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Using geostatistical techniques to map adaptive capacities of resource-poor communities to climate change

A case study of Nkonkobe Local Municipality, Eastern Cape Province, South Africa

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Abstract

Purpose – This paper aims to present a case study-based approach to identify resource-poor communities with limited abilities to cope with the adverse effects of climate change. The study area is the Nkonkobe Local Municipality, in the Eastern Cape which is one of South Africa's provinces ranked as being extremely vulnerable to the adverse effects of climate change because of high incidences of poverty and limited access to public services such as water and education. Although adaptive capacity and vulnerability assessments help to guide policy formulation and implementation by identifying communities with low coping capacities, policy implementers often find it difficult to fully exploit the utility of these assessments because of difficulties in identifying vulnerable communities. The paper attempts to bridge this gap by providing a user-friendly, replicable, practically implementable and adaptable methodology that can be used to cost-effectively and timeously identify vulnerable communities with low coping capacities.

Design/methodology/approach – A geostatistical approach was used to assess and evaluate adaptive capacities of resource-poor communities in the Nkonkobe Local Municipality. The geospatial component of this approach consisted of a multi-step Geographical Information Systems (GIS) based technique that was improvised to map adaptive capacities of different communities. The statistical component used demographic indicators comprising literacy levels, income levels, population age profiles and access to water to run automated summation and ranking of indicator scores in ArcGIS 10.2 to produce maps that show spatial locations of communities with varying levels of adaptive capacities on a scale ranging from low, medium to high.

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Findings – The analysis identified 14 villages with low adaptive capacities from a total of 180 villages in the Nkonkobe Local Municipality. This finding is important because it suggests that our methodology can be effectively used to objectively identify communities that are vulnerable to climate change.

Social implications – The paper presents a tool that could be used for targeting assistance to climate change vulnerable communities. The methodology proposed is of general applicability in guiding public policy interventions aimed at reaching, protecting and uplifting socio-economically disadvantaged populations in both rural and urban settings.

Originality/value – The approach's ability to identify vulnerable communities is useful because it aids the identification of resource-poor communities that deserve priority consideration when planning adaptation action plans to deliver support and assistance to those least capable of effectively coping with the adverse effects of climate change induced vulnerabilities.

Keywords South Africa, Climate change, Adaptive capacity, Geostatistical techniques, Nkonkobe Local Municipality, Vulnerability assessment

Paper type Research paper

1. Introduction

Adaptive capacity assessment is a significant component of vulnerability assessments because it aids the identification of resource-poor communities deserving priority consideration during the formulation of strategic responses to climate change (Gbetibouo, 2009) and the allocation of resources and provisioning of assistance. It is also useful in that it assists the governing of adaptation actions by facilitating effective and timely implementation of planned response measures. Climate change-driven afflictions are often difficult to respond to because climate change is a long-term continuous change in average weather conditions (Davis, 2011; IPCC, 2007; Marshall, 2014; Ramamasy and Baas, 2007; Rayner and Minns, 2015) with persistent adverse effects that require implementation of objectively informed interventions. Because climate change occurs over long period, the persistence of changes associated with it implies that interventions designed to mediate its effects have to be robust enough to enable vulnerable communities to cope with unpredictable stochastic events. The unpredictable nature of these events and their severity and duration often require recourse to high levels of flexibilities which resource-poor communities are often unable secure because their adaptive capacities are limited by poverty (IPCC, 2007).

Because low levels of flexibilities undermine the implementation of interventions by overstretching limited resources, the placement of well-versed adaptation strategies planned to augment human capacities to handle deteriorating climate conditions is critical, as adoption of effective strategies requires official acknowledgement of the non-transient character of current trends in climatic change (Hamandawana, 2007). The assessment of adaptive capacity provides decision makers on global, regional, national and local levels' useful information that helps to improve climate change adaptation policies (Juhola and Kruse, 2015; Smith *et al*, 2010).

Such information is extremely necessary in regions of the world like Southern Africa which is widely considered to be extremely vulnerable to climate change because of limited livelihood options, poorly developed infrastructure (Ziervogel *et al.*, 2006), different forms of human insecurity (Davies *et al*, 2010), the high prevalence resource-poor households (IPCC, 2007) and dependence on climate-sensitive sectors notably agriculture (Ambrosino *et al.*, 2010). Resource-poor communities are usually situated within rural areas which are susceptible to drought (Phaswana-Mafuya and Olsson, 2008). In South Africa, observations over 43 years before year 2003 point to a steady increase in temperatures with projections estimating increases by 1.2°C by 2020, 2.4°C by year 2050 and 4.2°C by the year 2080 while rainfall is projected to reduce by 5.4 per cent, 6.3 per cent and 9.5 per cent by year 2020, 2050 and 2080, respectively (Kruger and Shongwe, 2004). In similar studies, Department of Environmental Affairs (2013) and Erasmus (2014) have also pointed out to future increase in temperatures and rainfall reductions within South Africa with the latter being corroborated by a reported 4 per cent decrease for the rest of Southern Africa during the last century (UNECA - United Nations Economic Commission for Africa, 2011). Although the reliability of this estimate is contestable, Southern Africa has exhibited high inter-annual rainfall variability from the beginning of the second half of the past century (Conway *et al.*, 2009) which is likely to force much of South Africa's rural agriculture out of production (Bauer and Scholz, 2010). These scenarios are indicative of climate change in the entire country and signal immediate need to embrace appropriately informed intervention strategies.

The work done by Gbetibouo *et al.* (2010) in ranking South Africa's provinces' vulnerability to climate change-related problems shows that the Limpopo, Eastern Cape and KwaZulu-Natal Provinces are highly vulnerable to climate change-related problems because of their high dependency on rain-fed agriculture, densely populated rural areas, large numbers of small-scale farmers and high rates of land degradation. Although this paper is not intentioned to provide a countrywide perspective of the pervasive nature of climate change induced vulnerabilities, a synoptic overview of synchronous events can help to illustrate the perversity of climate induced vulnerabilities in South Africa. In 2004, KwaZulu-Natal Province, which borders the Eastern Cape Province in the north east was hit by a severe drought that left more than 700,000 people without water after boreholes, rivers and wells dried up with this drought having been preceded by similar others in 1979, 1980, 1983 and 1992-1993 (Reid and Vogel, 2006). In the Eastern Cape Province, consecutive droughts occurred in the years 1992, 2004 and 2009 (International Federation of Red Cross, 2004; ADM, 2012; Amathole District Municipality, 2010) with the most severe being experienced in Nkonkobe Local Municipality. The magnitude and severity of the 2004 drought became evident in Nkonkobe Local Municipality when 1,063 farmers submitted applications for drought relief support (ADM, 2004). This situation was followed by reports in July 2009, of critically low dam levels in Hogsback town which falls under the Eastern Cape Province's Nkonkobe Local Municipality (ADM, 2012; Amathole District Municipality, 2010). Thereafter, Nkonkobe Local Municipality was declared a drought disaster area by Amathole District Municipal council in February 2017 (Dayimani, 2017). These scenarios argue for the need to assess adaptive capacities in the Eastern Cape Province's Nkonkobe Local Municipality because most communities its communities do not have adequate capacities to cope with climate change-related problems because of high incidences of poverty occasioned by the majority of the people's dependence on rain-fed agriculture, livestock production and government social grants (Gbetibouo and Ringler, 2009; Ndhleve *et al.*, 2014; Zhou *et al.*, 2013). Nkonkobe Local Municipality's low adaptive capacity is further aggravated and evidenced by its low Human Development Index (HDI) of 0.60 which is very low according to the HDI report of United Nations (Nkonkobe Local Municipality, 2012). The HDI indicates the status of a place in terms of development (Nkonkobe Local Municipality, 2012). Nkonkobe's HDI of 0.60 suggests that this municipality is still poorly developed for which reason it is ranked as being highly vulnerable to disasters associated with climate change. A perceptive inference from these scenarios and statistics is that adaptive capacities are spatially variable and coextensive (Adger *et al.*, 2003) to the extent that it is extremely important to objectively identify hotspot areas to direct interventions to areas where they are most needed by using optimally selected indicators.

The choice of indicators for determining adaptive capacity is linked to a wide range of factors that are related to a community's demographics and socio-cultural arrangements (Wongbusarakum and Loper, 2011). Demographics are statistical data linked to the population and precise groups surrounding it. By identifying likely climate change impacts and conveying them in a map format with strong visual elements, hotspots maps can communicate issues in a manner that may be easier to interpret than text (de Sherbinin, 2014). Hence, the main objective of this paper was to delimit areas in Nkonkobe Local Municipality which are least capable of effectively coping with the adverse effects of climate change by providing a spatially explicit resource-based identification of communities.

2. Adaptive capacity conceptual framework

This section begins by defining adaptive capacity as commonly used in the literature and proceeds to provide a brief overview of selected examples of adaptive capacity assessments by different authorities with the latter being intentioned to shed light on the strengths and limitations of conventional techniques that have been used to assess adaptive capacity in different areas.

Adaptive capacity is defined as the ability of people to overcome the adverse effects of climate change (Frankel-Reed *et al.*, 2011; Heltberg and Bonch-Osmolovskiy, 2011; IPCC, 2012). As climate change impacts are presently witnessed, adaptation should also be conspicuous in present society (Adger *et al.*, 2005). The adaptive capacity of a system affects its vulnerability to climate change by varying exposure and sensitivity (Adger *et al.*, 2007; Gallopín, 2006; Yohe and Tol, 2002). The assessment of adaptive capacity is complex and may be prejudiced intensely by a few key characteristics, or by an extensive range of social characteristics (Wongbusarakum and Loper, 2011). For example, villages with varied income sources and additional livelihood alternatives are likely to have greater adaptive capacities to effects of climate change than those without (Brooks *et al.*, 2005). The shaping of adaptation policy can be promoted by diversion from climate impacts assessment to adaptation priorities (Adger *et al.*, 2005; Burton *et al.*, 2002). This prioritization of climate change adaptation is important because climate change is already occurring and will occur with greater urgency in the future at a range of scales.

The choice of indicators for an adaptive capacity assessment for communities at municipal or provincial level is limited by the type and level of demographic data available from data providers. In South Africa, Statistics South Africa (StatsSA, 2016) (www.statssa.gov.za) is the national statistical service provider mandated to timely produce accurate and official statistics to advance economic growth, development and democracy.

The work done by Ellis (2000) in developing a rural livelihoods framework can be used as a basis for empirically building an adaptive capability index. In this framework, adaptive capacity is conceptualized as an evolving property of various forms of human, natural, physical, social and financial capital from which rural livelihoods are derived with the flexibility to substitute between them being a reaction to exterior pressures. Equilibrium amongst these five capitals is unnecessary, as low levels of one capital can be offset by proficiently using another (Ellis, 2000). Adaptive capacity is high when non-farm income sources less directly affected by climate change supplement on-farm income sources.

Seminal works by authors (Adger *et al.*, 2005; Burton, 1998; Burton *et al.*, 2002) also provide discussion on adaptive capacity and propose typologies of adaptation to climate change. Burton *et al.* (2002) argue that at the end of the day, climate policy decisions are made by governments which have responsibility for the success or failure of the policies they adopt. The purpose of policy-related research for adaptation to climate change is not to decide or advocate policy, but to provide the policymakers with policy choices upon which they can base their judgements (Burton *et al.*, 2002). The review work by Bahadur *et al.* (2010) identifies sixteen conceptualisations of adaptive capacity within the context of climate change as a hazard. A capital-based approach for conceptualizing adaptive capacity (Bahadur *et al.*, 2010; Mayunga, 2007) is most appropriate for South Africa because the suggested indicators are related to demographic data which is readily available and easily accessible (www.statssa.gov.za).

The work done by Faling *et al.* (2012) on actions taken by South African local municipalities in strategizing for climate change provides evidence supporting the view that the formation of strategies for climate change adaptation in South Africa is still nothing more than sophisticated rhetoric in most areas. However, the generalizability of this observation is constrained by the fact that the study focussed on municipalities in Northern Cape and Western Cape Provinces without giving due attention to the Eastern Cape Province where there is one of the highest incidences of poverty in South Africa.

In a similar vein, Grecksch (2015) assessed adaptive capacity of water governance in the Keiskamma River Catchment in Eastern Cape Province using the Adaptive Capacity Wheel (ACW) framework. This assessment revealed medium adaptive capacity in this area and raised awareness among decision makers and the public by providing information on possible climate change effects and possible adaptation measures. Detailed assessments that demonstrate the usefulness of the ACW are provided by van den Brink *et al.* (2011) and Grecksch (2013). Their works provide a framework that supports the adaptive capacity assessment which was conducted in the Keiskamma River Catchment. Although these assessments demonstrate the usefulness of the ACW framework, nationwide use of this framework is undermined by its inclination to provide aggregated scenarios and inability to show exact locations of places with varied adaptive capacities.

Although an exhaustive overview of initiatives similar to those outlined above is outside the scope of this work, a brief presentation of the work done by Weis *et al.* (2016) in developing an adaptive capacity index for Grenada is helpful because it provides useful insights on wide-ranging possibilities that can be considered under different situations. Weis *et al.* assessed Grenada's adaptive capacity to flooding by mapping asset-based resource indicators of adaptive capacity comprising:

- human and civic resources;
- healthy population as a resource; and
- economic resources.

Their study was useful because unlike most assessments that have tended to be confined to sub-national constituencies, it provided a spatially co-extensive approach that can be used to guide policy formulation at national level the only downside being that it fails to adequately accommodate resource-poor communities at village level, where policy interventions are supposed to make a difference within municipalities by helping to alleviate the intractable difficulties confronting those least capable of helping themselves.

The examples outlined above have been presented to demonstrate that adaptive capacity can be cost-effectively assessed by using data most countries already have without overstretching limited resources by attempting to compile new information. Tools and techniques to do this are readily available and all that is needed is to tap on what is already accessible. This accessibility prompted the authors to share with those interested how Geographical Information Systems (GIS) can be used to assess and map adaptive capacity. GIS may be defined as a computer-based tool for mapping, querying and analyzing spatially referenced data (Quan *et al.*, 2001). GIS mapping can capture subnational variations in vulnerability by combining spatial data layers, generally by converting each layer to a unitless scale and aggregating the layers to reveal vulnerability levels (de Sherbinin, 2014). Although various methods of assessing adaptive capacity exist, GIS-based assessment of adaptive capacity is increasingly become popular because of its ability to produce information in map formats that provide comprehensible visual depiction of spatial variabilities in adaptive capacities.

GIS-based mapping offers the advantage that it can be applied at multiple scales which is extremely useful because it can not only handle vulnerability assessments for large areas but also is capable of effectively producing intelligible maps for small areas, thereby overcoming limitations confronting other approaches that are not able to provide disaggregated assessments at municipal levels. Because of this limitation, non-GIS-based methods often produce vulnerability assessments in which municipal disasters, food and water insecurities are, in many instances, analyzed at an aggregated national level giving rise to poorly targeted policy interventions. Although it is widely accepted that identification of villages with low adaptive capacities at municipal level is critical in the formulation of well-targeted adaptation and mitigation policies and strategies, this has been difficult to accomplish because of absence of methodologies that are capable of downscaling national-level data to municipal levels where policy interventions can be translated into action by engaging resource poor communities. Although data are in most cases usually available at national level, lack of equivalent datasets at municipal-level continues to be problematic (National Disaster Management Centre, 2005). This study attempts to bridge this gap by providing a step-by-step illustration of how GIS can be used to produce regional-level adaptive capacity information in the form of maps that accurately indicate villages in need of adaptation support. The ability of the proposed methodology to identify and show these villages is helpful because it enhances the effectiveness of wide-ranging interventions by assisting policy implementers to direct assistance where it is needed.

3. Materials and methods

3.1 Study area

Figure 1 shows the location of Nkonkobe Local Municipality in the Eastern Cape Province of South Africa.

Nkonkobe is a countryside municipality comprising 21 wards, covering an area of approximately 3,725 km^2 and has an average population density of 43 people per square kilometre (Nkonkobe Local Municipality, 2012). The major towns in Nkonkobe include Alice, Middledrift, Fort Beaufort and Seymour. The majority of the population (72 per cent) resides in villages and farms whilst the remaining 28 per cent resides in urban settlements (Nkonkobe Local Municipality, 2012). The entire municipality has a dispersed settlement pattern where pockets of developed urban centres are surrounded by scattered undeveloped rural villages, which implies great costs to provide basic infrastructure and services (Nkonkobe Local Municipality, 2013).

The area's climate is semi-arid with mean monthly temperatures that range from 6.2°C to 20.8°C in July and 17.2°C to 36.0°C in February; a wet summer season that begins in October and ends in April, a dry winter season that covers the remaining months of the year and average annual rainfall not exceeding 600 mm. This semi-arid climate poses serious problems by compromising the abilities of local communities to adapt to the adverse effects of climate change by inducing scarcities in the availability of basic requirements notably food and water. The majority of the population in Nkonkobe Local Municipality is highly dependent on natural resources and agriculture which are substantially influenced by rainfall and precipitation patterns. This limitation also provides part explanation of why

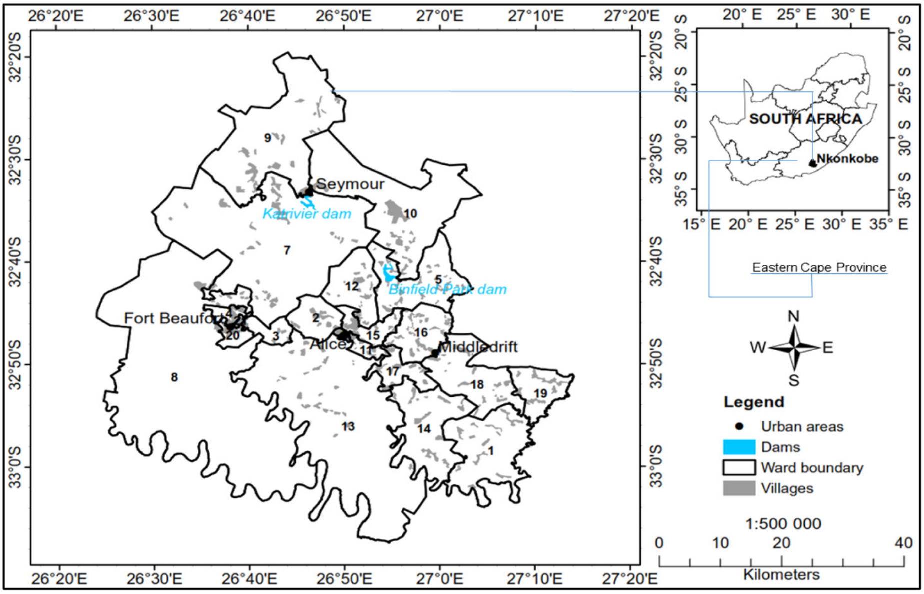


Figure 1. Geographic location of Nkonkobe local municipality in the Eastern Cape province, South Africa including ward boundaries

Source: Author's own

this municipality was deemed suitable for assessment of the adaptive capacity of resource-poor households to climate change.

3.2 Categories and sources of data that were used

Data used in this study were categorized as digitized village layer and census data. StatsSA provided the digitized village layer and 2011 census data (the most recent census survey date) in a raw table format at the municipal enumeration level.

3.3 Methods

The adaptive capacity of households to climate change was determined by adopting a multi-step GIS-based mapping of indicators that were simultaneously analyzed and averaged to determine the magnitude of adaptive capacity. Several adaptive capacity indicators were purposefully selected to enable spatial comparisons and the description of complicated reality in a comprehensible manner aided by the Nkonkobe Integrated Development Plan (IDP) for 2012-2017 (Nkonkobe Local Municipality, 2012) and expert knowledge which provided additional information and insights during the selection of assessment indicators. The selection of these indicators was based on the definition of adaptive capacity provided by Heltberg and Bonch-Osmolovskiy (2011) and the type and level of demographic data available for Nkonkobe Local Municipality. The following indicators (Table I) were selected on the basis of the logic described above and used to assess adaptive capacity within the municipality.

Shapefiles were created for each input indicator by linking the Microsoft Excel table for each indicator to the attribute table of the digitized-village shapefiles using the Join operation in ArcGIS 10.2 to allow expression as spatial layers that could be aggregated with

Narrative Indicator	Rationale	Ranking
Literacy levels	Specified adaptive capacity within the villages basing on highest level of education	Villages were given a score of 0 to 5 depending on the highest level of education. Villages with the least level of education were given a rating of 0. The ranking was as follows: No schooling = 0, Some Primary = 1, Completed Primary = 2, Some Secondary = 3, Completed Secondary = 4, Higher = 5
Income levels	Villages with a low income levels are less likely to have access to credit and less resilient to climate change	Villages were given a score of 0 to 4 depending on income profiles. Wards with the lowest income profiles were given a rating of 0. Ranked by Divided annual income into groups: No Income = 0, R1 – R9 600 = 1, R9 601 – R19 600 = 2, R19 601 – R38 200 = 3, R38 201 or more = 4
Age profiles	These were used to identify villages in which there were significant numbers of children or old people. Villages with majority being children or old age are most likely to be less resilient to climate change by virtue of being economically inactive	Villages scored between 0 and 3 and divided into three age groups; 0-14: Child (score of 0), 15-39: Young (score of 2), 40-59: Old (score of 3): Over 60 (score of 1)
Water access by source type	Specified the degree of adaptive capacity within the villages basing on water sources mainly utilized by different villages	Other sources = 0, Surface water = 1, Ground water = 2, Regional water scheme = 3

Source: Author's own

Table I. Description of input indicators used for assessing adaptive capacity

other layers to spatially depict adaptive capacity levels. The demographic data from StatsSA were analyzed at village-level because this was the lowest level at which the required information was available.

The following customized Python algorithm (Algorithm 1) was used to automatically assign scores to villages in the attribute table for village income levels. The same algorithm was also used for the same purpose to assign scores to the other three indicators (Literacy levels, Income levels and Age profiles) after being modified by changing the table names, field names and row numbers for each indicator following the criteria shown in Table I.

Algorithm 1. Algorithm that was used to automatically assign scores for village income levels

```
import arcpy module
specify file input location for income data attribute table
declare table_array for fields = ["No_income","R1_to_R9600",...,
"R38201_or_more"]
declare array for max_value field
declare array for max_value_fieldname
declare array for assigned_score field add max_value, max_value_-
fieldname, assigned_score fields to table_array
set cursor in table_array to update = true
with arcpy_UpdateCursor in table_array, put cursor at first row
    for row in cursor
```

```
find maximum value
find field name of maximum value
find assigned score
update rows
```

The geoprocessing algorithm was executed in ArcGIS 10.2 Python window using the Python execfile command.

A map was generated for each of the four indicators in the ArcMap 10.2 interactive environment based on the assigned scores to reveal detailed spatial variations for each indicator. Thereafter, all attribute tables were examined to identify villages with the lowest scores for each indicator. Adaptive capacity scores (Table II) were determined by automatic generation of a new shapefile and attribute table where the previously calculated scores from the four indicators were imported into and summed up for each village using automated Python geoprocessing algorithms (Algorithms 2 and 3). All equal weighting indicators were assigned because of limited availability of indicator data for the municipality but this limitation did not compromise the reliability of results because expert knowledge and the Nkonkobe IDP for 2012-2017 (Nkonkobe Local Municipality, 2012) confirmed that all indicators were equally important for adaptive capacity assessment.

Adaptive capacity scores were calculated in the attribute table (Table II) using the following formula:

$$\text{Adaptive score} = \sum_{n=S_1}^{S_4} n$$

where S_1, S_2, S_3 and S_4 are indicator scores.

The following Python algorithm (Algorithm 2) was used for automated creation of a new shapefile and attribute table and joining of Age_Profile scores to the IndicatorScores table.

Algorithm 2. Algorithm that was used for automated creation of a new shapefile and attribute table and joining of Age_Profile scores to the IndicatorScores table.

```
import arcpy module
import env module from arcpy
set the workspace
specify input feature class
specify output location
  specify output_feature_class
```

Village	Ward no.	Access to water	Literacy levels	Income levels	Age profile	Adaptive score	Adaptive capacity
V_1	W_1	3	5	4	3	15	HIGH
V_2	W_2	S_1	S_2	S_3	S_4	–	–
–	–	–	–	–	–	–	–
–	–	–	–	–	–	–	–
–	–	–	–	–	–	–	–
V_{180}	W_{21}	3	3	2	0	8	MEDIUM

Notes: $V_1 \ldots V_{180}$ – village names; W – ward numbers; S_1, S_2, S_3, S_4 – indicator scores; adaptive scores ranged from 1 – 15
Source: Author's own

Table II. Illustration of the evaluation of adaptive capacity in the attribute table

```
list fields to be retained as myfields = ["MP_NAME", "WARD_NO",
"Res_Age"]
create an empty field mapping object
 for field in myfields
   create individual field map
   add field map to field mapping object
   copy feature class using ["MP_NAME"] as matching field for rows
   store in output_feature_class in
 output location
```

Thereafter, Algorithm 3 was used for joining of the remaining three indicator scores to the IndicatorsScores attribute table using village name as the linking field.

Algorithm 3. Algorithm that was used for joining of the remaining three indicator scores to the IndicatorsScores table using MP_NAME as the linking field.

```
import arcpy module
import env module from arcpy
set the workspace environment
join IncomeScores_field to IndicatorScores table using JoinField_-
management operation
join LiteracyScores_field to IndicatorScores table using JoinField_
management operation
join WaterScores_field to IndicatorScores table using JoinField_
management operation
```

As the highest attainable adaptive capacity score from the summation of the four highest indicator scores was 15 (Table I), the computed adaptive capacity scores were automatically ranked into low-medium-high adaptive capacity as follows: Scores of 1-5 = LOW, Scores 6-10 = MEDIUM and Scores of 11-15 = HIGH using the following geoprocessing Python algorithm (Algorithm 4) that was run by executing the Python execfile command. A field for the ranked adaptive capacity scores was also automatically generated and added to the attribute table.

Algorithm 4. Algorithm that was used for automated summation and ranking of the four indicator scores.

```
import arcpy, math modules
specify file location of adaptive_capacity attribute table
add fields = ["Water_score","Assigned_score","Literacy_score",
"Res_Age"] into array
declare array for adaptive capacity_ score field as total
declare array for adaptive capacity field as rating
add total and rating fields to adaptive_capacity table
with arcpy UpdateCursor in adaptive_capacity table, put cursor in
first row
     for row in cursor
        sum indicator scores to total
        if total <= 5 then
         rating = "LOW"
        elseif total > 5 and total <= 10 then
           rating = "MEDIUM"
        else rating = "HIGH"
           update rows
```

An adaptive capacity map was generated in the ArcMap 10.2 interactive environment based on the rankings. Alice, Middledrift, Fort Beaufort and Seymour were excluded from the assessment of resource-poor communities because their classification as urban areas in Nkonkobe Local Municipality disqualifies them from being considered resource-poor communities.

Villages with low adaptive capacity were extracted from the attribute table using a geoprocessing algorithm (Algorithm 5) and displayed both in the Python window and a shareable separately created text file (*.txt).

Algorithm 5. Algorithm that was used to automatically generate list of villages with low adaptive capacity.

```
import arcpy, csv system modules
specify file location of IndicatorScores attribute table
add array fields = ["MP_NAME", "WARD_NO", "Adaptive_Capacity"]
specify output textfile location
set counter = 0
print heading
with output file open
    enable csv writer to output file
    write title specified to output file
    write fields and contents to output file
    with SearchCursor in first row and field in attribute table:
        for row in cursor:
            if Adaptive capacity = "LOW" then
            add 1 to count
            write row to output file
            print count and row
```

4. Results and discussion

The results of this investigation are presented in the form of maps and a table.

4.1 Spatial distributions of indicators used to assess adaptive capacity

Figure 2 shows maps that were produced from the four indicators that were used to assess adaptive capacity.

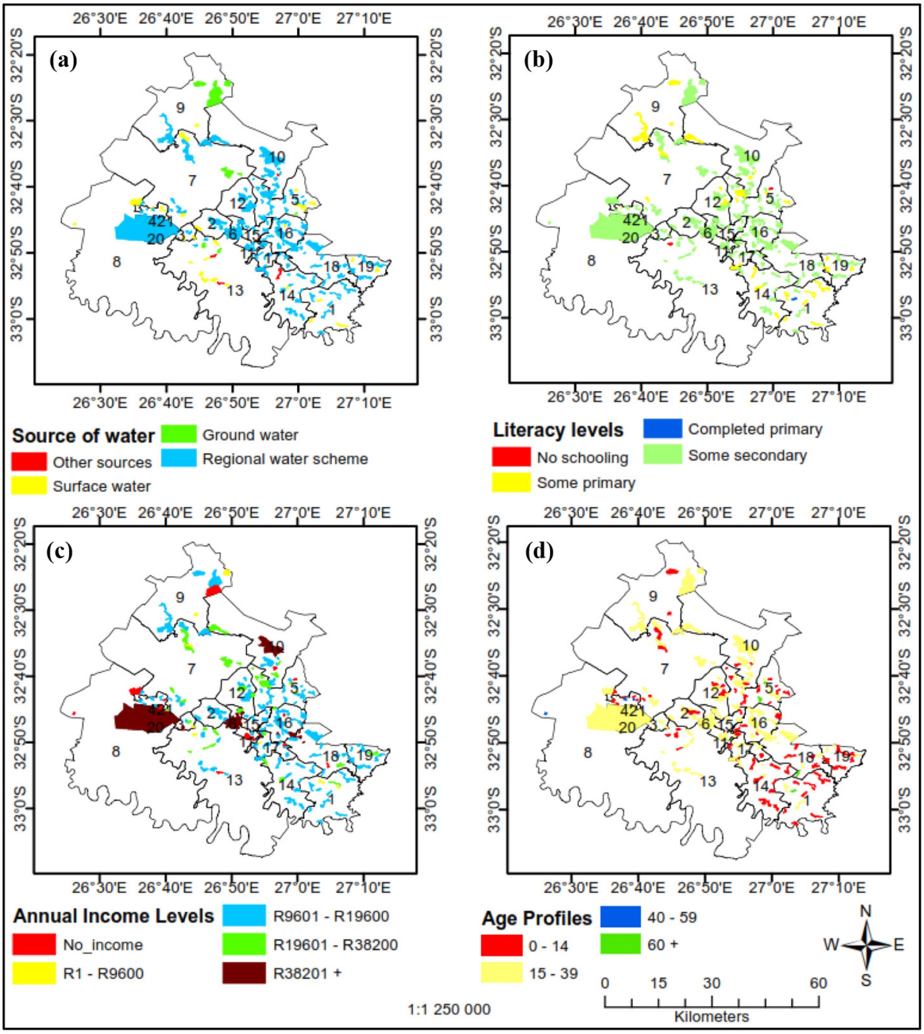
Figure 3 shows distributions of adaptive capacities that were obtained by mapping the ranked adaptive capacity scores that were calculated as explained in Table II to capture spatial variations in the abilities of individual villages to mitigate adverse effects of climate change. As explained earlier, major towns within the municipality (Fort Beaufort, Alice, Seymour and Middledrift) were excluded from the analysis because they have very few resource-poor communities.

Table III shows the numbers villages by ward number that were identified as having low adaptive capacity.

4.2 Discussion

The primary objective of the study was to provide a methodology that can used to objectively map adaptive capacity by using purposefully selected demographic data.

4.2.1 Access to water. The sources of water by source type in wards 1-21 [Figure 2(a)] affect the resilience of communities by influencing the availability of water. Although names of villages are provided in this discussion, the names are not shown in the maps to avoid



Source: Author's own

Figure 2. Maps produced from indicators that were used to assess adaptive capacity

overcrowded labelling. Ward 13 is most underdeveloped in terms of water access because of limited availability of regional water schemes. Four villages (Mmangweni in ward 10, Allandale and Mpozisa in ward 13 and Mavuvumezini in ward 14) are severely water stressed and get water from non-natural other sources comprising water vendors and water tankers.

4.2.2 Literacy levels. Figure 2(b) indicates degree of disaster awareness to climate change issues within the households. Two villages (Mdeni B in ward 5 and Lebanon in ward 13) have the majority of people with no schooling and need the greatest attention concerning schooling. Although the majority of people in the municipality attended secondary school,

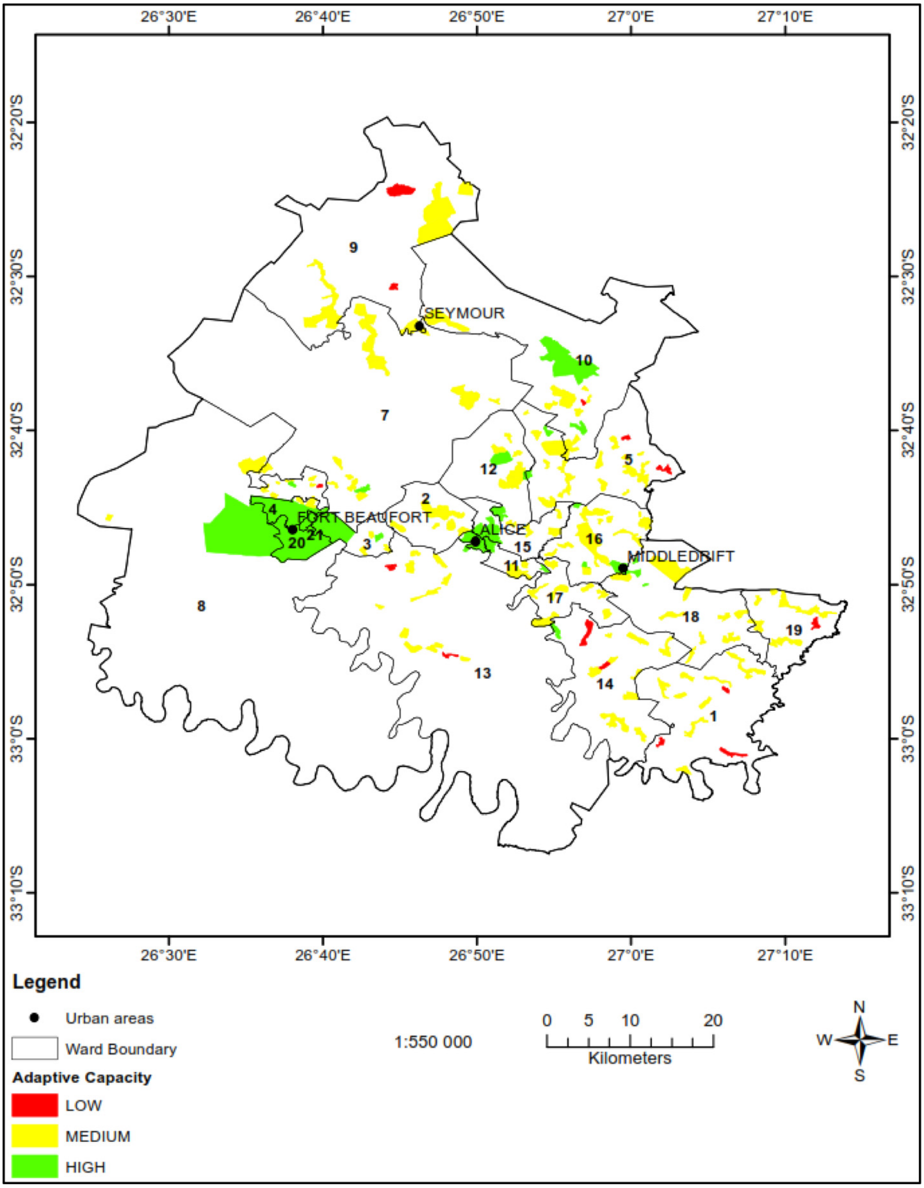


Figure 3.
Adaptive capacity map for Nkonkobe local municipality

Source: Author's own

awareness and practical implementation of climate change adaptation strategies requires additional traits like changes in individual attitudes and engagement, by being willing and able to connect with climate change issues, as knowing alone without motivation and ability to take action is not enough (Lorenzonia *et al.*, 2007). General lack of these traits especially

Village	Ward no.
Qamdobowa	1
KwaKulile	1
Mdeni B	5
Ndlovura	5
Luzini	8
Wellsdale	9
Cairns	9
Mmangweni	10
Lebanon	13
Mpozisa	13
Mavuzamezini	14
eMgwanisheni	14
Qutubeni	16
Ntonga	19

Source: Author's own

Table III. Villages with low adaptive capacity in Nkonkobe local municipality

ability to take action because of poverty related constraints implies that disaster awareness to climate change issues is modest if not marginal.

4.2.3 Annual income levels. Figure 2C indicates villages with and without income with the latter being unlikely to have access to credit and poorly resilient to most shocks linked to climate change. In total, 13 villages were revealed to be having majority of the people as having no income. Villages deemed as the poorest in the municipality are mostly in wards 6, 11, 15, 16 and 13 where the majority of people have the least income levels. These observations are again consistent with findings by Ziervogel *et al.* (2006) in the Ga-Selala village of Sekhukhune District Municipality where 58 (87.9 per cent) out of 66 interviewees did not have any household income.

4.2.4 Determination of resilience by age profiles. Resilience by age profiles Figure 2(d) was based on the reasoning that children and old people have low resilience by virtue of being economically inactive compared to their economically active counterparts of intermediate age. A total of 70 villages were identified as having the majority of the people in the ages between 0 and 14 years with four villages having the majority of people above 60 years of age. These two age profiles have the lowest coping capacity by virtue of being economically inactive. The intermediate age group has high resilience because of the majority of people having employment and recognizable awareness of climate change-related issues. The wards with high numbers of villages with low resilience to climate change are wards 5, 14, 17, 18 and 19.

Basing on the indicators used, low adaptive capacities were established in 14 villages of wards 1, 3, 4 and 5 (Table III), while medium level adaptive capacity was established in 146 villages from a total of 180 villages in the municipality. The results fit within the current planning and regulative framework in that they are providing information which will aid government in formulation of suitable climate adaptation policies. The need for information which aids in formulation of suitable climate adaptation policies at local municipal level has been reflected in the current Nkonkobe Local Municipality 2012-2017 Integrated Development Plan (IDP) under disaster management sector plan (Nkonkobe Local Municipality, 2012). The results can also be implemented as part of Nkonkobe Local Municipality's next IDP as a reflection of the previous adaptive capacity status. The presented results also support the improvement of service delivery by government to rural communities by providing information useful to municipal and government authorities on target communities with the least access to public services such as water and education.

When methodology is implemented in a wider context such as provincial level, the results are extremely helpful in the guiding formulation of provincial or national climate change response strategies and development action plans. Overall, results produced by using this methodology at any spatial extent assist to fulfil the main objective of the National Climate Change Response Plan White Paper (NCCRP) of South Africa (Department of Environmental Affairs, 2011) which is to boost climate change adaptation and effectively manage inevitable climate change impacts through interventions that build and sustain South Africa's social, economic and environmental resilience and emergency response capacity using cost-effective and implementable methodologies. Government, research institutions and civil societies are therefore encouraged to use the methodology with more appropriate available datasets to map adaptive capacity in rural Eastern Cape and other rural areas of South Africa. For example, in Joe Gqabi District Municipality which has been declared a drought disaster area (de Kock, 2016), the methodology can be applied using available data from StatsSA to map adaptive capacity of communities to climate change to produce results which will aid in disaster management sector planning in the Joe Gqabi 2017-2018 IDP. However, to appropriately compare adaptive capacities for different locations, there has to be a consensus on the choice of indicators to be used for each of the locations.

5. Conclusion and recommendations

The aim of the study was to provide a cost-effective, time saving, replicable and user-friendly case study-based approach to assess the adaptive capacities of resource poor households by systematically identifying villages with low adaptive capacities to the adverse effects of climate change. This was accomplished by identifying a multi-tiered suit of specific resources that need to be provided to villages that are vulnerable to scarcities and shortages of specific resources. The assessment conducted was able to provide a comprehensive overview of the spatial distributions of coping capacities at a municipal level. However, to apply the methodology at larger scales, the datasets need to be also confined to large scale such provincial or national level. The major advantages of the methodology are that it is time-saving, cost-effective, user-friendly, replicable and capable of offering tremendous scope for aiding quick climate policy decision-making by facilitating verifiable and objective identification of villages with low adaptive capacities to climate change. The social implication of the presented methodology is in guiding public policy interventions aimed at reaching, protecting and uplifting socio-economically disadvantaged populations in both rural and urban settings.

The methodology presented in this paper is extremely helpful because timely identification of communities with low adaptive capacities aids the implementation of intervention strategies by enabling policy implementers to direct assistance to those who are unable to cope with adverse impacts of climate change. Policy implementers, that is, governments and stake-holders such as research institutions and civil societies interested in mitigating the adverse effects of climate change are therefore urged to seriously consider using this methodology in identifying resource-poor communities deserving priority consideration when delivering support and assistance.

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