Understanding the relationship between farmers and burrowing mammals on South African farms: Are burrowers friends or foes?

Izak B. Foster, Trevor McIntyre, Natalie S. Haussmann

Abstract

Burrowing mammals are ubiquitous on farms in South Africa and can hinder agricultural practices. This study explored farmer perspectives of these species, and specifically the factors that influence these perspectives. Forty-four farmers responded to a questionnaire that assessed their ecological knowledge of, tolerance towards and lethal management of burrowing mammals that occur on their farms. The results from generalised linear models showed that neither farmer age, nor level of education are accurate predictors of ecological knowledge, overall tolerance towards burrowers, or their lethal management. Knowledge of burrowing mammals showed a significant relationship with tolerance, with more knowledgeable individuals displaying higher levels of tolerance. However, a farmer's overall tolerance towards burrowing species did not affect the number of species managed. Our results also suggest that different values are attached to different species when it comes to lethal management. Thus, farmers commonly controlled the numbers of the problem rodent species, Highveld gerbil (*Gerbilliscus brantsii*) and Cape ground squirrel (*Xerus inauris*), but were less likely to manage black-backed jackal (*Canis mesomelas*) and warthog (*Phacochoerus africanus*), even when experiencing these as problematic. We suggest that the larger, more charismatic species possibly evoke more sympathy from farmers. Agro-ecosystems are likely to become increasingly important for conservation in the future, and we encourage continued studies on the environmental attitudes and approaches of agricultural practitioners as a means to understanding the current status and future trends in ecologically sustainable agriculture.

Keywords

Agro-ecosystem, burrowing mammal, ecological knowledge, farmer perceptions, lethal management, sustainable agriculture

Abbreviations

FAO: Food and Agriculture Organization of the United Nations

GCSE: General Certificate of Secondary Education

GLM: Generalised Linear Model

IUCN: International Union for Conservation of Nature

UN: United Nations

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Biosketches

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Introduction

The importance of practising agriculture that is socially, economically and environmentally sustainable is increasingly being recognised (FAO 2017). In addition, conservationists also advocate for agriculture to be ecologically sustainable, through the co-existence of agriculture with natural wildlife populations (Madden 2004; Treves et al. 2006). Indeed, the conservation of biodiversity can even benefit agriculture (Chappell and LaValle 2011), a notion that is encapsulated in the ecosystem service concept, which places a monetary value on the societal benefits of functions provided by ecosystems (Daily et al. 2000). As such, the United Nations General Assembly includes the preservation of biodiversity in one of its Sustainable Development Goals for 2030 (UN 2015).

Despite recognition of the need for agriculture and nature to co-exist, it is challenging to implement in practice, because farmers often view wildlife on their farms as agricultural pests (Conover 1998) that need to be trapped or killed to protect their livelihoods (Treves et al. 2006). For example, crop raiding by both Asian (*Elephas maximus*) and African (*Loxodonta africana*) elephant often results in human-wildlife conflict and a loss of both elephant and human lives (Hoare 2000; Choudhury 2004). Accounts of livestock attacks by many wild cat species, such as jaguar (*Panthera onca*) and puma (*Puma concolor*) in South America (Zimmerman et al. 2005; Amit et al. 2013), tigers (*Panthera tigris*) in India (Dhungana et al. 2018) and leopards (*Panthera pardus*) in Africa (Chase Grey et al. 2017; Pirie et al. 2017), are plenty, and the North American wolf (*Canis lupus*), which was once abundant, has been nearly exterminated to protect livelihoods (Bangs and Shivik 2001).

In South Africa, a number of burrowing mammal species, such as warthog (*Phacochoerus africanus*, Swanepoel et al. 2016), aardvark (*Orcyteropus after*, Whittington-Jones et al. 2011) and porcupine (*Hystrix africaeaustralis*, Bragg et al. 2005), are ubiquitous on farms. From an agricultural perspective, a number of reasons exist for farmers to potentially view burrowing mammals in an unfavourable light. Burrowing can damage infrastructure, such as fences (Swanepoel et al. 2016), and the burrows of larger species can damage farm machinery when these run over burrow mounds (Witmer et al. 2012), or injure livestock when these step into burrows (Witmer et al. 2012; Swanepoel et al. 2016). Furthermore, the presence of burrows in irrigated pastures make it difficult to control the spread of water, which can result in water loss and ditch bank erosion (Borgatti et al. 2017). In addition to their burrowing behaviour potentially conflicting with farming practices, a number of the burrowing mammal species are also held accountable for crop and livestock losses. For example, warthog, and a number of the rodent species, are often perceived as agricultural pests, because they feed on crops (Warren et al. 2007; Swanepoel et al. 2016). Carnivores, such as various mongoose species, are in turn thought to catch poultry (Holmern and Røskaft 2014), and black-backed jackal, *Canis mesomelas*, are even blamed for killing larger livestock (van Niekerk 2010; Nattrass and Conradie 2015; Drouilly et al. 2018; Minnie et al. 2018). Measures to control perceived problem species are often implemented at the discretion of the farmer. For example, both warthog (Swanepoel et al. 2016) and black-backed jackal (van Niekerk 2010; Minnie et al. 2018), are commonly hunted on farms as a means to reduce crop and livestock losses.

For ecologically sustainable agriculture to be viable, all local stakeholders, including farmers, need to be involved in the planning and implementation of measures to mitigate ecological footprints (Treves et al. 2006). However, although many farmers may recognize the social and economic value of wildlife on their farms, the issue of whether and how to farm alongside them is often complex, leaning both on ecological and agricultural knowledge (Nattrass and Conradie, 2015). Such knowledge, in turn, may influence farmer perceptions (Hughes and Fernandez-Duque 2010) and attitudes (Aertsens et al. 2011), which again influence behaviour (Ajzen 1985). As such, ecological knowledge can be viewed as a potential driver of the level of tolerance that a farmer perceives towards wildlife, with better informed farmers hypothesised to be more tolerant. Farmer tolerance in turn is hypothesized to influence their management of species perceived as problematic, with more tolerant farmers being less likely to practise lethal management. Furthermore, studies on the role that socio-economic factors play in environmental decision-making show inconsistent findings (Reimer et al. 2012). Mhuriro-Mashapa et al. (2017) found that education level played a significant role in people's willingness to pay for human-wildlife conflict management. Similarly, Swanepoel et al. (2016) and Zimmerman et al. (2005) found that age played a role in farmers' attitudes towards wildlife, and Sumner et al. (2017) showed that gender played a role in the adoption of conservation agriculture. In contrast, Knowler and Bradshaw (2007) showed no significant links between adoption of conservation agriculture and farmer age, education or environmental awareness.

Thus, the role that demographic determinants play in the farmer-wildlife relationship warrants further study.

This paper aims to identify the factors influencing the ecological knowledge, tolerance and behaviour (lethal management) of farmers in the context of wildlife conflict, by using burrowing mammals on South African farms as a case study. More precisely, the following research questions were posed: (1) How knowledgeable are farmers on the ecology, behaviour and diet of burrowing mammal species that are likely to occur on their farms and does this differ between farmer profiles? (2) How tolerant are farmers of burrowing mammals on their farms and does this differ between species and farmer profiles? (3) What lethal management techniques are used to control burrowing mammal numbers and does this differ between species and farmers? (4) What is the link, if any, between a farmer's ecological knowledge, his tolerance towards wildlife and his management of problem species?

Although the impetus for selecting burrowing species was because of the potential damage that their digging behaviour inflicts, we realise that many of these species also have impacts on farms that are independent of their burrowing (e.g. black-backed jackal are believed to prey on livestock). Given that these impacts are likely to affect how farmers perceive and manage these species, the paper also seeks to explore farmer grievances and reasons behind liking/disliking certain species.

Materials and methods

Study area

The town of Ottosdal is located in the North West Province of South Africa, and is situated approximately 290 km south-west of South Africa's capital city, Pretoria (Fig. 1). It is situated in a summer rainfall area and the predominant economic activity in the region is agriculture, mainly of commercial crop and beef production. The main crops produced are maize, sunflower and soya. Apart from beef cattle, some farmers also keep sheep, chickens and other farm animals.

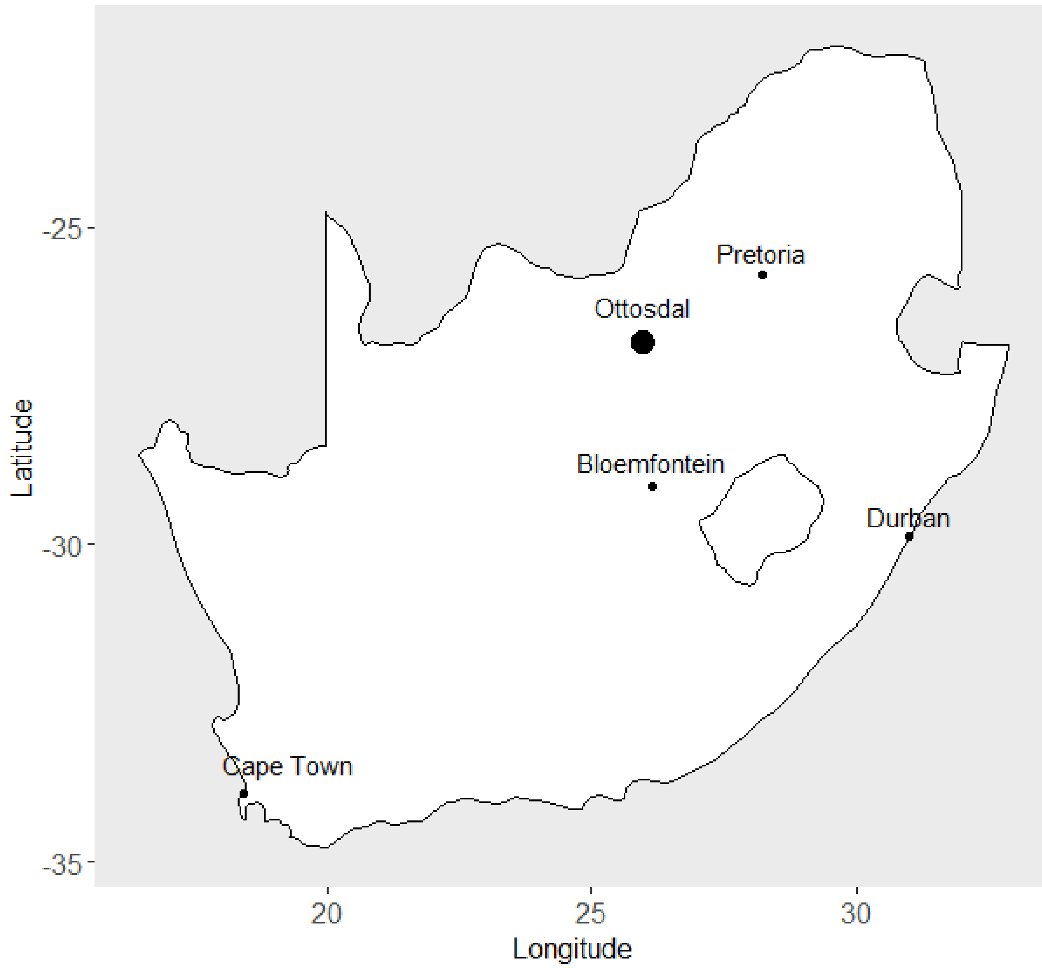

Fig. 1 The location of Ottosdal within South Africa.

Study species

A list of burrowing mammal species that are likely to occur in the Ottosdal region, based on IUCN Red List distributions (see iucnredlist.org), was compiled for the study (Table 1). This list consists of 32 species and is believed to include all well-known burrowers that occur in the region. In addition to species that dig their own burrows, either for food or to acquire shelter, a number of species are known to substantially enlarge existing burrows (e.g. aardwolf, *Proteles cristata*, are known to enlarge burrows of springhare, *Pedetes capensis*). Although the majority of the 32 species are nocturnal, some of the species are active in the day (Table 1). Burrow sizes range from massive structures (e.g. on average brown hyena, *Hyaena brunnea*, excavate in excess of 900 litre of soil per burrow (Owens and Owens 1979) and aardvark burrow entrances can be over 1 m wide (Melton 1976)) to much narrower, complicated tunnel and warren structures (e.g. those made by some of the gerbil species (Nel 1967)) (also see review by Haussmann 2017).

Data collection

Data for the study were collected primarily by means of questionnaires. To meet farmers to complete the questionnaire, one of the monthly Ottosdal farmer meetings was attended. This led to a snowball sampling approach, as farmers at the meeting supplied further contact details of potential participants. Participants had to meet a single criterion – they had to be commercial farmers. A total of 44 farmers agreed to complete the questionnaire. In addition, as a measure to gauge farmer knowledge, 44 non-farming members of the general public were also approached to complete the knowledge section of the questionnaire. These control group respondents were selected based on two criteria: they had to be male (to match the all-male farmer profiles) and they could not be farmers.

Table 1 Diet and time of activity of the 32 burrowing mammal species that are likely to occur in the Ottosdal region.

Species	**Type of diet**	**Time active**
Aardvark (*Orycteropus afer*)	Insectivore	Nocturnal
Aardwolf (*Proteles cristata*)	Insectivore	Nocturnal, sometimes diurnal during winter
African savanna hare (*Lepus microtis*)	Herbivore	Nocturnal
African striped weasel (*Poecilogale albinucha*)	Carnivore	Nocturnal
Bat-eared fox (*Otocyon megalotis*)	Carnivore, mainly insectivore	Nocturnal during summer, diurnal during winter
Black-backed jackal (*Canis mesomelas*)	Omnivore, mainly carnivore	Nocturnal, sometimes diurnal
Brown hyena (*Hyaena brunnea)*	Carnivore, scavengers	Nocturnal
Bushveld gerbil (*Gerbilliscus leucogaster*)	Omnivore	Nocturnal
Cape fox (*Vulpes chama*)	Carnivore	Nocturnal
Cape ground squirrel (*Xerus inauris*)	Omnivore, mainly herbivore	Diurnal
Cape hare (*Lepus capensis*)	Herbivore	Nocturnal
Cape porcupine (*Hystrix africaeaustralis*)	Omnivore	Nocturnal
Cape short-eared gerbil (*Desmodillus auricularis*)	Herbivore, mostly seeds	Nocturnal
Common warthog (*Phacochoerus africanus*)	Omnivore	Diurnal
Four-striped grass mouse (*Rhabdomys pumilio*)	Omnivore, mainly herbivore	Diurnal
Gerbil mouse (*Malacothrix typica*)	Omnivore, mainly herbivore	Nocturnal
Hairy-footed gerbil (*Gerbillurus paeba*)	Herbivore, mostly seeds	Nocturnal
Highveld gerbil (*Gerbilliscus brantsii*)	Herbivore, mostly seeds	Nocturnal
Honey badger (*Mellivora capensis*)	Omnivore, preference for bee honey	Diurnal, but nocturnal in places with high human populations
Krebs's fat mouse (*Steatomys krebsii*)	Omnivore, mainly seed eaters	Nocturnal
Meerkat or suricate (*Suricata suricatta)*	Omnivore, mainly insectivore	Diurnal

Species	**Type of diet**	**Time active**
Namaqua rock rat (*Aethomys namaquensis*)	Omnivore	Nocturnal
Scrub hare (*Lepus saxatilis)*	Herbivore	Nocturnal
Slender mongoose (*Herpestes sanguinea*)	Carnivore, but opportunistic omnivore	Diurnal, but sometimes active on warm, moonlit nights
South African pouched mouse (*Saccostomus campestris*)	Omnivore, mostly granivore	Nocturnal
Southern African Hedgehog (*Atelerix frontalis*)	Omnivore, mainly insectivore	Nocturnal
Southern multi-mammate mouse (*Mastomys coucha*)	Omnivore	Nocturnal
Springhare or springhaas (*Pedetes capensis*)	Omnivore, mainly herbivore	Nocturnal
Striped polecat (*Ictonyx striatus*)	Carnivore	Nocturnal
Tete veld rat (*Aethomys ineptus*)	Omnivore, mainly herbivore	Nocturnal
White-tailed mongoose (*Ichneumia albicauda*)	Omnivore, mainly insectivore	Nocturnal
Yellow mongoose (*Cynictis penicillata*)	Carnivore	Diurnal, sometimes nocturnal

Data from Skinner and Smithers (1990), except for African savanna hare (Kingdon et al. 2013) and Tete veld rat (Chimimba 1997)

The overall questionnaire was designed based on the researchers' *a priori* research questions, as well as informal discussions with farmers in the general area. It was designed not to be too cumbersome and long for farmers, while enabling the collection of information relevant to the research questions. Farmers were encouraged to provide critique of the questionnaire during the survey, however, no suggestions for improvement were received. The questionnaire consisted of four sections. The first section collected demographic data, such as age and level of education, of the respondent. The second section contained a 15 question multiple-choice quiz that tested the respondent's knowledge of burrowing mammal ecology, diet and management. The third section gathered information on farmer tolerance of the 32 species and required the farmers to rate their intolerance towards each of the 32 species on a Likert scale of one to five (with one being very tolerant and five being very intolerant). In the fourth section, data on lethal management of the various burrowing mammal species were obtained.

In addition to the questionnaire, a smaller group of farmers participated in a focus group discussion. The focus group discussion took place at one of the monthly farmer meetings, and lasted approximately 30 minutes. Open-ended questions related to the questionnaire questions were posed, with the aim of initiating conversation between farmers and probing deeper into their perceptions, while still keeping the discussion on point. The focus group discussion was facilitated by the first author.

Statistical analyses

Three scores were calculated per farmer from the data collected via the questionnaire, namely a knowledge score, intolerance score and management score. Knowledge scores were calculated as the number of correct answers out of 15 for the multiple-choice quiz. Intolerance scores were calculated as the average intolerance score across all of the species scored by the farmer. An overall management score was calculated for each farmer, based on the number of burrowing mammal species that he intentionally set out to manage, regardless of the management technique.

GLMs were used to model the relationships between knowledge, intolerance and management, and the socio-economic characteristics of the farmers. Response variables were knowledge scores, intolerance scores and management scores (Fig. 2). For the predictor variables, age (continuous variable) and highest level of education (Grade 12, tertiary technical training or university degree) were used. Knowledge was included as a predictor in the model for attitude, and both knowledge and attitude were included as predictors for management. In addition, for the model on management, two measures of farming scale (i.e. size of the farm) were included, namely the number of livestock kept by the farmer and the number of hectares planted with crops (Fig. 2). These were included as farm size has been shown to influence practical matters, such as environmental management, on farms (Mkhabela 2002; Tavernier and Tolomeo 2004), but there was no logical reason for the size of the farm to affect the knowledge or attitudes of a farmer (although also see Thompson et al. 2015 in this regard). A Gaussian distribution was used for knowledge and intolerance, and a Poisson distribution for management.

Based on the intolerance scores, four key species were identified as particularly problematic and disliked by farmers, namely Highveld gerbil, Cape ground squirrel, black-backed jackal and common warthog. In addition to the GLMs, chi-square tests of association were carried out to see whether a farmer’s management (managed or not managed) of these four key species depended on whether or not the farmer experienced problems with the species. Furthermore, chi-square tests were carried out to test whether the management techniques that the farmers used against the four key burrowing mammal species depended on predictor variables, i.e. age, highest level of education, knowledge, intolerance towards species, number of livestock kept and number of hectares planted. For this, the main methods that the farmers used to manage burrowing mammal population sizes were categorised into four categories, namely chemical control (mostly using poisons), mechanical control (mostly through trapping), biological control (the use of natural enemies, such as owls, to control population sizes) and hunting. All statistical analyses were conducted in the R programming environment (R Core Team, 2017).

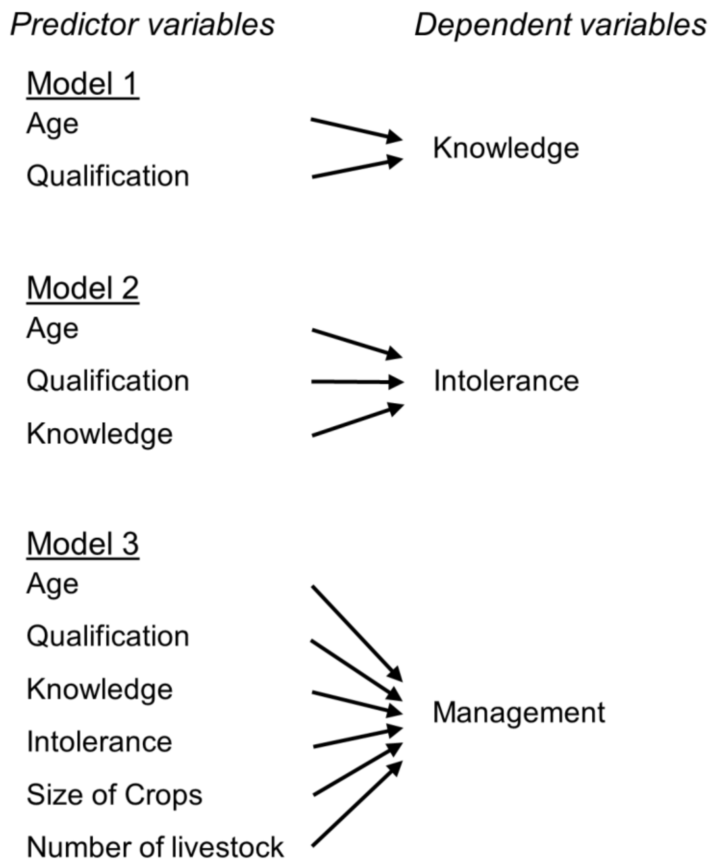

Fig. 2 The relationship between the modelled variables

Results

The characteristics of farmer respondents

All 44 of the farmers who agreed to participate were male. Farmer age ranged from 29 to 75 years, with a mean age of 49 years. Farming experience, i.e. the number of years that a farmer has been involved in the agricultural industry, ranged from 9 to 49 years, and was significantly positively correlated with farmer age (Pearson correlation, $r = 0.8$, $n = 44$). As a result, only age was included in the statistical models, and not farming experience. Nineteen of the 44 farmers had no formal qualification beyond a South African Grade 12 (GCSE certificate). Of the remaining 25, ten had a university degree and 15 a technical qualification. Furthermore, only eight of the 25 farmers with tertiary education qualifications, received an agriculture orientated education. The control group was of a similar age as the farmers (age range = 22 to 76 years, mean age = 46 years). Likewise, farmer and non-farmer qualifications were comparable, with 20 of the 44 non-farmers having no qualification beyond Grade 12, 13 having a technical qualification and 11 a university degree.

In total, the farmers produced a combination of 33 products. The vast majority (41 out of 44 farmers) produced beef cattle, but most of these farmers also planted white maize, yellow maize, sunflower, or kept sheep. Cattle herd size ranged from 35 to 800 head, with a mean of 235 head. The largest crop sizes were for white maize (mean = 750 ha). Whereas the crop sizes for sunflower and yellow maize were far smaller, the number of farmers that produced these commodities did not differ from those producing white maize.

How knowledgeable are farmers on the ecology of burrowing mammals?

The mean number of correct answers scored by farmers for the multiple-choice quiz was ten (Fig. 3), but ranged from four to full marks (Fig. 3). Furthermore, farmers did not receive higher scores than the general public ($t = -1.27$, $df = 43$, $p = 0.2$, Fig. 3). In general, questions that were answered correctly most often by the farmers related to the diet and time of activity of species, but this differed somewhat per species (Table 2). In contrast, the most incorrectly answered question was on the conservation status of springhare (Table 2).

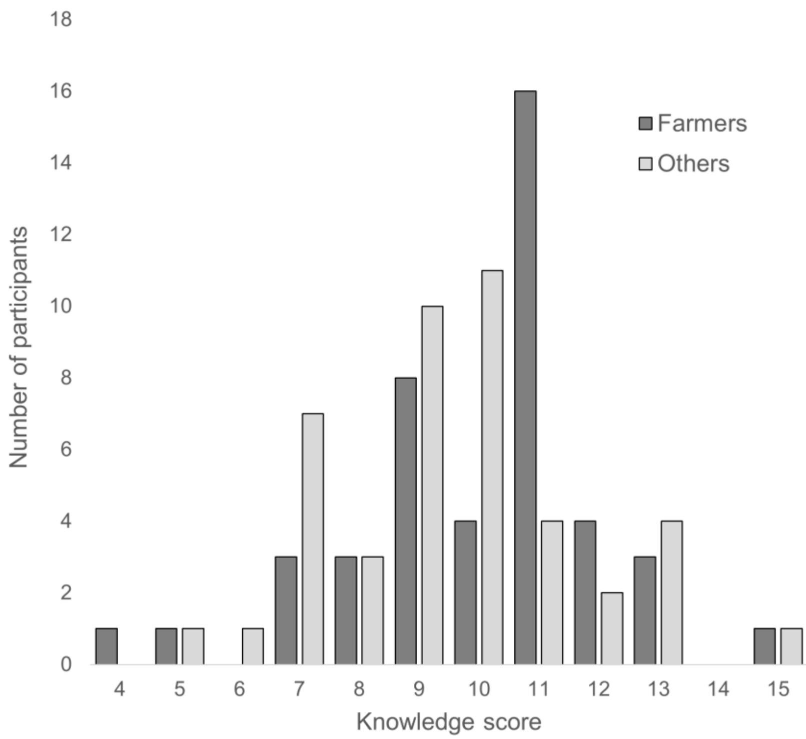

Fig. 3 Knowledge score distributions of farmers and non-farmers

Table 2. The number of correct answers scored by farmers (n = 44) per topic.

Question topics	**Correct**
Identification of the yellow mongoose (*Cynictis penicillata*)	35
Identification of the Cape fox (*Vulpes chama*)	26
Diet of aardwolf (*Proteles cristata*)	25
Identification of the Highveld gerbil (*Gerbilliscus brantsii*)	21
Diet of aardvark (*Orycteropus afer*)	36
Recognition of the species that makes the largest burrows	17
Consequences of pest control methods	12
Recognition of herbivorous species	40
Recognition of diurnal species	40
Recognition of species that kills the largest prey	36
Diet of the Highveld gerbil (*Gerbilliscus brantsii*)	38
Diet of the southern African hedgehog (*Atelerix frontalis*)	41
Hunting behaviour of bat-eared foxes (*Otocyon megalotis*)	43
Diet of scrub hare (*Lepus saxatilis*)	25
IUCN status of springhare (*Pedetes capensis*)	9

The entire questionnaire is available as online supplementary content.

How tolerant are farmers of burrowing mammals on their farms?

Seven species had mean intolerance scores above three (the score for “indifferent”), indicating some degree of intolerance towards these species (Table 3). These were black-backed jackal, Cape ground squirrel, common warthog and the four gerbil species, in particular the Highveld gerbil. The reasons for farmers feeling intolerant towards these species were mainly because they are believed to prey on livestock (black-backed jackal) or feed on crops (Cape ground squirrel, common warthog and Highveld gerbil, Table 3).

What management techniques are implemented to control burrowing mammals?

The four least tolerated species were also managed most often (Table 4). Whereas chemical methods were mostly used for the smaller rodents (i.e. Cape ground squirrel and Highveld gerbil), larger mammals (i.e. black-backed jackal and common warthog) were often hunted. Mechanical and biological control methods were rarely used, and almost exclusively for Highveld gerbil (Table 4).

Factors that influence farmer knowledge, intolerance and management

Neither age nor level of education were significant predictors of farmer knowledge, intolerance, or the number of species managed by a farmer (Table 5). However, knowledge showed a statistically significant negative relationship with level of intolerance ($p = 0.049$; Table 5; Fig. 4)

Table 3. Mean intolerance score per species (1 – 5; 1 = very tolerant, 5 = very intolerant) and the perceived damage that species cause.

		Perceived damage by species			
Species	**Mean intolerance score**	**Feeds on crops**	**Preys on livestock or poultry**	**Burrow injures livestock**	**Infrastructure/ equipment damage**
Cape ground squirrel	**4.19**	**33**		**1**	**2**
Highveld gerbil	**4.00**	**32**			
Common warthog	**3.86**	**23**		**8**	**8**
Black-backed jackal	**3.81**		**24**	**1**	**1**
Bushveld gerbil	**3.45**				
Hairy-footed gerbil	**3.32**	1			
Cape short-eared gerbil	**3.30**				
Slender mongoose	2.9		2		
Yellow mongoose	2.46		3		
Cape fox	2.46		1	1	
Cape porcupine	2.41	15		6	8
Springhare	1.85	1			
Cape hare	1.54			1	
Aardvark	1.32			2	2

Perceived damage values are the number of farmers that believe a species to cause that damage. Species in bold are those that stood out as particularly disliked by farmers. Only species that were perceived as causing some kind of damage, or that had intolerance scores above three, are reported.

Table 4. Management techniques used by farmers to manage species.

	Management category			
Species	**Chemical**	**Mechanical**	**Biological**	**Hunting**
Black-backed jackal		1		11
Cape ground squirrel	12		1	20
Cape porcupine	1			2
Common warthog		1		9
Four-striped grass rat	1			
Hairy-footed gerbil			1	
Highveld gerbil	28	12	9	
South African springhare	1			

Values below each management category are the numbers of farmers employing that technique.

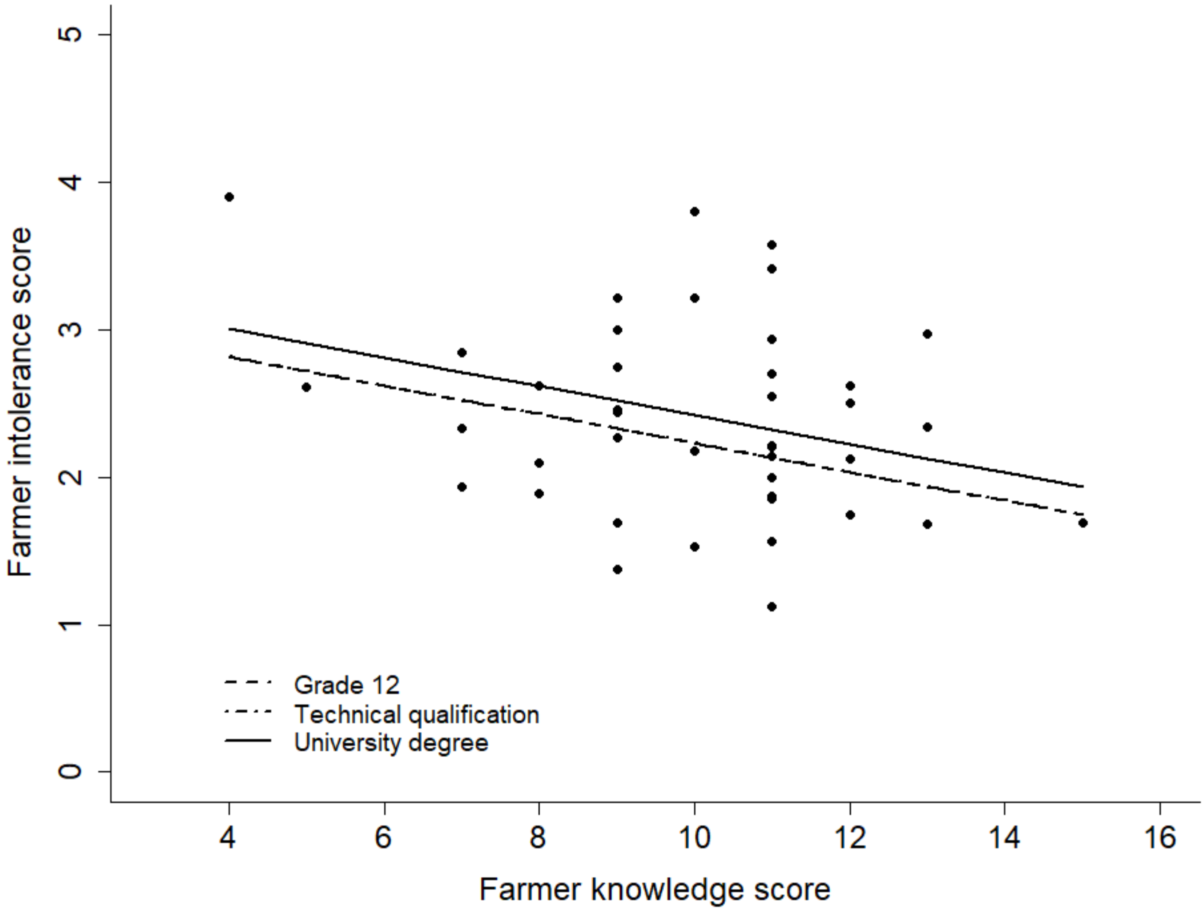

Fig. 4 Farmers' intolerance scores (1 = very tolerant, 5 = very intolerant) in relation to farmers' knowledge scores of digging mammals. Trend lines indicate the modelled (GLM) relationships for farmers with varying education qualifications. Note that the trend lines for Grade 12 and technical qualifications overlap.

Table 5. Results from the GLMs, showing the effect of age, level of education, knowledge and intolerance on the three response variables.

Response variable	Predictor	Chi^2	df	p
Knowledge	**Age**	0.12	1,42	0.73
	Education	3.03	2,40	0.22
Level of intolerance	**Age**	0.02	1,42	0.90
	Education	0.84	2,40	0.66
	Knowledge	3.88	1,39	0.05
Number of species managed	**Age**	0.09	1,42	0.77
	Education	0.63	2,40	0.73
	Knowledge	1.18	1,39	0.28
	Intolerance	2.52	1,38	0.11
	Size of crops	0.28	1,37	0.60
	Number of livestock	0.36	1,36	0.55

Table 6. Chi-square test outputs showing the relationship between management of the four key species and whether or not a farmer experienced problems with the species

Experienced problems with the species	**Managed the species**		**Test output**
	No	Yes	
Cape ground squirrel:			$Chi^2 = 18.86$, df = 1,
No	10	1	**$p < 0.001$**
Yes	6	27	
Common warthog:			$Chi^2 = 1.29$, df = 1,
No	15	2	$p = 0.26$
Yes	20	7	
Black-backed jackal:			$Chi^2 = 2.78$, df = 1,
No	17	3	$p = 0.1$
Yes	15	9	
Highveld gerbil:			$Chi^2 = 15.28$, df = 1,
No	8	4	**$p < 0.001$**
Yes	3	29	

While significant, this relationship was also characterised by a substantial variation in intolerance around the model fit (Fig. 4). Lastly, the number of species managed was not determined by knowledge or intolerance (Table 5).

The association between management of a species and whether or not a farmer experienced problems with that species differed between species. Thus, for common warthog and black-backed jackal, the decision to manage or not was not determined by whether or not the farmer experienced problems with these species and a number of farmers implemented no lethal management strategies for these species, despite claiming to experience problems (Table 6). On the other hand, farmers that experienced problems with Cape ground squirrel or Highveld gerbil were significantly more likely to lethally manage these species than those not experiencing problems (Table 6). Lastly, the only significant predictor of the management technique that farmers used was farmer age, specifically for mechanical management. Specifically, older farmers were less likely to employ mechanical management techniques than younger farmers ($Chi^2 = 4.36$, df = 1, p = 0.04).

Discussion

How knowledgeable are farmers on the ecology of burrowing mammals?

One of the key findings of this study was that the Ottosdal farmers are not more knowledgeable on the ecology of burrowing mammals than similarly-aged, equally educated members of the non-farming public. This was unexpected, as farmers are intuitively seen as people with close ties to the land, giving them an increased knowledge and responsibility as stewards of the land (*sensu* Sullivan et al. 1996). However, on average, both farmers and non-farmer respondents answered two-thirds of the multiple choice questions related to the ecology of burrowing mammals correctly. Although these results do not provide a conclusive verdict on farmer knowledge, they do provide a comparison and suggest that it is incorrect to assume that farmers have an increased knowledge on environmental considerations simply because they are dependent on the land for their livelihood and are in close contact with the land on a daily basis. Specific areas where farmers generally fared well in the test suggest a utilitarian approach (*sensu* Serpell 2004) to the environment, with productivist concerns mainly informing decisions. Thus, farmers scored highest on questions related to the diet and times of activity of species, aspects which potentially have direct bearing on farming productivity.

Two competing initial hypotheses existed in terms of the relationship between farmer age and their ecological knowledge of burrowing mammals on their farms: (1) older farmers have been exposed to these animals for a longer period of time, which would have allowed them to construct a better knowledge base than their younger counterparts, or (2) younger farmers have potentially been exposed to more information and more modern management practices than older farmers, leading to them scoring higher in the knowledge quiz. Contrary to both hypotheses, farmer age had no bearing on their knowledge. This finding aligns with Segnon et al. (2015), who found that age did not influence farmer knowledge of agroforestry systems and practices in Benin. In terms of education, farmers with higher qualifications were expected to have an increased ecological knowledge and score higher in the test, because they had presumably acquired ecological knowledge as part of their schooling. For example, people in Bangladesh with higher educational levels have been found to be more knowledgeable about climate change-related issues (Kabir et al. 2016). However, our results revealed that the level of education of farmers did not affect their knowledge on burrowing mammal ecology. A lack of agriculture-orientated training (and training within the biological sciences) amongst participants with tertiary qualifications, possibly explains this.

How tolerant are farmers of burrowing mammals on their farms?

Farmers were consistently intolerant towards the same species, namely Cape ground squirrel, the four gerbil species (particularly the Highveld gerbil), black-backed jackal and common warthog.

During the focus group discussion, the same four species emerged as problematic, particularly Highveld gerbil and black-backed jackal. Sentiments that were expressed by farmers included:

> "The animals that caused the most problems for me over the past few seasons were Highveld gerbils and pheasants. They keep me quite busy. The damage they cause can be ugly."

And

> "I have lost many lambs and sheep because of jackals."

The high level of intolerance towards these four key species harboured by farmers in this study is not unexpected. Ground squirrels have been found to be the largest single agent of damage to maize seed in Kenya (Key 1990) and in 1968 Zumpt advocated that the Cape ground squirrel should be completely destroyed, as it causes tremendous damage to maize crops in South Africa. The Highveld gerbil is also commonly poisoned, because of its destructiveness (Nell 2014). Similarly, warthog are known agricultural pests in South Africa, with farmers complaining about damage to fences, veld plants, soil systems and crops (Swanepoel et al. 2016). Indeed, introduced warthog in the Eastern Cape even display characteristics of an invasive species, proliferating at a profound rate, despite attempts to regulate numbers (Nyafu 2009). With regards to the black-backed jackal, livestock, including cattle and sheep, can make up more than 16% of black-backed jackal diets in summer and almost 20% in winter in some parts of South Africa (Humphries et al. 2015). In the North West Province specifically, the majority of jackal scats sampled contained both large and small mammal remains, with the percentage of invertebrates found in scats decreasing in unprotected areas (van der Merwe et al. 2009). One farmer in the present study stated when asked about the damage caused by black-backed jackal:

> "What the black-backed jackals do is they eat the cow and the calf while the cow is in labour. That means you lose the calf, and most often the cow too."

Interestingly, farmers seemingly do not so much dislike these burrowing mammals because of their burrowing behaviour, but rather because of their foraging behaviour. As such, the creators of the largest excavations, the aardvark (Whittington-Jones et al. 2011) were amongst the most tolerated species. In contrast, the Highveld gerbil, which creates tunnels too small to cause infrastructure damage (Skinner and Smithers 1990), but is believed to inflict large-scale crop damage (Nell 2014), evoked a sense of desperation amongst some of the farmers. One farmer felt that Highveld gerbil numbers on his farm were so large that they could completely destroy his crops, if not controlled:

> “I had to make a plan very fast with these Highveld gerbils. They were busy eating everything I planted.”

Another stated:

> “I experienced a plague of Highveld gerbils in one of my fields a few seasons ago, so I decided to plough to destroy the nests. There were so many that some of the ones ploughed out were scattering for cover. Many birds came to feed on them, especially the baby ones.”

Results from this study suggest that neither age, nor the level of education of a farmer affect his overall tolerance towards wildlife on his farm. The literature on the relationship between age, education and pro-environmental attitudes is divided. On the one hand, a number of studies support the notion of a positive association between higher levels of education and pro-environmental attitudes. This ranges from general concern for the environment (Buttel and Flinn 1978), to farmer attitudes towards adopting sustainable soil and water conservation measures (Anderson 1990; Moges and Taye 2017) to student affinities towards fauna (Schlegel and Rupf 2010). Similarly, a number of studies suggest a relationship between age and environmental concern, with older farmers, for example, often portrayed as less tolerant of wildlife. As such, Zimmerman et al. (2018) found that older cattle farmers in Brazil had more negative views of jaguars than younger farmers. In South Africa, Swanepoel et al. (2016) reported that older farmers preferred areas without warthogs and both Lindsey et al. (2005) and Thorn et al. (2012)

found that older people were less tolerant of carnivores on South African farms. On the other hand, there are also many studies which show no relationship (or even the opposite relationships to those intuitively expected) between education, age and the adoption of conservation agriculture (see review by Knowler and Bradshaw (2007)). The lack of a relationship between farmer age, education and tolerance towards wildlife was thus not completely unexpected.

Which species do farmers set out to manage?

Not surprisingly, the least tolerated species were also managed most often. During the focus group discussion, some farmers provided detailed accounts of their killing techniques, suggesting that they have quite strong feelings towards these animals. One farmer stated:

> "To control Highveld gerbils I use phostoxyn tablets. I try to throw them as deep into the hole as I can, and then I would step on the burrow to make sure that it closes."

Other farmers explicitly expressed their dislike for killing, but emphasized the perceived necessity for doing so:

> "I have problems with ground squirrels and warthogs. I don't enjoy killing animals, but when they become a problem I will shoot them."

Of particular concern is the potential unintended management of non-problem species during problem species management. The managed species recorded in this study are species that the farmers set out to manage, but unless the farmer sees what he is killing (e.g. through hunting), or knows which species the burrow he is targeting belongs to, management meant for a specific species could obviously also kill other unintended species. In addition, killing species can have cascading effects further in the food chain (Nyhus, 2016). An encouraging outcome in this regard, which emerged during the focus group discussion, was that some farmers seemed to take notice of these knock-on consequences, as well as the benefits of biological management. For example, one farmer stated:

> “I used to experience many problems with Highveld gerbils in one corner of a sandy maize field. Ever since I stopped hunting black-backed jackals over there, I experienced fewer problems with Highveld gerbils.”

And yet another recognised the value of biological control:

> “The owl boxes have definitely helped. I have very few problems with Highveld gerbils were there are owls. On my neighbour’s farm very close to one of my maize fields is an old abandoned diesel tank that the owls use. I must remind him to never take that down, because those owls assist me very much.”

In line with the literature on the relationship between tolerance, age and education, older and less educated farmers were also expected to apply lethal management more readily. Indeed, Chase Grey et al. (2017, p. 61) suspect that “older generation farmers will pay anything to kill a leopard”, and Thorn et al. (2012) found that older farmers were more likely to use lethal control to manage carnivore predation on their farms. However, the only significant finding on the relationship between age and lethal management was that older farmers were less likely to employ mechanical management. Similarly, no relationship between the number of species that a farmer set out to manage and his highest qualification was found.

Different values attached to different species

Although the four least tolerated species were also most often intentionally managed, these species were not equally likely to be managed when problems were experienced. Cape ground squirrel and Highveld gerbil were significantly more likely to be managed when they were seen as problematic and management intended for Highveld gerbil even exceeded the number of farmers who viewed this species as problematic. On the other hand, the management of common warthog and black-backed jackal was independent of whether or not problems were experienced with these species. Indeed, a large number of farmers did not intentionally manage warthog and jackal, despite claiming to experience problems with these species.

A number of potential explanations exist for the discrepancy in the application of lethal management between species in this study. It is possible that farmers feel more guilty when killing larger species, as larger species carry more “highly charged symbolism” (Treves et al. 2006, p. 385). On the other hand, both warthog (Swanepoel et al. 2016) and black-backed jackal (van Niekerk, 2010; Thorn et al. 2012; Minnie et al. 2018) are notoriously being killed elsewhere in the country, partially because of perceived increases in their numbers and consequent destruction (Nyafu 2009; Drouilly et al. 2018). This suggests that the Ottosdal farmers are perhaps not completely honest about their management of the two larger species, again possibly because they intuitively feel that many people attach more ecological value to larger than smaller mammals (Treves et al. 2006). Importantly, both explanations suggest that different human values are attached to different species (see also Schlegel and Rupf, 2010) within the agriculture-conservation domain. Lastly, although factors other than financial losses have been reported to drive human-carnivore conflict in South Africa (Lindsey et al. 2005; Thorn et al. 2012), this is possibly not the case with the smaller rodent species, which typically cause more extensive economic losses (Naughton-Treves et al. 2000), suggesting that management can also be driven purely by the extent of the problem.

The relationship between knowledge, tolerance and management

Farmers are often expected to live in “some sort of ecological balance” with wildlife (Nattrass and Conradie, 2015, p. 23) and perceive wild animals not as pests, but as co-inhabitants of the agro-ecosystem (Treves et al. 2006). Farmers who don’t adhere to this ideology are subsequently perceived as ecologically ignorant (Nattrass and Conradie 2015). However, the relationship between knowledge of animals, attitudes towards them and behaviour is complicated (Serpell 2004). While some studies suggest that an increased animal knowledge is related to an increased positive attitude towards animals (Kellert 1993), it is not clear whether knowledge affects attitudes or attitudes affect knowledge (Serpell 2004). Others suggest that it is at the individual species level that increased knowledge leads to increased affinity (Schlegel and Rupf 2010).

Although our data suggested a negative relationship between the overall animal knowledge scores of farmers and their levels of intolerance towards burrowing mammals (i.e. more knowledgeable farmers were also less intolerant), the generally high variance from the modelled trend, coupled by a limited sample size, suggest that this result be interpreted conservatively. Furthermore, a potential limitation of our study was that our intolerance score does not provide a broad, comprehensive measure of environmental attitude, but was designed to specifically address tolerance towards a set number of species. It is possible that more robust relationships exist between broader environmental attitudes, control methods and perceptions of different species, but our study did not test that. We recommend that future research include more comprehensive attitude indices, such as the New Ecological Paradigm scale (Dunlap et al. 2000), which was designed to test more deeply held beliefs about nature, alongside more study-specific indices such as ours.

As with the relationship between knowledge and behaviour, the relationship between environmental attitude and behaviour has also been questioned (Mkhabela 2002). Our results suggest that farmers with more negative overall attitudes towards wildlife (i.e. higher overall intolerance scores) do not apply lethal management more readily than those who claim to be more tolerant. Part of the explanation is that lethal management is not necessarily anti-environment (Nattrass and Conradie 2015). Whether or not lethal management is justified is far more complex (Nattrass and Conradie 2015), with factors such as the conservation status of a species obviously playing an important role (Drouilly et al. 2018). Farmers with overall positive attitudes towards wildlife, but high management scores, are therefore possibly aware of these factors. Our results therefore suggest that lethal management is not driven by farmer characteristics, such as knowledge or tolerance, but rather by species characteristics, such as destructiveness and/or charismatics.

Conclusions

Through interviews with both farmers and the non-farming community of a small agricultural town in South Africa, this research has made a number of contributions to our knowledge of agriculture-wildlife conflict involving a group of mammal species with something specific in common: they all dig. Surprisingly, the digging itself is not considered a substantial problem for farming. Instead, our results show that the foraging behaviour, particularly of black-backed jackal, common warthog, Cape ground squirrel and Highveld gerbil, cause intolerant attitudes amongst many of the farmers. None of these four species are endangered. In fact, both jackal and warthog numbers are increasing in parts of the country (Nyafu 2009; Drouilly et al. 2018). As such, the controversies surrounding their control is not so much a conservation issue, as an animal cruelty issue (see also Nattrass and Conradie 2015; Nattrass and Conradie 2018). Our results add onto this notion, by suggesting that different human values are attached to different species when it comes to lethal management, with larger taxa viewed with more sympathy. While the species in this study are largely region-specific, the findings are more broadly applicable, as they possibly point towards general trends in human values associated with different animal taxa. In light of human population growth, decreasing food security and associated increases in agricultural land, we argue that the role of the agro-ecosystem as a platform for conservation is likely to become increasingly important in the future. We therefore advocate that studies such as these, which explore pro-environmental thinking amongst agricultural practitioners, play a necessary role in striving towards ecologically sustainable agriculture.

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Questionnaire:

Burrowing mammals in the Ottosdal Region, South Africa: Understanding farmer knowledge, tolerance and management

Section 1

1. What is your age?____

2. How many years have you been a farmer? ______________________________

3. What is your highest qualification obtained? (Please specify the name of the course/diploma/degree etc.)________________

____

____

____

____

____

____

____

4. As a farmer, what do you produce? Please indicate how many hectares you cultivate or the number of livestock or poultry you own.

Produce	**Mark X if applicable**	**hectares/kilograms/number**
White Maize		
Yellow Maize		
Sunflower		
Soya		
Peanuts		
Sorghum		
Beef cattle		
Oxen		
Milk cows		
Sheep		
Goats		
Horses		
Chickens (poultry)		
Ducks		
Geese		
Emu		
Game		
Other (please specify)		
Other (please specify)		
Other (please specify)		

Section 2

1. Please identify the following species: (place an X in the box next to the correct answer)

(Sanbi.org, 2016)

South African ground squirrel (*Xerus inauris*)	
Yellow mongoose (*Cynictis penicillata*)	
Slender mongoose (*Galerella sanguinea*)	
White-tailed mongoose (*Ichneumia albicauda*)	
Meerkat or suricate (*Suricata suricatta*)	

2. Please identify the following species: (place an X in the box next to the correct answer)

(Encyclopedia of Life, 2016)

Cape fox (*Vulpes chama*)	
Aardwolf (*Proteles cristata*)	
Black-backed jackal (*Canis mesomelas*)	
Bat-eared fox (*Otocyon megalotis*)	
Brown hyena (*Hyaena brunnea*, formerly *Parahyaena brunnea*)	

3. What do Aardwolf (*Proteles cristata*) mainly feed on?

Rats and mice	
Termites	
Hares	
Snakes	
Lizards	

4. Please identify the following species: (place an X in the box next to the correct answer)

	Hairy-footed gerbil (*Gerbillurus paeba*)	
	Tete veld aethomys or Tete veld rat (*Aethomys ineptus*)	
	Namaqua rock rat (*Aethomys namaquensis*)	
	Southern multimammate mouse (*Mastomys coucha*)	
	Highveld gerbil (*Gerbilliscus brantsii*)	

(Mammals' Planet, 2016)

5. What do Aardvark (*Orycteropus afer*) mainly feed on?

Lizards	
Insects such as crickets	
Plants and roots	
Ants and termites	
Rats and mice	

6. Which one of the following species makes the largest (in diameter) burrow?

Cape porcupine or South African porcupine, (*Hystrix africaeaustralis*)	
Aardvark (*Orycteropus afer*)	
Springhare or springhaas (*Pedetes capensis*)	
South African ground squirrel (*Xerus inauris*)	
Highveld gerbil (*Gerbilliscus brantsii*)	

7. Which one of the following burrowing mammal pest control methods holds no unintended consequences?

Biological pest control	
Mechanical pest control	
Chemical pest control	
None of the above	
All of the above	

8. Which of the following species are most likely to feed on plant material?

South African ground squirrel (*Xerus inauris*)	
Yellow mongoose (*Cynictis penicillata*)	
Slender mongoose (*Galerella sanguinea*)	
White-tailed mongoose (*Ichneumia albicauda*)	
Meerkat or suricate (*Suricata suricatta*)	

9. Which of the following species are diurnal?

Aardvark (*Orycteropus afer*)	
Cape porcupine or South African porcupine (*Hystrix africaeaustralis*)	
Cape ground squirrel (*Xerus inauris*)	
Highveld gerbil (*Gerbilliscus brantsii)*	
Cape hare (*Lepus capensis*)	

10. Which of the following species are able to kill the largest prey?

Aardwolf (*Proteles cristata*)	
Cape fox (*Vulpes chama*)	
Bat-eared fox (*Otocyon megalotis*)	
Black-backed jackal (*Canis mesomelas*)	
Striped polecat (*Ictonyx striatus*, also called the African polecat, zoril, zorille, zorilla, Cape polecat, and African skunk)	

11. The Highveld gerbil (*Gerbilliscus brantsii*) is considered a carnivore. Please indicate if this statement is true or false.

True	
False	

12. The Southern African Hedgehog (*Atelerix frontalis*) is mainly insectivorous. Please indicate if this statement is true or false.

True	
False	

13. Bat-eared foxes (*Otocyon megalotis*) must be killed because they prey on livestock. Is this statement is true or false?

True	
False	

14. What do the Scrub hare (*Lepus saxatilis*) mainly feed on? Please indicate below.

Green grasses	
Plant roots	
Insects	
Snakes	
Wild fruits	

15. What is the IUCN status of the Springhaas/ Springhare/ Spring Hare (*Pedetes capensis)* species? Please indicate in the table below.

Least concern	
Near threatened	
Vulnerable	
Endangered	
Critically endangered	

Section 3

1. Please write down the species of mammals that have affected you and please indicate how they have affected you.

Please mention species	Destroyed crops (please mention the crop type)	Attacked livestock/poultry (please mention animal type)	Livestock got stuck in burrow (please mention the type of livestock	Vehicle damaged by burrow (please mention vehicle)	Damaged electrical wiring (please mention to what)	Another impact (please mention)

2. Please rate your tolerance towards the following burrowing mammals.

Species	1. Very tolerant	2. A little tolerant	3. Indifferent	4. A little intolerant	5. Very intolerant	Don't know
Aardvark						
Cape porcupine						
Springhare						
South African ground squirrel						
Gerbil mouse						
Krebs's fat mouse						
South African pouched mouse						
Cape short-eared gerbil						
Hairy-footed gerbil						
Highveld gerbil						
Bushveld gerbil						
Tete veld aethomys						
Namaqua rock rat						
Southern multimammate mouse						
Four-striped grass mouse or four-striped grass rat						
Cape hare						

African savanna hare						
Scrub hare						
Southern African Hedgehog						
Yellow mongoose						
Slender mongoose						
White-tailed mongoose						
Meerkat or suricate						
Brown hyena						
Aardwolf						
Cape fox						
Black-backed jackal						
Bat-eared fox						
Species	**1. Very tolerant**	**2. A little tolerant**	**3. Indifferent**	**4. A little intolerant**	**5. Very intolerant**	**Don't know**
Striped polecat						
African striped weasel						
Honey badger						
Common warthog						

3. In the following table, please write down the five worst mammal pest species on your farm, in order from worst to the least worst.

Worst mammal pest	
Second worst mammal pest	
Third worst mammal pest	
Fourth worst mammal pest	
Fifth worst mammal pest	

4. In the following table, please write down the five most favourable mammal species on your farm, in the order of favourability.

Most favourable mammal	
Second most favourable mammal	
Third most favourable mammal	
Fourth most favourable mammal	
Fifth most favourable mammal	

Section 4

1. For which burrowing mammal species do you often have to apply a form of pest control? (Please indicate all the species, the type of pest control method, and the cost per hectare/per season in the table below)

Species	**Pest control method (what do you use as pest control e.g. type of chemicals/pesticides, owls, hunting, trapping, ploughing, or any other)**	**Cost per hectare/per season (please indicate hectare or season)**

2. Why do you use the mammal pest control methods you are using?____

____

____

____

3. When making a decision about the management methods to use, please rank the criteria in the table below that you would take into account by assigning number 1 to the highest priority, number 2 to the 2nd highest priority, 3 to the third-highest priority etc.

Cost: The cost of the management method	
Effectiveness: The effectiveness of the management method	
Ease of use: The ease at which to employ the management method	
Popularity: The popularity of the management method	
Personal familiarity: Your familiarity with the management method	
Urgency: The urgency of requiring control over the pest species	
Environmental impact: Secondary effects of using a management method, such as the effect on other animals	
Humaneness: How the animal will suffer when using this method	
Threatened status: whether the targeted animal is a threatened species, or how the method can harm a threatened species	
Other, please specify.	

4. When are your crops generally damaged by burrowing mammals?

	Within 2 months after planting.	**2 to 4 months after planting.**	**More than 4 months after planting.**
White maize			
Yellow maize			
Soya			
Peanuts			
Sunflower			
Sorghum			
Other (please specify)			
Other (please specify)			
Other (please specify)			

5. In general, when do you apply burrowing mammal pest control for the following crops?

	Within 2 months before planting	**Within 2 months after planting**	**2 to 4 months after planting**	**More than 4 months after planting**	**Within 2 months after harvesting**
White maize					
Yellow maize					
Soya					
Peanuts					
Sunflower					
Sorghum					
Other (please specify)					
Other (please specify)					
Other (please specify)					

6. Are you able to differentiate between the different species of mice and rats found in the Ottosdal area? Please answer yes or no, and to what extent you are able to differentiate.____