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# Local Perceptions of Hydraulic Fracturing Ahead of Exploratory Drilling in Eastern South Africa

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## Abstract

Applications for exploratory shale gas development via hydraulic fracturing (fracking) have raised concern about energy development impacts in South Africa. Initially, focus was on the arid Karoo, but interest now includes KwaZulu-Natal, a populous, agricultural province with high cultural, ecological, and economic diversity. We conducted focus groups and an online survey to determine how some South Africans perceive fracking. Focus group participants were unanimous in their opposition, primarily citing concerns over water quality and rural way-of-life. The survey confirmed broad consistency with focus group responses. When asked which provinces might be affected by fracking, KwaZulu-Natal ranked behind provinces in the Karoo, suggesting an awareness bias towards Karoo projects. Frequently-identified concerns regarding Agriculture and Natural Resources were Reduced quality of water, Negative impacts to ecosystems and natural biodiversity, Reduced quantity of water, and Pollution hazards. Frequent concerns regarding Social, Cultural, and Local Community issues were Impacts to human health, Visual/aesthetic degradation of tourism areas, Degradation of local infrastructure, and Physical degradation of tourism sites. Most survey respondents were pessimistic about potential benefits of fracking to South Africa's domestic energy supply, and did not agree fracking would reduce negative impacts of coal mining or create jobs. Survey respondents were pessimistic about government's preparedness for fracking and agreed fracking created opportunity for corruption. Many respondents agreed they would consider fracking when voting, and identified needs for more research on fracking in South Africa, which focused heavily on environmental impacts, especially water, in addition to the welfare of local citizens and their communities.

**Keywords** Fracking in KwaZulu-Natal · Energy and social science · Sustainable energy development · Unconventional natural gas in South Africa · Veld management and the energy industry

## Introduction

Recent decades have seen energy production worldwide reshaped by new technologies that allow extraction of so-called unconventional oil and gas resources. Among these technologies are horizontal drilling and hydraulic fracturing, in which a high-pressure mixture of water, sand, and chemicals is injected into geologic substrates such as shale to create small pore spaces into which otherwise "tight" natural gas and crude oil can flow through the well (AER 2016, Jackson et al. 2014). Colloquially known as "fracking" (Wakeford 2016), these technologies have facilitated the development of unconventional resources and thus greatly expanded the spatial extent of energy production, often into areas unfamiliar with the industry and its impacts (Meng 2015). Areas rich in unconventional oil and gas resources, referred to as "plays," are located worldwide, and the nature of injecting chemicals deep belowground to extract fossil fuels raises concerns about water and air quality essentially everywhere. Thus, many countries and local jurisdictions have moved to ban or restrict fracking, although fracking remains a tempting approach for emerging economies seeking to develop domestic energy reserves.

South Africa is an example of an emerging economy dependent on mineral and fossil fuel resources within the context of a Constitution lauded for its attention to human

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rights and natural resource protection. To make things even more interesting, South Africa is also underlain by a major shale gas play, for which exploration rights were sought by three multi-national companies between 2008 and 2010 (Glazewski and Esterhuyse 2016b). Currently heavily reliant on coal for energy production, South Africa faces the tension between energy security and a lower pollution footprint (Bellos 2018; Andreasson 2018). Recognising the potential for fracking to unlock a domestic source of cleaner-burning gas, the South African government in 2012 lifted a moratorium on fracking and positioned shale gas development within the existing framework for mineral and fossil fuel extraction, the Mineral and Petroleum Resources Development Act 28 of 2002 (MPRDA). President Jacob Zuma's 2013 characterisation of fracking for shale gas as a "game-change" opportunity…for our economy at large" was widely quoted in local media (e.g., News24 2013), and formal Fracking Regulations within the scope of the MPRDA were released in 2015 (Glazewski 2016).

The public has been more circumspect than their government on shale gas extraction, especially with fracking. On one hand, unconventional shale gas could provide a clean, domestic source of electricity; South Africa depends on coal for over 90% of electricity production and faces poor air quality as a result: South Africa is behind only China in anthropogenic mercury emissions (Dabrowski et al. 2008) and suffers over 2200 premature deaths from coal burning per annum (Holland 2017). On the other hand, the fracking process currently used to extract unconventional natural gas is associated with substantial environmental and social impacts, especially water (Allred et al. 2015; Costa et al. 2017; Jackson et al. 2014; Vengosh et al. 2014), and South Africa's governance structures might lack the robust environmental regulations and enforcement necessary to ensure fracking could proceed without severe environmental and social degradation. The South African Constitution affords various human rights to clean and plentiful water and other natural resources, and several Departments and Ministers oversee a myriad of laws to regulate these resources, including the National Water Act 107 of 1998 (Water Act), National Environmental Management Act 107 of 1998 (NEMA), and the National Health Act 61 of 2003 (Glazewski 2016). After several high court rulings on various cases involving environmental and natural resource legislation emphasised the "sustainable" in "sustainable development," a legal framework known as the One Environmental System emerged in 2014 within which all environmental issues were put under NEMA and guided by "principles of integrated environmental management" (Plit 2016).

Thus, all of the components of an interesting environmental management case study were in place: A valuable natural resource was identified, which not too long after attracting the attention of multi-national energy companies including Royal Dutch Shell was vetted and regulated by government, but the technology to be employed was opposed by a public armed with several potential legal challenges rooted in the Constitution. To satisfy the principles of integrated environmental management under NEMA, the government commissioned the Council for Scientific and Industrial Research to conduct the Shale Gas Strategic Environmental Assessment (SEA), which was completed in 2016 (Scholes et al. 2016). Around the same time the Academy of Science of South Africa (2016) released a report on South Africa's technical readiness to support the shale gas industry, and Glazewski and Esterhuyse (2016a) published their comprehensive academic review of the legal, environmental, and social contexts of fracking. All three of these efforts focused on the arid, scantly-inhabited Karoo region of western South Africa (Fig. 1), where initial onshore exploration permits had been sought.

Unfortunately the scope of the above work and discussion fails to include the full spatial extent of potential fracking in South Africa. Recently, attention has turned to eastern South Africa, including the eastern Eastern Cape and northern KwaZulu-Natal (KZN) provinces. The presence of fossil fuels in the geologic formations beneath the area around Utrecht (Fig. 1) and Dannhauser, KZN, has been known for decades (Rowsell and Connan 1979), and exploration rights were authorised for five farms near Dannhauser in July 2017 (Petroleum Agency of South Africa reference number 12/3/311). While the company was reported to have withdrawn the application shortly after the decision (iOL News 2017), this interest and other applications for exploration rights fought in court (e.g., Oellermann 2016) highlights the attention fracking development in KwaZulu-Natal receives from energy companies and local residents, all beyond the purview of the Shale Gas Strategic Environmental Assessment, which was conducted prior to industry interest outside of the Karoo. Meanwhile, although a comprehensive list of impacts on local resources and municipal services has been articulated with respect to the Karoo (du Plessis 2016), actual perceptions of fracking among local citizens and landowners in rural South Africa have not been well-studied.

To be clear, fracking is not yet established in South Africa. To our knowledge, no production rights have been granted, and few if any exploration rights have been acted on such that fracking has occurred at even a limited scale. A recent analysis concludes with doubt as to whether the South African government will reach a coherent position on shale gas development (Andreasson 2018), but again the focus is on the Karoo and ignores recent interest in energy development in the eastern grasslands. Understanding public perceptions, then, can serve purposes as varied as

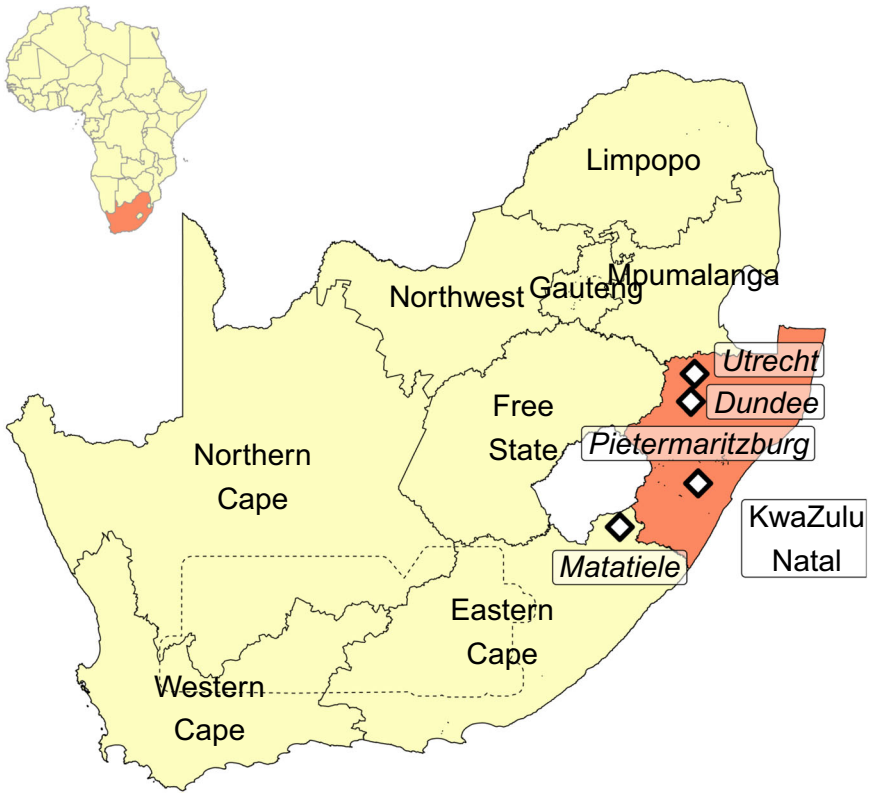


**Fig. 1** Map of South Africa highlighting KwaZulu-Natal province and the four towns in which focus groups were held. Broken line represents the area within the scope of the Shale Gas Development Strategic Environmental Assessment (Scholes et al. 2016), which focused on the Karoo region

helping local residents and communities fully understand and prepare for the breadth and intensity of fracking's footprint should it come, and identifying issues energy development proponents might address to increase the palatability of fracking within local communities.

Here we report on perceptions of fracking in South Africa, with a focus on the agriculturally-important grasslands of KwaZulu-Natal with potential for unconventional natural gas development. Following the design of a recent study of agricultural landowners in the Bakken play of North Dakota, in the United States (McGranahan et al. 2017), we held focus groups in four key towns and distributed a survey online. In discussing our results we make novel comparisons between this grassland region of eastern South Africa and the similarly rural and agriculturally-dominated Bakken region in North Dakota; in reviewing experiences with fracking from other jurisdictions, including the US, du Toit (2016) failed to consider the Bakken oil patch despite North Dakota's status at the time as the US state with the second-highest daily onshore crude oil production. Ahead of exploratory drilling in eastern South Africa, we pursued the following research question: How do South Africans concerned about issues related to the environment, energy, natural resources, and local communities perceive fracking? Our research sought to describe how focus groups and survey respondents perceived potential impacts of fracking on agricultural and natural resources, and social, economic, and cultural issues; how fracking fits into South Africa's energy, economic, and political landscape; and what avenues of additional research must be pursued to ensure environmental and socio-economic sustainability.

## Methods

We modified a mixed-method approach developed and applied by McGranahan et al. (2017) to study landowner perceptions of fracking in the rural Bakken region of North Dakota, USA: focus groups with community leaders and agricultural and natural resource professionals were used to inform a by-mail survey of landowners across the landscape. Following that research, our methodology here was similar except the survey was administered online.

### Focus Groups

We conducted focus groups in four towns in eastern South Africa: Utrecht, Dundee, and Pietermaritzburg in western KwaZulu-Natal province and Matatiele in Eastern Cape (Fig. 1). Utrecht, Dundee, and Matatiele were selected for having been locations for community meetings held by energy companies regarding exploratory drilling in the region, and as a administrative centre for the area

Pietermaritzburg is a central location for other farmers. Focus group participants were invited by contacts made by D.A.M. in each town; some specific types of participants were targeted (e.g., community leaders, representatives of local agricultural and conservation groups, and members of tourism boards, when applicable) although meetings were made available to all-comers. Attendance ranged from 9–15. Focus groups were conducted within a one-week period at the end of July–early August, 2017.

Demographics of focus groups reflected those of the districts in which they were held. While several languages would be identified as first languages among focus group participants, all participants were fluent in English, which was used for all discussions. Participants in Utrecht and Dundee were all white South Africans and mostly older and primarily Afrikaans-speaking. The Pietermaritzburg focus group was a mixture of both older and younger white and black farmers. The Matatiele focus group comprised mostly black South Africans representing local cattle farmers and a few white South Africans working for a local environmental non-governmental organisation; in addition to being the only focus group location outside the province of KwaZulu-Natal, the Matatiele meeting was also the only focus group held in an area with substantial non-commercial, communally-managed grazingland.

Each focus group was facilitated by D.A.M. and proceeded with one hour of discussion propelled by open-ended prompts meant more to foster dialogue than produce specific answers (McGranahan et al. 2017). Audio was recorded and used to (1) identify the major topics of concern and interest about fracking among residents of small towns and rural areas in the region, and (2) provide insight into the vocabulary and tone with which local residents use to dicsuss fracking, which we used firstly in survey development to make language more precise and secondly in survey interpretation.

## Survey

In August 2017 we launched an online survey meant to gain broader insight into perceptions of fracking held by South Africans. While we made several specific attempts to gain a breadth of demographic diversity and increase sample size (described below), in the end our word-of-mouth and social media-based distribution tactics likely led to an over-representation of participants who are against fracking and more likely to be both connected to the environmentalist groups that more actively promoted the survey among memberships more likely to engage the survey. While potentially confounding were we to extrapolate these results to the general South African population, we limit our scope of inference to those South Africans knowledgeable of, and interested in, the potential impacts of fracking.

### Survey creation and distribution

Survey questions were originally developed from the natural resource, agricultural, and socio-economic concerns identified by residents of the rural Bakken oil patch in North Dakota, USA (McGranahan et al. 2017) and refined for use in South Africa based on a review of scientific literature and popular press articles, as well as insight gained from focus group discussions. The survey asked respondents to:

- Identifty their familiarity with fracking in general, and in South Africa, specifically, with five-point Likert-style questions, and check the provinces most likely to be impacted by fracking
- Assess their familiarity with firstly agricultural and natural resource issues, and secondly social, economic, and cultural issues, in South Africa, on a five-point Likert scale concerns
- Identify their top three concerns in each of two lists of potential impacts to firstly agriculture and natural resouces and secondly social, economic, and cultural issues.
- State their level of agreement with various statements about fracking with respect to the economy and the environment, and government and politics, on a five-point Likert scale.
- Answer various demographic questions about age, gender identity, citizenship, education, residence, and how they learned about the survey.

The survey was administered via Google Forms and Qualtrix web platforms through North Dakota State University and was available to anyone with the link. Initially, survey respondents were recruited through small cards printed with unique identifiers and the link to the survey on Google Forms; small packets of these cards—totalling several hundred cards—were given to academic colleagues at the 2017 Grassland Society of Southern Africa annual meeting in Limpopo province (to increase national participation) and distributed among focus group participants (to ensure local participation), the idea being that these individuals could distribute additional cards to their friends, family, and colleagues. After two months, the survey was migrated word-for-word to the Qualtrix platform, which uses Internet Provider addresses to anonymously identify unique responses. The Qualtrix survey used the same link as the Google Form, which we sent to contacts made through the field work portion and encouraged them to share the link electronically (most often through group messaging apps and social media). The survey was available online through the end of 2017, by which time we received 118 responses.

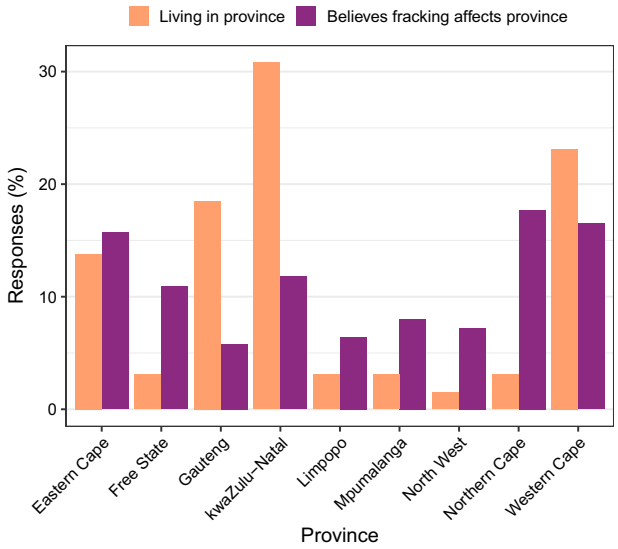


**Fig. 2** Relative distribution of survey respondents ($n = 118$) by the provinces in which they live, and the provinces they believe will be affected by fracking

### Survey analysis

Most survey results were reported as counts and proportions of respondents. All analyses were conducted in the R statistical environment (R Core Team 2017). Several questions invited open-ended responses and we used qualitative analysis for these data. Specifically, We used the RQDA package (Huang 2017) to code individual responses that we summarised as response frequency. For responses to survey prompts for respondents to describe their associations with fracking in general, and in South Africa, specifically, we assigned codes to Negative, Neutral, and Positive categories based on content and context.

For Likert-style questions, we employed a unique analysis developed by McGranahan et al. (2017) that uses statistical simulations to estimate an agreement index and 95% confidence intervals for each question; this analysis provides robust measurement of both the magnitude of agreement or disagreement, and whether the overall response differed from zero (no opinion, or ambivalence). To compute the agreement index, we first determine the degree of difference between the actual distribution of the responses and a null multinomial distribution (equal responses per category, or 20% responses in each of the five Likert choices); the magnitude of this difference is represented as $\phi$, the effect size for the $\chi^2$ statistic testing the actual multinomial distribution against the null (Menzel 2013). The effect size, $\phi$, is then multiplied by the median Likert response value to account for the direction of skew in the actual multinomial distribution, which determines if $\phi$ should be represented as positive or negative—agree vs. disagree, respectively—in the final, weighted agreement index, $\phi_\omega$. We estimated 95% confidence intervals for each response by performing the $\phi_\omega$ computation in 1000 simulations and calculating the 2.5 and 97.5% quantiles of all results; when 95% confidence intervals do not include zero, the agreement index is interpreted as significantly different from zero, or no opinion.

## Results and discussion

### Familiarity with, and Perceptions of, Fracking

Sixty-nine percent of survey respondents claimed to be Somewhat or Very familiar with fracking in general; 68% claimed to be Somewhat or Very familiar with fracking in South Africa, specifically. Interestingly, although KwaZulu-Natal was the highest-reported province of residence among survey respondents (about one-third), just over 10% of respondents believed KwaZulu-Natal would be affected by fracking (Fig. 2), highlighting low public awareness of potential energy development quite near to home.

The survey also prompted respondents to describe their associations with fracking in general, and with respect to South Africa, specifically. In both cases, the majority of associations were negative and pertained to environmental degradation and water pollution and consumption (Table 1). Although job creation was mentioned by several respondents as an association made with respect to fracking in South Africa, specifically, all but one instance were included under the Negative category as Social/economic damage because respondents were actually sceptical of job creation rhetoric, expressing concern that fewer jobs would be created than promised and that most created jobs would be low-skill and temporary.

While negative environmental associations were consistently highly ranked in both general and South Africa-specific questions, Political bias or corruption and Social/economic damage were notable associations made with respect to fracking in South Africa, specifically (Table 1). These associations reflect several concerns raised by focus group participants about potential forms of corruption, including fast-tracked permitting and lax oversight of operations and clean-up, as well as a general concern about whether government interest in fracking was more about creating opportunities for kick-backs and sweetheart deals on contracts. The Utretcht focus group was particularly sceptical based on local experiences with the coal mining industry. More broadly, corruption is understood to be a national challenge to governance in South Africa, and these concerns extend to the regulation of shale oil and gas development, as well (Hedden et al. 2013).

**Table 1** Frequency of topics identified by online survey participants prompted to describe their associations with fracking in general, and with respect to South Africa, specifically

| Scope | Perception category | | |
|---|---|---|---|
| | Negative | Neutral | Positive |
| General | | | |
| | Environmental degradation (17) | Familiarity via informal research and news media (22) | Energy security (4) |
| | Water pollution (17) | Familiarity via formal research into impacts (19) | Job creation (2) |
| | Water consumption (7) | General interest and awareness (5) | Economic development (1) |
| | Civic opposition (7) | Familiar with energy industry (4) | |
| | Land/habitat degradation (6) | General description of process (3) | |
| | Social/economic damage (5) | | |
| | General concern (4) | | |
| | Increased seismic activity (4) | | |
| | Climate change (2) | | |
| | Air pollution (1) | | |
| | Untrustworthy companies (1) | | |
| South Africa, specifically | | | |
| | Environmental degradation (24) | Familiarity via formal research into impacts (10) | Energy security (3) |
| | Political bias or corruption (11) | General interest and awareness (6) | Economic development (2) |
| | Water consumption (11) | Familiarity via informal research and news media (5) | Job creation (1) |
| | Social/economic damage (10) | General description of process (2) | |
| | Water pollution (10) | Familiar with energy industry (1) | |
| | Civic opposition (8) | | |
| | General concern (8) | | |
| | Land/habitat degradation (7) | | |
| | Lack of regulations (4) | | |
| | Diminished food security (2) | | |
| | Distraction from renewable energy (2) | | |
| | Infrastructure damage (2) | | |
| | Lack of research/knowledge (2) | | |
| | Viability of extractable resources (2) | | |
| | Air pollution (1) | | |
| | Untrustworthy companies (1) | | |

Responses were coded in qualitative data analysis software and assigned to one of three categories based on whether the tone of the response was critical of fracking (negative), purely descriptive of fracking and/or the respondent described how they came to know about fracking (Neutral), or whether the respondent supported fracking development (Positive)

## Concerns about Fracking Impacts

### Agricultural and natural resource concerns

Ninety percent of survey respondents said they were somewhat or very familiar with agricultural and natural resource issues. Over 50% of survey respondents identified Impaired water quality and Harm to ecosystems and natural biodiversity among their top three concerns, followed by Less water availability and pollution concerns (Fig. 3). Despite the high rate of reported familiarity with agriculture and natural resource issues in South Africa, only a handful of respondents (<5%) listed labour and farm management issues as high-priority concerns. This contrasts with landowners in the Bakken region in the USA, who were generally more concerned about fracking impacts to their

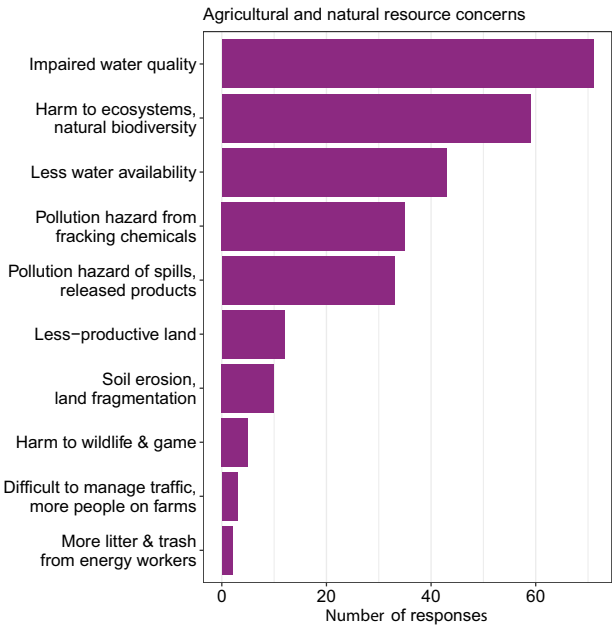


**Fig. 3** Most frequently-identified concerns among survey respondents about potential fracking impacts to agricultural and natural resources. Major focus on pollution, especially water, with less concern for surface disruptions like impacts to farm management

farming and ranching operations than pollution and environmental degradation (McGranahan et al. 2017). Although individual well pads can be as small as a few hectares, the land required for energy production in sum is massive: Allred et al. (2015) estimate that North America lost nearly five million animal unit-months' worth of grazing, and the equivalent of nearly 6% of the 2013 wheat export, to oil and gas development between 2000 and 2012. These land-use concerns should merit heavy consideration within the context of food security in South Africa, especially in agriculturally-rich provinces like KwaZulu-Natal.

The emphasis among survey respondents on impacts to water and biodiversity strongly reflected sentiments raised by participants in all four focus groups. Water was such a primary topic of concern that not only was it raised by individual participants much more frequently than any other topic, but attempts by the facilitator to consider impacts other than water were met with rapid shifts back to the topic of water. As for specific concerns about water, survey respondents more frequently listed water quality as a concern than water availability (71% vs. 43%, respectively). Likewise, each focus group recognised South Africa's aridity and tight water supply, but placed emphasis on fracking's potential to impair water quality. The context of water pollution concerns varied slightly among focus groups. In Utrecht, and to a lesser extent Dundee, focus group participants used examples of coal mine impacts on groundwater as evidence for their concerns. Conversely, in Dundee, and to a lesser extent Utrecht, water pollution concerns included associations between fracking, tourism, and real or perceived impacts on the visitor experience. Emphasising the local community's dependence on grazing resources, focus group participants in Matatiele expressed concern that less-available fresh water from both pollution and use in the fracking process would compromise their cultural and economic identity as cattle farmers.

Water pollution from fracking is of general concern worldwide, although the actual degree of risk and potential benefits of the fracking process itself appear related to the geology and depth of the substrate being fracked, especially in spatial relation to groundwater (Zou et al. 2017; Esterhuyse et al. 2016b). Water can be divided into surface and belowground resources, and impacts from fracking broadly include depletion through direct consumption in the fracking process, and contamination through contact with chemicals used in fracking process or released by it (Vengosh et al. 2014). Depletion of course comes from the massive quantities of water required: fracking for shale gas in the US uses 10,000–36,620 $m^3$ per well (Gallegos et al. 2015); for scale, this level of consumption means that in one year a single play in Texas, the Barnett Shale, used an amount of water equal to nearly 10% of that used by the City of Dallas, the ninth-largest city in the US (Nicot and Scanlon 2012). Chemicals are deliberately added to water prior to injection to further fracture belowground shale, and the water that emerges from the well in the fracking process—"produced water"—includes the deliberately-added chemicals and other chemicals released from the belowground shale formation (Lewis et al. 2016). Fracking has also been associated with greater concentrations of naturally-occuring belowground chemicals in groundwater accessed by wells (Osborn et al. 2011; Jackson et al. 2013).

While the compounds added to fracking water can be intimidating—a situation made worse in the public eye by an unwillingness of energy companies to disclose the chemical content of fracking fluids, citing trade secrets (Avenant et al. 2016)—we suggest the greatest environmental threat is in fact unintentionally released (spilled) produced water. Produced water is also known as brine because of its high salt content, which can exceed ocean water by several orders of magnitude (Daigh and Klaustermeier 2016). As such, release of this produced water into surface water bodies can destroy ecosystems; spills across agricultural land can render it unproductive for decades or more; and contaminated shallow aquifers are useless for drinking or irrigation. The management of waste water should be among the highest regulatory priorities. Theoretically, produced water can be treated as any waste water and released back into the environment, reused in the fracking process, or used in non-potable applications like irrigation, however, the most frequently employed technique worldwide is simply injecting untreated produced water into "disposal wells" drilled specifically to discard brine; this


**Fig. 4** Most frequently-identified concerns among survey respondents about potential social, economic, and cultural impacts of fracking. Major focus on pollution, especially water, less on surface disruptions like impacts to farm management, infrastructure, and communities

practice is currently explicitly banned in South Africa (Lewis et al. 2016).

### Social, Economic, and Cultural Concerns

Slightly fewer (77%) respondents said they were somewhat or very familiar with social, economic, and cultural issues. The high ranking of human health impacts (Fig. 4) is consistent with literature worldwide expressing concern about unconventional gas development and public health (Korfmacher et al. 2013; Werner et al. 2015; Willems et al. 2016; Currie et al. 2017; Cotton and Charnley-Parry 2018).

Missing from much of the discussion on the effects of energy development in South Africa are other potential impacts to social aspects including infrastructure, local economies, and overall quality of life. Fracking, in particular, is associated with very high levels of traffic as fresh water and produced water must be trucked into and away from each well. On account of this high volume of traffic, road safety is a major concern in other areas with substantial fracking activity (Anderson and Theodori 2009; Fernando and Cooley 2015; Graham et al. 2015), but less than 10% of respondents ranked heavy traffic among their top three concerns (Fig. 4). Likewise, only about 5% of respondents gave weight to the impact on local economies described in other areas with fracking (Esterhuyse et al. 2016a; McGranahan et al. 2017), such as more expensive goods and services and difficulty hiring workers due to competition from energy industry jobs.

Energy booms can have substantial impacts on local communities, where leaders must balance development and service delivery within their jurisdictions (Weber et al. 2014; Ellis et al. 2016). South Africa might be particularly sensitive to these impacts: as a quasi-federal state, power is shared among several spheres of government extending from the national and provincial levels to local municipalities (Glazewski 2016). With respect to services and infrastructure, the national Infrastructure Development Act 25 of 2014 lays out the responsibility of government to facilitate and co-ordinate "public infrastructure development which is of significant economic or social importance to the Republic…," which arguably applies to unconventional gas development given the rhetoric of political officials (legislative quotation and analysis provided by Glazewski 2016). But under the Constitution's Co-operative Government philosophy, actual service delivery falls to the responsibility of local municipalities (du Plessis 2016). And with what resources? The national government retains the sole authority to levy royalties on extracted mineral and petroleum resources (Plit 2016), setting up a situation similar to that in the Bakken where local communities complained about having to take on the bulk of infrastructure maintenance and upgrades to support the energy industry while tax revenues from the extracted resources were slow in coming back from revenue collectors in the state government or went to infrastructure projects in more populated parts of the state (McGranahan et al. 2017). An analysis of industry structure and revenue-sharing in North Dakota indicates larger firms transfer more revenue to the state, but suggests smaller firms better target needs of local communities (Litzow et al. 2018). These findings suggest the nature of corporate structures and industry-government relationships strongly influence the nature of social impacts of the energy industry. Thus, local governments ought to exert influence on the complexion of the nascent unconventional hydrocarbon extraction industry via the co-operative governance framework to ensure revenue sharing schemes can address local concerns. Unfortunately survey respondents were even less likely to consider fracking issues in local elections than national elections (Fig. 5).

The extensive visual impact of energy infrastructure—utility lines, drilling rigs, pipelines, well pads, flares, storage tanks, and water depots—within landscapes under energy development seems to be appreciated among survey respondents (Fig. 4). These concerns echo those of the focus groups, who all raised concerns about impacts to landscapes and viewsheds but for slightly different reasons: Utrecht is wholly surrounded by a private game park; Dundee is a tourism centre for KwaZulu-Natal's economically-important Battlefields Route, which connects culturally-significant sites and relies on the aesthetic of open rural

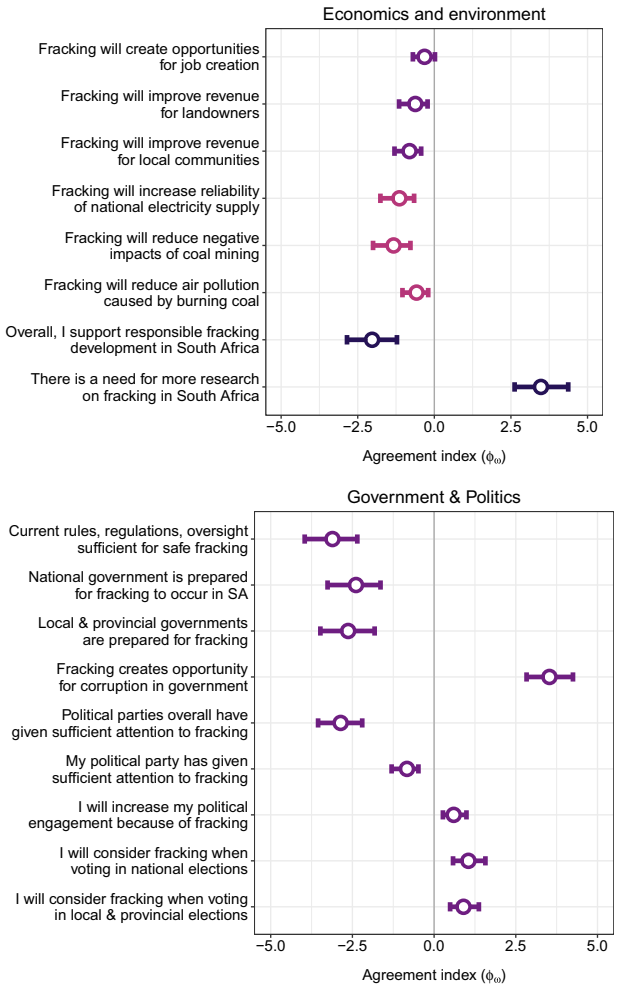


**Fig. 5** Degree to which survey respondents agreed with various statements of a five-point Likert scale, Strongly disagree - Strongly agree. Agreement index and associated 95% confidence intervals calculated by simulation; see Methods

grasslands; and Matatiele, where community members highlighted their identity as cattle farmers and emphasised their connection to grassland resources on which such a culture and livelihood depend. Given the diversity of economic land-uses in the study region, those involved in ecotourism, and commercial and communal farming, will likely need to rally around the integrity of the grassland ecosystem to find a unified voice in the fracking debate. Indeed, a participant in one focus group representing a farmers' union identifed fracking as the one issue that cuts across all farmers in the province, regardless of size or market. However, in the same meeting, representatives of black farmers cautioned that the emergence of the fracking debate must not detract from perennial issues such as land reform. To sustain rural livelihoods, the fracking debate in South Africa must remain above the bumper sticker rhetoric that pervades Western ethical claims against fracking (Evensen 2016).

## Current Perspectives on the Fracking Situation

### Economics and the environment

Survey respondents tended to disagree with the claim that fracking—and the industrial development around it—will create jobs (Fig. 5). This echoes both concerns that job creation rhetoric is hyperbolic (discussed above; Table 1) and comments made by some focus group participants who felt energy companies made exaggerated claims about job creation to local communities as a way to increase positive attitudes towards fracking among the general population and overcome environmentalist resistance. Such cynicism might be overblown. Hundreds of thousands of jobs in North America have been attributed to shale gas exploration and supporting industries (IHS Global Insight 2010), and small rural towns that otherwise face population decline have benefited from an influx of workers and revenue from shale oil exploration in the Bakken region of North Dakota, USA (McGranahan et al. 2017). (Konigsberg 2011) describes how North Dakota had an unemployment rate below 4%—half that of the national average—at the height of the Bakken boom. But survey respondents disagreed that fracking has the potential for positive economic impacts to local communities (Fig. 5).

A major source of differences in fracking perceptions among landowners in different countries is likely opportunity to financially benefit from fracking (or at least offset costs incurred through development). (Merrill 2013) attributes the development of the fracking revolution in the United States to the fact that most mineral rights are privately held. While their point was that the incentive for individuals to benefit financially from energy extraction promotes development of new extraction technologies, a consequence of private rights-holding is that landowners regard belowground petroleum resources as just another marketable commodity alongside surface products like crops and livestock. Thus, although horizontal drilling and fracking were game-changing technologies that unlocked the unconventional Bakken shale, western North Dakota has been "oil country" since the 1950s and landowners receive financial compensation for extraction (McGranahan et al. 2017).

South African landowners, however, have no such rights or opportunity under the law to benefit financially from belowground energy reserves (short of extracting it themselves). The Mineral and Petroleum Resources Development Act names the state as custodian of belowground mineral resources, who retains sole authority to grant exploration and production rights and receive royalties (Plit 2016). And once exploration and production rights are conferred to developers, rightsholders only need to give landowners notice that they will be accessing the resources

**Table 2** Frequency of topics identified by online survey participants prompted to identify priorities for research on fracking in South Africa

| Category | | |
|---|---|---|
| Natural resources and environment | Social and economic impacts | Energy |
| Environmental degradation (22) | Social impacts (10) | Alternative energy (10) |
| Hydrology and groundwater (13) | Local communities (8) | Viability of resource (6) |
| Water quality (13) | Political bias/corruption (6) | Energy security and independence (2) |
| Ecosystems and biodiversity (9) | Human health (5) | Waste handling (2) |
| Water (generally) (9) | Policy (4) | |
| Water supply (5) | Infrastructure (3) | |
| Pollution (generally) (4) | Potential benefits (3) | |
| Air pollution (1) | Rural livelihoods (3) | |
| Fugitive dust (1) | Job creation (1) | |
| Reclamation (1) | Food security (1) | |
| Seismic activity (1) | | |

Responses were coded in qualitative data analysis software and assigned to one of three broad categories

and have wide latitude under the law to manipulate the surface environment as necessary, including water use; no payment to, or even consent from, landowners is required (Plit 2016). Landowners can only receive compensation for demonstrable loss and damage on a post-hoc basis. Focus group participants in Utrecht described situations in which landowners have arranged compensation with coal mines on a case-by-case basis, which only reinforces the divisive approach to landowner relations scorned by farmers in the Bakken (McGranahan et al. 2017). In the Bakken, landowners and energy firms alike benefit from swift, transparent contracts on easements for land taken up by the surface footprint of energy development. Without any means to financially benefit from belowground resources or even arrange fair and ongoing compensation for the aboveground footprint, it is not surprising so few focus group participants or survey respondents see any potential gains for unconventional gas development in South Africa.

Elsewhere, interest in unconventional gas development is driven by desire for cleaner-burning fuels to reduce the environmental footprint of fossil fuels consumption (e.g., in Europe, Weijermars et al. 2011). While this should appeal to South Africans, who suffer over 2,200 premature deaths per annum due to emissions from coal-burning power plants (Dabrowski et al. 2008; Holland 2017), survey respondents generally did not agree with statements that fracking could improve reliability and reduce negative impacts of mining and burning coal (Fig. 5). With low expectations for potential benefits of fracking to communities, landowners, and the country as a whole, survey respondents did not support fracking development in South Africa and agreed strongly that more research on fracking in South Africa is needed (Fig. 5); specific topics for research are summarised in Table 2.

### Government and politics

Whether worker immigration and revenue due to unconventional gas development benefits local communities, provinces, and the country as a whole depends largely on the capacity of government to manage impacts and benefits —i.e., their capacity to regulate (Goldthau 2016). As such, regulatory structures in South Africa have received considerable scrutiny (Chapman et al. 2016; Corrigan and Murtazashvili 2015). Survey respondents were sceptical that institutional capacity is adequate: respondents overwhelmingly disagreed that rules, regulations, and oversight are sufficient for fracking to be done safely, and likewise disagreed with statements about local, provincial, and national governments being prepared for fracking to occur in South Africa (Fig. 5). And again, echoing associations made with fracking in South Africa, specifically, survey respondents strongly agreed that fracking creates opportunities for corruption, further highlighting the need for transparency in governance.

Despite little historical petroleum activity in South Africa, policy and practice of coal mining in the focal region of the present study offers insight into the basis and outlook of survey respondents' concerns about fracking. On one hand, the robust-on-paper but weakly-implemented Environmental Impact Assessment structure has been criticised for susceptibility to abuse and poor public participation in the coal mine development process (Ridl and Couzens 2010; Leonard 2017) and abuses of water law are a particular concern (Forrest and Loate 2018). On the other hand, the One Environmental System legal framework was developed to address many of these shortcomings (Humby 2015). One concern that remains unaddressed is that the primary instrument to ensure the principles of integrated

environmental management are upheld with respect to fracking, the Shale Gas Strategic Environmental Assessment, does not include KwaZulu-Natal yet government has considered and authorised applications for exploration rights in the province.

## Research Directions

Environmental concerns, including general degradation and water concerns, dominated the topics for further research suggested by survey respondents (Table 2). Study of impacts to ecosystems and biodiversity was also mentioned as a topic for natural resources research. In terms of potential socio-economic research, survey respondents most frequently suggested study of general social impacts and impacts to local communities, as well as political bias and corruption, human health, and policy.

The low frequency of some responses as research priorities might indicate that their potential impacts are not widely known among survey respondents. As is clear from our data, South Africans are principally concerned about water.

Several respondents placed a priority on researching alternative energy sources, echoing a frequent comment from focus group participants: with so much sun and so little water, why is solar energy not being pursued ahead of fracking? On one hand, the conflation of energy sectors is a bit naive: it is not unreasonable for petroleum development companies to pursue petroleum development. And just because solar radiation is freely available does not mean converting it to electricity is economical or even free of negative environmental impacts (Timilsina et al. 2012; Rudman et al. 2017). On the other hand, frustration among the public about the lack of solar development speaks to broad institutional issues in South Africa's energy policy, especially with respect to domestic consumption. Developing unconventional resources with fracking is just another example of an energy policy based on extractive fossil resources. The South African energy industry is characterised by high path dependency: 86% of South Africa's electricity comes from coal, of which South Africa has one of the world's largest reserves; as such neither government nor utilities have much incentive to develop and integrate alternative sources (Sebitosi and Pillay 2008; Pegels 2010; Scholvin 2014; Andreasson 2018). Meanwhile the lack of initiative, along with other national-level problems with poverty and access to the electricty grid, deter private investment in renewable energy (Ghoorah and Makina 2014).

Focus group participants and survey respondents both raised the critical question that will likely determine the footprint of fracking in South Africa: Are unconventional oil and natural gas resources sufficient to justify investment in a new energy development industry in South Africa? It must be clearly stated that all fracking activity and applications heretofore in South Africa relate to exploratory drilling, part of the process to determine whether known deposits are economically viable. In our opinion, it is unlikely that the massive investments in not only drilling and fracking equipment but also surface infrastructure (roads, electricty, pipelines, storage and handling facilities, etc) necessary to develop unconventional resources will occur in South Africa unless a substantial amount can be extracted. Indeed, recent work from the Karoo Basin has substantially reduced the expected volume of extractable gas (de Kock et al. 2017), and local media report Shell to be scaling back on Karoo projects (Anonymous 2018).

## Study Relevance and Scope of Inference

In addition to providing original insight into the perceptions of citizens concerned about fracking impacts in South Africa, our study represents a novel international comparison of potential energy development scenario with an already-developed play in the United States. Because fracking technology was developed in the US and a diversity of industry standards and regulatory frameworks have emerged there, the US "shale gas revolution" represents a baseline against which unconventional hydrocarbon development must be compared (Andreasson 2018). While many studies have made comparisons within countries and regions (e.g., Haggerty et al. 2019, Grubert 2018: McLaughlin and Cutts 2018), we address the call by (Evensen (2018) for research comparing less developed and more developed nations. Previous discussions of fracking in South Africa within a global context overlooked both the Bakken play of North America and the province of KwaZulu-Natal (du Toit 2016), which we explicitly considered here.

There are however some caveats and limitations to this initial attempt to describe the perceptions of South Africans to fracking. Firstly, our moderate sample size of 118 survey respondents prevented us from parsing the frequency of responses by geographic or demographic criteria. Secondly, due to the nature of distribution that reached the most respondents—by word-of-mouth and social media—our sampled pool of South Africans consists primarily of those concerned about fracking or involved in the industry, who are likely already more informed about the issues associated with fracking technology, especially abroad. While this perspective likely does not represent the average citizen of South Africa—who might be quite uninformed about energy issues due to lack of interest or exposure to news media—it remains important to understand the perceptions and priorities for research and policy among those citizens who are engaged with the issues. Most importantly, the majority of survey respondents reported a high degree og familiarity with agriculture, natural resource, and socio-economic issues in South

Africa. To build on our coarse descriptions of public perceptions, future research should focus on specific demographics and use appropriate social science methodologies.

## Conclusion

Widespread fracking activity in South Africa faces several challenges: technical readiness must be improved across several sectors to support the industry domestically (Academy of Science of South Africa 2016), the actual amount of recoverable resource is uncertain (de Kock et al. 2017), and at least in the highest courts, the bar for "sustainable" development is high given the various environmental and social protections afforded in the South African Constitution (Glazewski 2016). Thus it is uncertain whether fracking will ever go beyond the exploration phase in either the Karoo or KwaZulu-Natal. But should fracking reach the production scale, our data suggest South Africans are unprepared for its potential effects on their environment and local communities, given their lack of familiarity and low degree of concern with the breadth of social and economic impacts known to affect ecosystems and communities elsewhere (du Plessis 2016). Whether one is an activist trying to limit fracking development, a concerned citizen or lawmaker looking to ensure development proceeds sustainably, or an energy firm seeking to address stakeholder concerns, the fracking discussion in South Africa will be more robust once it goes beyond—although it certainly should not ignore—water issues.

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### Compliance with ethical standards

**Conflict of interest** The authors declare no conflict of interest.

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