly a contrast between the two groups of respondents on the right-hand side of the origin (Groups B and C), characterised by higher than average scores for CK, CB and EA (in order of decreasing weight or importance), and the group on the left-hand side of the origin (Group A), with lower than average scores for these LVs. Willingness to collaborate (WC) projects close to the origin on the first dimension and therefore makes virtually no contribution to the separation of groups in that dimension (variable loadings on the two dimensions are shown in Figure 2c). Post-hoc analysis of the dimension shows that Groups B and C differed significantly from Group A but did not differ significantly from each other (Table 2).

Table 2: Post-hoc pairwise comparisons (Tukey contrasts) showing the estimated difference (linear contrast) between the three groups of land managers along the first and second dimensions of the constrained principal component analysis (Figure 2b). The null hypothesis tested is that there is no difference between group-scores; p-values were adjusted for multiple testing using a single-step method based on the t-distribution.

Comparison	Dimension 1			Dimension 2		
	Estimate	*t*-value	*p*-value	Estimate	*t*-value	*p*-value
A – B = 0	-1.940	-3.56	0.0053	-0.538	-1.04	0.5598
C – B = 0	-0.151	-0.23	0.9715	-1.293	-2.06	0.1229
C – A = 0	1.790	3.08	0.0153	-0.755	-1.37	0.3737

The second dimension of the analysis explains 18.48% of the total variation. Figure 2b shows a minor separation between Groups B and C in the second dimension, because of different scores on WC, and to some extent on EA (see the bars for WC and EA of Groups B and C in Figure 2a). The second dimension is not, however, statistically significant ($F_{[df=2,20]}$=2.13, p=0.15). Given this fact, and the fact that almost all of the variability in WC lies in the non-significant second dimension, we may conclude that the three groups of respondents do not differ from each other to any significant degree in their scores for WC. This is borne out by a post-hoc analysis of the dimension (Table 2).

Figure 2b also illustrates the extent to which respondents in each group diverge from the predicted (or mean) score of the group (marked by the large symbol at the centroid of the convex hull enclosing each group). It illustrates the extent to which respondents do not fit the pattern of LV-scores predicted by the MRT model, i.e. by the social identifiers 'years spent farming' and 'farm size'. If we exclude the unusual member of Group A in the bottom right-hand corner of the biplot (quadrant IV), with the highest, or close to highest, scores on all four LVs, and two members of Group B, who marginally overlap with Group C, then all three groups are distinct with respect to their scores on the LVs. Despite the relatively small size of the sample, the MRT-determined characteristics of 'years spent farming' and 'farm size' are thus good predictors of respondents' scores and therefore of their attitudes and behaviour.

Discussion

Land managers' current practices and attitude to change

Despite research efforts there is still much to be learned about why farmers voluntarily adopt, or fail to adopt, improved technologies and sustainable practices.[11] The majority of land managers interviewed maintained a traditional flock breeding system on natural veld, even though this practice has been reported to lead to land degradation.[31] South Africa is one of the few countries (along with Israel and Zimbabwe) where traditional flock breeding of ostriches in large populations is widely practised.[53] More economically and ecologically sustainable alternatives to flock breeding have been recommended by agricultural economists and by the Ostrich Industry Biodiversity Management Project. Intensive pen breeding in particular is supported by the SAOBC, because its impact is limited to much smaller spatial scales than that of extensive ostrich flock breeding.[31,35] This raises the question of why land managers still overwhelmingly implement flock breeding in the Little Karoo, and elsewhere in South Africa. The reasons for flock breeding in our study area, and likely other parts of the Little Karoo, appear to be a combination of a preference for established low-intensity practices, and positive (although seemingly unrealistic) perceptions of the economic and ecological sustainability of current practices.

The stocking rate preferred by most land managers was 10 ha/ostrich. This stocking rate is more than double the recommended agricultural stocking rate of 22.8 ha/ostrich that land managers considered unprofitable. There is a wide gap between these rates considered to be economically and ecologically sustainable, and most studies on sustainable ostrich stocking rates have only addressed a single dimension of sustainability.[32] The lack of agreement on an ecologically and economically sustainable stocking rate is likely to be an important factor hindering the adoption of alternative, more sustainable farming practices in the Little Karoo.

Attitudes, knowledge, behaviour and willingness to collaborate

On the whole, land managers reported positive attitudes towards the natural environment of the Little Karoo, a good knowledge of the global importance of its biodiversity and conservation, and conservation behaviours such as soil conservation, ecological monitoring, and environmental management. This corresponds to the farmers' own assessments as operating in an environmentally sustainable manner, but contrasts with ecologists' views of the actual impacts of extensive ostrich farming.

A key aim of this study was to assess whether positive environmental attitudes and high levels of conservation knowledge corresponded to high levels of conservation behaviour (actual practices) and a willingness to collaborate (the potential to influence and support the improvement of practices). Both CK and EA were moderately and significantly correlated with conservation behaviour, but were more weakly and insignificantly correlated with each other. Inferences that can be drawn from the two causal models are, firstly, that little would be gained from investing in improving CK as a way of improving CB, EA or WC, because CK has no causal effect on them. Secondly, and likewise, there is no point encouraging a willingness to collaborate (WC), because WC was found to have no effect on CB, CK or EA. Finally, both models indicate that CK is a consequence of CB, rather than CK influencing or being a cause of CB.

The finding that CK does not lead to an increase in conservation-related behaviour (or to a greater willingness to collaborate) is echoed by the findings of other recent studies of environmental behaviour among farmers. Environmental awareness was not sufficient to motivate the adoption of water conservation in Finland[16], and information from the media did not significantly influence farmers' intentions to farm sustainably in Ethiopia[11]. The theory of planned behaviour[5] describes behaviour as being driven by intention (itself a function of attitude, subjective/societal norm, and perceived behaviour control), and by perceived behaviour control directly. Knowledge is not included in this model as a direct determinant of behaviour, although some modifications[1] include it as an indirect driver in the form of awareness of the need for, and consequences of, the behaviour. Several recent studies have applied the theory of planned behaviour and variants thereof to understand the drivers of farmer behaviour, including the adoption of technologies and sustainable practices.[11] A common finding, similar to that in this study, is that farmers often have positive attitudes towards the environment but do not act on them because of a perceived inability to change, with economic constraints being a commonly cited factor.[18]

Willingness to collaborate was found to be distinct from the other scales and to be uncorrelated with EA, CB and CK. This finding suggests that farmers who had positive attitudes and behaviours were not necessarily willing to collaborate with a variety of agencies and institutions to achieve greater ecological sustainability. It is probable that respondents' stated willingness to collaborate with particular organisations reflected their trust/distrust, or pragmatism and discernment with regard to particular organisations, rather than a fundamental (un)willingness to collaborate with organisations to achieve better land management and conservation. As it was implemented in this study, the WC scale measures at least three things: (1) a willingness to collaborate *sensu stricto* (i.e. in the sense of a latent trait), (2) a willingness to collaborate conditional on the nature of the organisation (i.e. additional to the latent trait, but tempered by discrimination/judgement), and (3) a general knowledge of organisations that engage in conservation or in conservation-related activities. Future work to identify land managers who are open to engagement on conservation issues, and who potentially would be willing to adapt their management practices, should be designed to disentangle these different, interrelated, dimensions of willingness to collaborate.

In addition to individual attitudes, norms and values, the most commonly applied theories in environmental psychology recognise two other important determinants of environmental behaviour.[5,54] These determinants are societal or subjective norms (what is expected by society, especially peers, and how strong such pressure is), and perceived behaviour control (an individual's perceived capability to perform a behaviour). Initiatives encouraging the adoption of conservation practices should therefore target entire farming communities, in an effort to change societal norms in tandem with personal ones[4], and to address perceived constraints to behaviour change. Farmers' perceived ability to change behaviour, even when they recognise the value of nature conservation, is very often constrained by economic factors.[18,55] Incentives such as tax rebates and other material support may help to reduce this obstacle to adopting more sustainable farming practices, as indicated by farmers in this study. Lastly, frequent behaviours become more strongly influenced by habit and less determined by intent.[1] Influencing routine behaviours thus requires not only a change in personal and societal attitudes but also a disruption of established habits.

Predicting conservation opportunity based on farmers' attributes

We expected that older land managers with more years of farming experience would be less likely to change their traditional farming practices and therefore would be less willing to innovate. We also expected that individuals who own or manage larger farms would be in a better position to implement conservation actions, given that such farmers were likely to have more financial and other resources, as well as being better placed to benefit from economies of scale if changing their practices. Farm size and years of farming did, indeed, emerge as the key predictors of an individual's EA, CK, CB and WC profile and could be used in conjunction with other information to identify land managers who present an opportunity for championing more ecologically sound ostrich farming practices. Age and farm size also emerged as factors correlated with landholder attitudes and behaviour toward the conservation of Renosterveld, with younger farmers, and those with bigger farms and more remnant Renosterveld vegetation, being more inclined towards conservation.[22] Cultivated acreage size (together with attitudes and past behaviour) was also found to be a significant factor in influencing an intention to adopt sustainable practices in Italy.[13]

Land managers with 30 or fewer years of experience and larger properties (≥2050 ha) had above-average mean scores for all four LVs. In terms of actual practices, attitudes and willingness to collaborate, this group (Group B in Figure 2) presents the greatest opportunity for intervention to improve ecological sustainability, as well as for championing newer and more sustainable farming methods. Conservation behaviour and CK were highest in respondents who had farmed for ≥31 years (Group C in Figure 2). Land managers in this older group of land managers had average EA scores and, as expected, were the least willing to collaborate. Given their long experience (and hence likely good standing among their peers) and high CB scores, this group of land managers is important to engage. Our findings suggest that engaging older farmers would require a different approach than that used for working with the younger farmers with larger properties (Group B), whose willingness to collaborate was already high. It is important to determine whether the low CK scores in this group of older farmers is because of a fundamental conservatism and unwillingness to collaborate, and/or their perception of the particular set of organisations they were presented with in the questionnaire.

The largest group in our sample comprised land managers with more limited farming experience (<31 years) and smaller farms (<2050 ha; Group A in Figure 2). Given their low scores for all latent variables, this group should not be a priority for an investment of time and effort in an attempt to change attitudes or behaviours. Although their lack of experience could mean that with more input they could become more aware and involved, land managers with small farms may have a more limited opportunity for change as they are unable to compete without the economies of scale available to larger farms.[33] There is also potentially less natural land to conserve on smaller farms, meaning that the return-on-investment of partnerships built to initiate positive changes of attitude and behaviour is likely to be relatively small.

Conclusions

Despite positive attitudes to biodiversity and conservation, the majority of ostrich farmers in the Little Karoo practise flock breeding, which is deemed environmentally unsustainable. Farmers themselves believed that flock breeding at stocking rates far exceeding the recommended carrying capacity was economically viable, and that land used in this way was in good ecological condition. The big difference between the assessments and recommendations of conservationists, ecologists and the majority of farmers points to a need to close this gap.[32] This requires communication and co-operation, and also perhaps a more tempered and realistic assessment of what ecological sustainability in a production (as opposed to a conservation) landscape should look like. The factors that constrain farmers from adopting new methods and finding effective and appropriate ways to make alternative methods more viable for land managers, should be research priorities. Agricultural organisations that are trusted by farmers have a key role to play in bridging the gap between farmer and conservation perceptions. At a time when shrinking budgets reduce the availability of extension services and other face-to-face farmer support, social learning among farmers should be fostered and supported.[56]

Acknowledgements

We thank the land managers of the Little Karoo for supporting this research and participating in the survey, the South African Ostrich Business Chamber for providing assistance and permission to use information, and the veterinary technicians of the Oudtshoorn Research Farm for providing data that supported the research. The research was funded by the National Lottery Distribution Trust Fund, which supported the South African Ostrich Business Chamber's Biodiversity Management Project. CapeNature provided logistic and administrative support.

Authors' contributions

A.W., A.T.K. and S.V. conceptualised and designed the research. A.W. collected the data. M.D. performed data analyses. A.W. and S.V. wrote the manuscript with substantial editorial contributions from A.T.K. and M.D.

References

1. Klöckner CA. A comprehensive model of the psychology of environmental behaviour – A meta-analysis. Glob Environ Chang. 2013;23:1028–1038. https://doi.org/10.1016/j.gloenvcha.2013.05.014
2. Tremblay KR Jr, Dunlap RE. Rural-urban residence and concern with environmental quality: A replication and extension. Rural Sociol. 1978;43:475–491.
3. Williams JA Jr, Moore HA. The rural-urban continuum and environmental concerns. Great Plains Res. 1991;1:195–214.
4. Quinn CE, Burbach ME. A test of personal characteristics that influence farmers' pro-environmental behaviours. Great Plains Res. 2010;20:193–204.
5. Ajzen I. The theory of planned behaviour. Organ Behav Hum Dec. 1991;50:179–211. https://doi.org/10.1016/0749-5978(91)90020-T
6. Kaiser FG, Wölfing S, Fuhler U. Environmental attitude and ecological behaviour. J Environ Psychol. 1999;19:1–19. https://doi.org/10.1006/jevp.1998.0107
7. Milfont TL, Duckitt J. The Environmental Attitudes Inventory: A valid and reliable measure to assess the structure of environmental attitude. J Environ Psychol. 2010;30:80–94. https://doi.org/10.1016/j.jenvp.2009.09.001
8. Curran P, Smedley D, Thompson P, Knight AT. Mapping restoration opportunity for collaborating with land managers in a carbon-credit-funded restoration program in the Makana Municipality, Eastern Cape, South Africa. Restor Ecol. 2012;20:56–64. https://doi.org/10.1111/j.1526-100X.2010.00746.x
9. Knight AT, Cowling RM, Difford M, Campbell BM. Mapping human and social dimensions of conservation opportunity for the scheduling of conservation action on private land. Conserv Biol. 2010;24:1348–1358. https://doi.org/10.1111/j.1523-1739.2010.01494.x
10. Reimer AP, Thompson AW, Prokopy LS. The multi-dimensional nature of environmental attitudes among farmers in Indiana: Implications for conservation adoption. Agric Hum Val. 2012;29:29–40. https://doi.org/10.1007/s10460-011-9308-z
11. Zeweld W, Van Huylenbroeck G, Tesfay G, Speelman S. Smallholder farmers' behavioural intentions towards sustainable agricultural practices. J Environ Manage. 2017;187:71–81. https://doi.org/10.1016/j.jenvman.2016.11.014
12. Martínez-García CG, Dorward P, Rehman T. Factors influencing adoption of improved grassland management by small-scale dairy farmers in central Mexico and the implications for future research on smallholder adoption in developing countries. Livest Sci. 2013;152:228–238. https://doi.org/10.1016/j.livsci.2012.10.007
13. Menozzi D, Fioravenzi M, Donati M. Farmer's motivation to adopt sustainable agricultural practices. Bio-Based Appl Econ. 2015;4:125–147.
14. Borges JAR, Tauer LW, Lansink AGJMO. Using the theory of planned behavior to identify key beliefs underlying Brazilian cattle farmers' intention to use improved natural grassland: A MIMIC modelling approach. Land Use Policy. 2016;55:193–203. https://doi.org/10.1016/j.landusepol.2016.04.004
15. Fielding KS, Terry DJ, Masser BM, Bordia P, Hogg MA. Explaining landholders' decisions about riparian zone management: The role of behavioural, normative, and control beliefs. J Environ Manage. 2005;77:12–21. https://doi.org/10.1016/j.jenvman.2005.03.002
16. Grammatikopoulou I, Pouta E, Myyrä S. Exploring the determinants for adopting water conservation measures. What is the tendency of landowners when the resource is already at risk? J Environ Plann Manage. 2016;59:993–1014. https://doi.org/10.1080/09640568.2015.1050551
17. Power EF, Kelly DL, Stout JC. Impacts of organic and conventional dairy farmer attitude, behaviour and knowledge on farm biodiversity in Ireland. J Nat Cons. 2013;21:272–278. https://doi.org/10.1016/j.jnc.2013.02.002

18. Šorgo A, Špur N, Škornik S. Public attitudes and opinions as dimensions of efficient management with extensive meadows in Natura 2000 area. J Environ Manage. 2016;183:637–646. https://doi.org/10.1016/j.jenvman.2016.09.024

19. Cumming T, Driver A, Pillay P, Martindale G, Purnell K, McCann K, et al. The business case for biodiversity stewardship. A report produced for the Department of Environmental Affairs. Pretoria: South African National Biodiversity Institute; 2015.

20. McDowell C. Factors affecting the conservation of Renosterveld by private landholders [doctoral thesis]. Cape Town: University of Cape Town; 1988.

21. McDowell C, Sparks R. The multivariate modelling and prediction of farmers' conservation behaviour toward natural ecosystems. J Environ Manage. 1989;28:185–210.

22. Winter SJ, Prozesky H, Esler KJ. A case study of landholder attitudes and behavior toward the conservation of Renosterveld, a critically endangered vegetation type in the Cape Floral Kingdom, South Africa. J Environ Manage. 2007;40:46–61. https://doi.org/10.1007/s00267-006-0086-0

23. Pasquini L, Cowling RM, Twyman C, Wainwright J. Devising appropriate policies and instruments in support of private conservation areas: Lessons learned from the Klein Karoo, South Africa. Conserv Biol. 2009;24:470–478. https://doi.org/10.1111/j.1523-1739.2009.01344.x

24. McDowell C. Legal strategies to optimize conservation of natural ecosystems by private landholders: Restrictive legislation. Comp Int Law S Afr. 1986;19:450–460.

25. McDowell C. Legal strategies to optimize conservation of natural ecosystems by private landholders: Economic incentives. Comp Int Law S Afr. 1986;19:461–474.

26. Savy C. Conserving wattled crane (*Grus canrunclulatus*) on private land in KwaZulu-Natal, South Africa: Attitudes, economics and potential incentives [MSc thesis]. Cape Town: University of Cape Town; 2003.

27. Mittermeier RA, Gil PR, Hoffman M, Pilgrim J, Brooks T, Mittermeier CG, et al. Hotspots revisited: Earth's biologically richest and most endangered eco-regions. Chicago, IL: University of Chicago Press; 2005.

28. Thompson MW, Vlok JHJ, Rouget M, Hoffman MT, Balmford A, Cowling RM. Mapping grazing-induced degradation in a semi-arid environment: A rapid and cost-effective approach for assessment and monitoring. Environ Manage. 2008;43:585–596. https://doi.org/10.1007/s00267-008-9228-x

29. Vlok JHJ, Cowling RM, Wolf T. A vegetation map for the Little Karoo. Unpublished maps and report for the SKEP project. 2005.

30. Herling MC, Cupido CF, O'Farrell PJ, Du Plessis L. The financial costs of ecologically non-sustainable farming practices in a semi-arid system. Restor Ecol. 2009;17:827–836. https://doi.org/10.1111/j.1526-100X.2008.00419.x

31. Cupido CF. Assessment of veld utilization practices and veld condition in the Little Karoo [MSc (Agric) thesis]. Stellenbosch: Stellenbosch University; 2005.

32. Wheeler A, Knight AT, Vetter S. Examining the evidence for ecologically sustainable ostrich breeding practices on natural veld in the Little Karoo, South Africa. Afr J Range Forage Sci. 2015;32:233–241. https://doi.org/10.2989/10220119.2014.982708

33. Wheeler A. Factors influencing ecological sustainability in the ostrich industry in the Little Karoo, South Africa [MSc thesis]. Grahamstown: Rhodes University; 2014.

34. Le Maitre DC, Milton SJ, Jarmain C, Colvin CA, Saayman I, Vlok JHJ. Linking ecosystem services and water resources: Landscape-scale hydrology of the Little Karoo. Front Ecol Environ. 2007;5:261–270. https://doi.org/10.1890/1540-9295(2007)5[261:LESAWR]2.0.CO;2

35. Murray MI. Economic case for pen-breeding. Unpublished report for the South African Ostrich Business Chamber Biodiversity Management Project supported by Critical Ecosystems Protection Fund (CEPF). 2008.

36. Pasquini L. Assessing the suitability and feasibility of implementing a biosphere reserve in the Gouritz Initiative Domain. Internal report for the Gouritz Initiative. 2008.

37. Bickerstaff K, Simmons P. The right tool for the job? Modelling, spatial relationships, and styles of scientific practice in the UK foot and mouth crisis. Environ Plann D. 2004;22:393–412. https://doi.org/10.1068/d344t

38. Hinchliffe S. Indeterminacy in-decisions – Science, policy and politics in the BSE (Bovine Spongiform Encephalopathy) crisis. Trans Inst Brit Geog. 2001;26:182–204. https://doi.org/10.1111/1475-5661.00014

39. Law J. Disaster in agriculture: On foot and mouth mobilities. Environ Plann A. 2006;38:227–239. https://doi.org/10.1068/a37273

40. De Champlain AF. A primer on classical test theory and item response theory for assessments in medical education. Med Educ. 2010;44:109–117. https://doi.org/10.1111/j.1365-2923.2009.03425.x

41. Cronbach LJ. Coefficient alpha and the internal structure of tests. Psychometrika. 1951;16:297–334. https://doi.org/10.1007/BF02310555

42. McDonald RP. Test theory: A unified treatment. Mahwah, NJ: Lawrence Erlbaum Associates; 1999.

43. Revelle W. Hierarchical cluster analysis and the internal structure of tests. Multivariate Behav Res. 1979;14:57–74. https://doi.org/10.1207/s15327906mbr1401_4

44. Mokken RJ. A theory and procedure of scale analysis. Berlin: De Gruyter; 1971. https://doi.org/10.1515/9783110813203

45. De'ath G. Multivariate regression trees: A new technique for modeling species-environment relationships. Ecology. 2002;83:1105–1117.

46. Rao CR. The use and interpretation of principal component analysis in applied research. Sankhya A. 1964;26(4):329–358.

47. Spirtes P, Glymour C, Scheines R. Causation, prediction, and search. 2nd ed. Cambridge, MA: MIT Press; 2000.

48. Shipley B. A new inferential test for path models based on directed acyclic graphs. Struct Equ Modeling. 2000;7(2):206–218. https://doi.org/10.1207/S15328007SEM0702_4

49. R Core Team. R: A language and environment for statistical computing. Vienna: R Foundation for Statistical Computing; 2016. Available from: http://www.R-project.org/

50. Scutari M, Denis J-B. Bayesian networks with examples in R. New York: Chapman & Hall/CRC; 2014. https://doi.org/10.1201/b17065

51. Monecke A, Leisch F. semPLS: Structural equation modelling using partial least squares. J Stat Softw. 2012;48(3):32.

52. Hothorn T, Bretz F, Westfall P. Simultaneous inference in general parametric models. Biometrical J. 2008;50:346–363. https://doi.org/10.1002/bimj.200810425

53. Deeming DC, Burbier NE. Behaviour in natural and captive environments. In: Deeming DC, editor. The ostrich: Biology, production and health. Wallingford: CABI Publishing; 1999. p. 83–104.

54. Jackson T. Motivating sustainable consumption: A review of evidence on consumer behaviour and behavioural change. Guildford: Centre for Environmental Strategy, University of Surrey; 2005.

55. Vanclay F, Lawrence G. Farmer rationality and the adoption of environmentally sound practices; a critique of the assumptions of traditional agricultural extension. Eur J Agric Educ Extension. 1994;1:59–90. https://doi.org/10.1080/13892249485300061

56. Genius M, Koundouri P, Nauges C, Tzouvelekas V. Information transmission in irrigation technology adoption and diffusion: Social learning, extension services, and spatial effects. Am J Agric Econ. 2013; 96(1):328–344.