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Identifying land suitable for agricultural land reform using GIS-MCDA in South Africa

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Abstract Land reform is identified as a key tool in fostering development in South Africa. Twenty years after the advent of democracy in South Africa, the land question remains a critical issue for policy makers. Several frameworks have been put in place by the government to identify land that is strategically located for land reform. However, many of these frameworks are not well aligned and not objective in defining strategically located land for land reform and often lead to unsustainable land use management practices. This has hampered the government's land reform initiative in promoting agricultural land reform and food security. Accordingly, there is a need to develop a decision support tool that facilitates the identification of strategically located land for land reform. This study proposes the use of geographic information systems (GIS) and multi-criteria decision analysis (MCDA) to develop a strategically located land index (SLLI) to identify land suitable for agricultural land reform. Participatory workshops and the group analytical hierarchy process were utilised to identify and weigh criteria used in computing the SLLI. The results indicate that land that is suitable for agricultural land reform is scarce, and there are also competing needs on the highly suitable land for agriculture. The study demonstrates that GIS and MCDA are invaluable tools in facilitating evidence-based decision-making for land reform and sustainable land use management practices. The SLLI is not the panacea to land identification; there is also need to appreciate the contested nature of land in South Africa.

Keywords Land reform · GIS-MCDA · Agriculture · Sustainable · South Africa · Land suitability · Strategically located land

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1 Introduction

The sustainable use of agricultural land is an issue of global concern. In developing countries, particularly land suitable for agriculture is key to food security and economic growth (World Commission on Environment and Development 1987). It is therefore essential that land use plans determine the agricultural opportunities and constraints of land parcels through land suitability analysis. Land suitability has been defined as the fitness of a given type of land for a specified kind of agricultural land use (Food and Agricultural Organisation (FAO) 1976). Land suitability is very important as it provides information regarding the use that can be suitable for a certain land and thus it results in sustainable management of finite resources such as land (Akıncı et al. 2013; Elsheikh et al. 2013). Consequently, land suitability is a vital link in the chain leading to sustainable management of land resources (FAO 1993; Verheye et al. 2008).

Land use suitability is a spatial problem that often requires evaluating a set of alternatives using multi-criteria. Consequently, geographic information systems (GIS) have to be integrated with multi-criteria decision analysis/aiding (MCDA) techniques (Jankowski 2006; Malczewski 2006a; Malczewski and Rinner 2015). Common MCDA techniques include the weighted linear combination, the analytical hierarchy (AHP)/network process (Satty 1980) and outranking methods (Malczewski 1999, 2006a, b). Combining GIS and MCDA stems from the need to make the GIS capabilities more relevant for decision-making and planning (Malczewski 2006a; Malczewski and Rinner 2015). GIS-based MCDA (GIS-MCDA) therefore enables combining geographic data (input maps) and the decision-maker's (expert or agent) preferences into a map that can be used by land use planners (Malczewski and Rinner 2015). Integrating GIS with MCDA is very useful because value judgements can be included and this empowers decision-makers to comprehend the results of GIS-based decision-making procedures and providing a methodical and defensible way to develop policy recommendations for complex problems (Kalogirou 2002; Malczewski 2006a; Mbũgwa et al. 2015). It is because of these capabilities that GIS-MCDA research has exploded in land use suitability studies (Çetinkaya et al. 2016; Anwarzai and Nagasaka 2017).

Subsequently, Palmisano et al. (2016) used GIS and the group analytic hierarchy process to model greenways for rural sustainable development. Similarly, a study by (Feizizadeh and Blaschke 2012) investigated the optimal utilisation of land resources for agricultural production in Tabriz County, Iran. In the same way, Elsheikh et al. (2013) developed an agriculture land suitability evaluator (ALSE) for subtropical crops. Meanwhile Xu and Zhang (2013) developed a land suitability evaluation (LSE) for wheat production. Likewise, Kumar and Jhariya (2015) developed a land quality index assessment for agricultural purposes using GIS-MCDA.

These studies on the application of GIS-MCDA in land suitability demonstrate that GIS-MCDA are important tools in assisting policy makers to make consistent decisions as well as providing a framework for evaluation and accountability. Nonetheless, despite the usefulness of GIS-MCDA in land suitability models, they are hardly used to inform policy makers in acquiring land suitable for land reform. To the best knowledge of the authors, no GIS-MCDA studies and/or tool exists that has been explicitly developed to support and inform decisions regarding land reform in South Africa.

The remainder of the paper is structured as follows, the next section discuses land reform in South Africa, a description of the study area then follows, the methodology, the results and discussion and lastly lessons learnt, challenges and conclusions are presented.

2 Land and Land Reform in South Africa

Land is regarded as a basic source of livelihoods as South Africans depend on it for agriculture, tourism and housing (Moyo 2005). Land and race played a major role in shaping patterns of land ownership and occupation in South Africa. The concept of racialised space was made law through the Native Land Act of 1913 and later with legislations implemented between 1923 and 1991, for instance, the Group Areas Act, 1950 (Ramutsindela 2003; Ntsebeza and Hall 2007). The Native Land Act of 1913 resulted in most Whites appropriating about 90% of land that was productive in terms of agricultural use while the remaining marginal portions which were occupied by Black people (Moyo 2005). Similarly, the Group Areas Act resulted in forced removals whereby most African people lost their land and also occupied most of the land that was located in peripheries (Ntsebeza and Hall 2007). Black people were left out with unproductive land that could not be used for agriculture in the so-called Bantustans or Black homelands, whereas Whites dominated in ownership and occupancy of productive agricultural land (Letsoalo and Thupana 2013). Therefore, these inequalities and divided space has resulted in high levels of poverty, poverty nodes and also over population in urban areas coupled with high levels of unemployment (La Rosa et al. 2014)

With the dawn of democracy in 1994 land reform was seen as a tool to address the skewedness of land ownership, especially the productive land. Land remains the most contested issue in South Africa, as it is in most post-colonial and post-apartheid societies (Gumede 2014). As Fanon (1963: 9) explains, "for a colonial people the most important essential value, because the most concrete, is first and foremost the land: the land which will bring them bread and, above all dignity". It is therefore fundamental that land reform in the 'new' South Africa redresses the injustices of apartheid and, by redistributing land to black South Africans, to transform the structural basis of racial inequality (Hall 2004a, 2007).

Nevertheless, land reform has fallen far short of both public expectations and official targets and is often regarded as a dismal failure (Hall and Williams 2003; Hall 2010b; Gumede 2014). Hall (2004b, 2010a) attributes this to the largely driven willing buyer willing process where the owners have been reluctant to relinquish land for redistribution while others have taken advantage of the willing buyer willing seller strategy by inflating land prices in order to make it harder for government to buy back the land (Ntsebeza and Hall 2007; Lahiff 2008; Sikor and Müller 2009). Furthermore, the question still remains, is the land that has been redistributed suitable for agricultural productivity so as to ensure food security, alleviate poverty and create employment (Ntsebeza and Hall 2007). This question is of utmost importance because some of the land that the government redistributed to the people has failed to improve people's livelihoods; instead, it has led to impoverishment (Ntsebeza and Hall 2007). For example, in the case of Northern Cape province where land was redistributed to the people, but only to find out was not suitable and not strategically located for agriculture (Bradstock 2006). Bradstock (2006) concludes that restitution or redistributing land that is 'unstrategic', geographically isolated from the residence location of the beneficiaries, far from amenities, services and infrastructure, provides no effective solution to reducing poverty and promoting food security in rural South Africa. Hence, the quality of land and its location are critical when acquiring land. Similarly, the ministry in charge of land reform, The Department of Rural Development and Land Reform (DRDLR) does not have a guideline or framework that clearly outlines what land is referred to as "strategically located" land suitable for agriculture (Hall 2004b, 2010b). Consequently, The Minister in the then Department of Land Affairs noted that at least 50% of government land reform projects have failed to make their beneficiaries permanently better off (Centre for Development and Enterprise (CDE) 2008). Identifying suitable and strategically located land is vital and it is more than a formal, nominal or constitutional validity (James Williams 2000). Similarly, Hall (2009) notes that the current acquisition of land under the willing seller willing buyer does not ensure that suitable and strategic land is acquired, in terms of size, location and quality for agricultural production. Hall also notes that there is little or no focus on how land acquired for redistribution is acquired as well as lack of spatial targeting from a national level. Nonetheless, Hall (2009) and the DRDLR note the potential of using GIS in identifying land suitable for agricultural land reform. National policies such as the National Development Plan (NDP) prescribe spatial targeting for land reform and GIS can be a useful tool in this regard. Therefore, the aim of this paper is to develop a strategically located land index (SLLI) using geographic information systems (GIS) and multi-criteria decision analysis (MCDA) to aid decision-makers in acquiring land for land reform that is generally suitable for agricultural land reform.

3 Study area

South Africa is located on the southern most tip of the African continent (Fig. 1). It consists of a diverse population of fifty-two million (Statistics South Africa 2011). Poverty and inequality remain a threat to South Africa's development agenda, whereas a burgeoning urban population of 62% of the total population presents both an opportunity and a threat (World Bank 2010). It is also a diverse country in terms of terrain, weather, economic

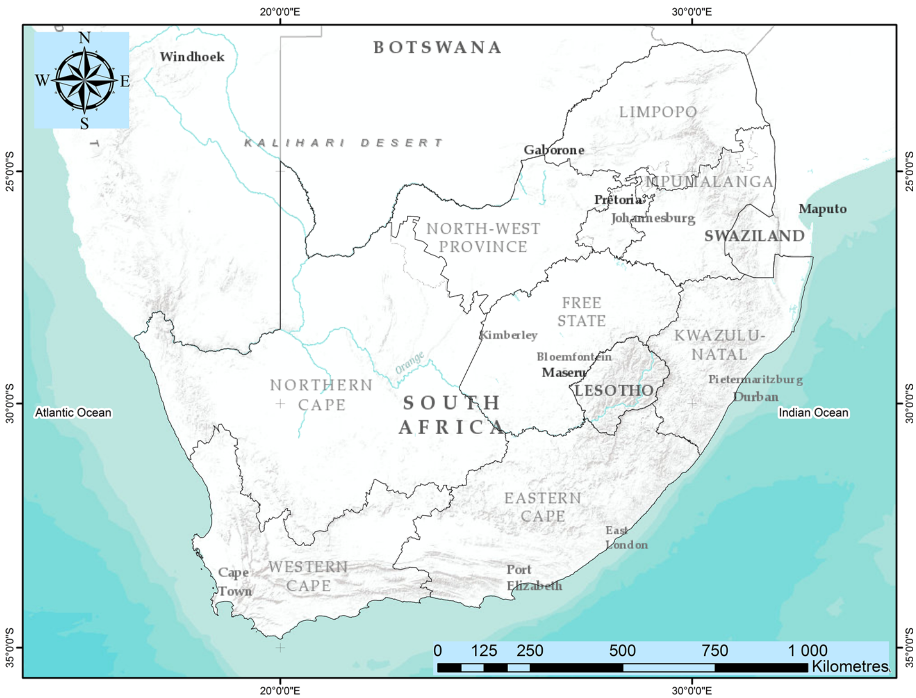

Fig. 1 Location of South Africa

opportunities and cultures amongst other things. South Africa has nine provinces of which Gauteng is the economic hub with the economic capital Johannesburg and administrative capital Pretoria. The Western Cape and KwaZulu-Natal are the other major economic hubs. Limpopo province and the Eastern Cape province are the most impoverished while the Northern Cape has harsh climatic conditions. The North West province is well known for its mineral resources, whereas Mpumalanga and the Free State province are mostly agricultural. These differences amongst areas in South Africa make it necessary to identify and allocate land with the potential to alleviate poverty and inequality.

4 Methodology

The land suitability assessment for identifying strategically located land for agriculture was done using a consultative and participatory process so as to improve user acceptance (Fig. 2). This was done through three stages (1) criteria identification, (2) criteria weighting and the group analytical hierarchy process, (3) mapping and assigning rule sets and (4) employing the weighted linear combination (WLC) to generate the SLLI (Fig. 2).

4.1 Criteria identification

Criteria identification for developing the SLLI was done through participatory workshops (Fig. 2). The first workshop was conducted in September 2013, which consisted of professional experts in government departments, consultants, and policy makers with expertise in areas such as policy, agronomy, GIS, agriculture, crop management, economics and rural development. Criteria selection at the initial workshop was mainly guided by national policy documents and legislation such as the National Development Plan, The Integrated Growth and Development Plan (IGDP) 2012, Spatial Planning and Land Use Management Act 2013 (SPLUMA), Green Paper on Land Reform 2011, the DRDLR Strategic Plan 2015–2022 and DRDLR reports. This resulted in over 30 themes that produced over 30 criteria, which would make it impossible and complex to develop a GIS-MCDA tool. Accordingly, a core team of academics, crop specialists, GIS experts, social scientists and key personnel within the DRDLR were appointed to streamline the criteria. Literature on land suitability for agriculture (Ahamed et al. 2000; Serneels and Lambin 2001; Elsheikh et al. 2013; Mbũgwa et al. 2015; Naughton et al. 2015; Zabihi et al. 2015; Zolekar and Bhagat 2015), land use management, national policies and legislation (Republic of South Africa 2010) and the Food and Agriculture Organisation (FAO) guidelines (FAO 1976; Verheye et al. 2008) were consulted extensively in criteria selection. Subsequently, the number of criteria was rationalised to (15) to reduce redundancy, duplication and complexity (Table 1). This ensured that criteria are logically sound and consistently relate to the objective and problem; realistic, transparent, simple and minimal (Saaty 1987).

4.2 Group analytical hierarchy process

In a follow-up participatory workshop, with a core team,[1] the 15 criteria were weighted using the group analytical hierarchy process (GAHP) process. The GAHP was selected

[1] Academic experts in GIS; professionals such as agronomists, development economists, crop specialists, livestock specialists, town planners, GIS professionals, environmentalists, agricultural experts, economists from various government departments together with civil society.

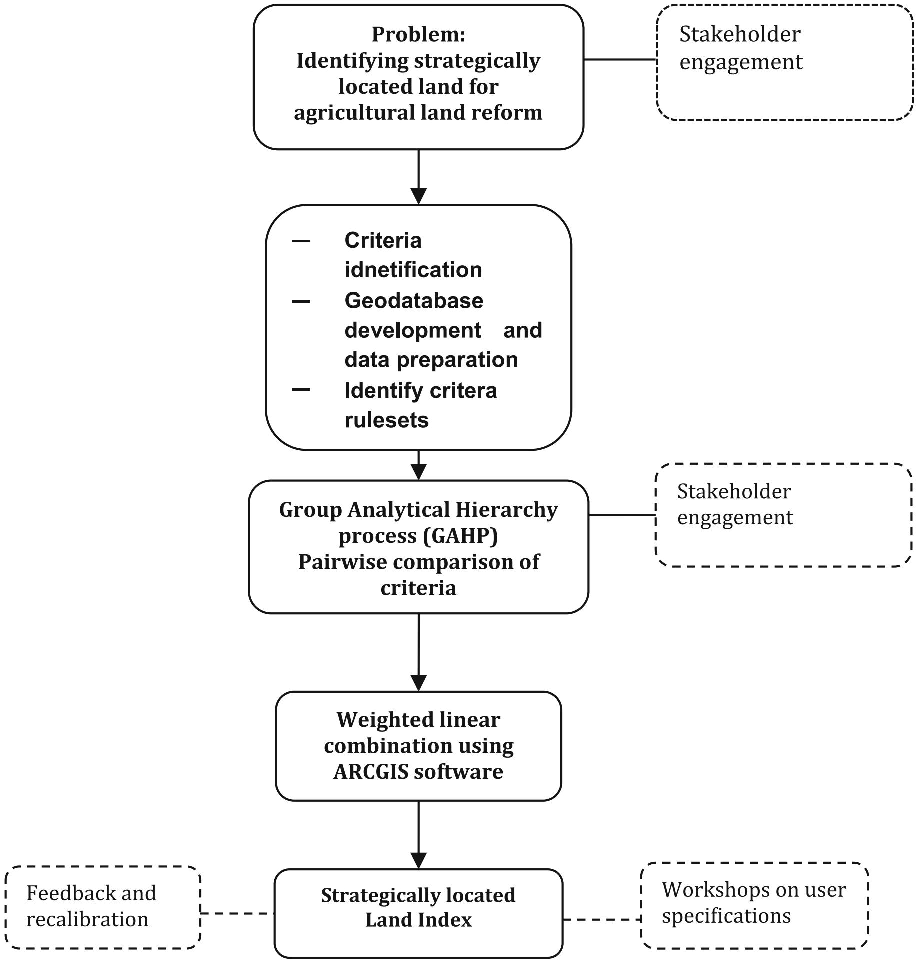

Fig. 2 Stepwise process of developing the strategically located land index for agriculture

because it the mostly wised MCDA technique in literature, it is flexible, comprehensive, easy to use, highly participatory, and it is considered as the best suitable method because it is straightforward and convenient (Malczewski and Rinner 2015). The workshop participants applied the GAHP for weighting each criterion using a pairwise comparison matrix (Satty 1980). The pairwise comparison matrix asks how important one criterion is relative to another based on a 1–9 scale (Table 2).

Consequently, the workshop participants were issued with a template consisting 106 pairwise comparisons of the 15 criteria to complete. This template was developed using the GAHP calculator by Goepel (2014). Subsequently, the participants used the GAHP software calculator to generate an overall weighting matrix that involved synthesising each of the expert's judgments and combining the resulting priorities using a geometric mean (Malczewski and Rinner 2015). Such an approach is more appropriate than the group consensus reaching model since it employs an automatic feedback mechanism and relieves

Table 1 Agricultural criteria and weighting

Agriculture criteria	Weight	Rank
Normalised difference vegetation index (NDVI)	15	1
Soil PH	13.4	2
Proximity to rivers and dams	12.2	3
Soil texture	10.1	4
Average annual rainfall	10	5
Elevation	8.7	6
Average temperature min	7.2	7
Average temperature max	7	8
Proximity to roads	4.4	9
Proximity to cities and town	3.6	10
Proximity to economic development corridors (EDC)	2.6	11
Groundwater quality	2.2	12
Proximity to railway line	1.5	13
Proximity to strategic infrastructure projects (SIP)	1.3	14
Proximity to mining/deposits	0.8	15
Total	100	

Table 2 Pairwise comparison matrix. *Source* Satty (1980)

How important is A relative to B	Preference index assigned
Equally important	1
Moderately more important	3
Strongly more important	5
Very strongly more important	7
Overwhelmingly more important	9
Values in between	2; 4; 6; 8

the group[2] of the need for a moderator who may be biased (Dong and Cooper 2016; Grošelj et al. 2015). The pairwise matrix had a consistency ratio of 0.025, which implies that there were no logical inconsistencies in the matrix. Likewise, the sum of weights for all the criteria adds up to 100 (one hundred) to ensure consistency (Table 1).

It is important to note that climatic, physical and environmental criterion such as vegetation, temperature, elevation, rainfall, soil PH, proximity to rivers and dams were deemed more important than other criteria such as proximity to cities and towns (Table 1). This is because criteria such as soil PH, temperature, elevation have a significant growth and development rates of many crops as well as livestock.

4.3 Assigning criterion rule sets and mapping

GIS data of the 15 criteria were collected from the National Geospatial Inspectorate (NGI) and other government departments. The next step was assigning rule sets to the criteria and

[2] Aggregating using an automated algorithm was utilised because it avoids using a moderator or judge who may be biased (Dong and Cooper 2016). Moreover, reaching consensus is almost impossible in the real world; hence, utilising the algorithm by Goepel (2014) ensures consistency and avoids biases.

these were identified from literature (FAO 1976; Hurni 2000; Farrow and Winograd 2001; Akıncı et al. 2013; Elsheikh et al. 2013; Mbũgwa et al. 2015). Accordingly, maps for each criterion were classified using suitability scale of −1 to 2 where 2 is highly suitable, 1 moderately suitable, 0 marginally suitable and −1 unsuitable (Table 3).

Assigning these rule sets enabled statistical analysis using the weighted linear combination (WLC) to derive the strategically located index. In addition, the classification scale of −1 to 2 enables comparisons, normalisation and simplifies interpretation of the results.

4.4 Computing the strategically located index

To compute the SLLI, the weighted linear combination (WLC) was selected, where S_l is the total score of strategically located land for a land unit is calculated using the following Eq. (1).

$$S_l = \sum_{i=1}^{n} W_i P_i \quad (1)$$

where W_i of each criterion is calculated using GAHP, P_i represents value of each criterion based on corresponding standards and n is number of criterion. This approach was preferred because it is a risk averse and it is a full trade-off solution (Van Niekerk et al. 2016). Nevertheless, when more control is required over the trade-off, one can apply the ordered weighted average (OWA) (Van Niekerk et al. 2016). ArcGIS 10.2 and the model builder tool in ArcGIS 10.2 were used to develop the algorithm to compute the SLLI raster with a cell size of 500 m by 500 m (Fig. 3).

To make the SLLI more usable, the raster values were extracted to points and accompanying criteria justifying each point were attached using structured querying language. These points were also converted to Thiessen polygons of 500 m × 500 m containing the SLLI and accompany criteria to improve visualisation. A spatial resolution of 500 × 500 m was chosen to create a uniform scale of analysis that captures sufficient detail at national level. Lastly, these polygons were reclassified to improve usability using a range of 1–100 where 0–25 represents unstrategic locations, 26–50 marginally strategic, 51–75 moderately strategic and 76–100 highly strategic land for agricultural purposes. Extensive validation and accuracy assessments were also carried out to determine if the SLLI and accompanying criterion corresponds. The Thiessen polygons were later ploughed into the SLLI web viewer that managers could use as a spatial decision support system (SDSS) to make queries.

5 Results and discussion

The SLLI for agriculture is visualised (Fig. 4), whereas Fig. 5 classifies strategically located land for agriculture according to suitability classes for agriculture. The majority of the highly strategic land (SLLI of >75) for agriculture is in the central highlands in the North West, Free State, Gauteng, Limpopo and Mpumalanga provinces (Fig. 6). There are also, land parcels of highly strategic land in the south-eastern Western Cape and southern Eastern Cape provinces (Fig. 6).

Likewise the KwaZulu-Natal midlands are also identified as highly strategic. The Northern Cape is largely not strategic. However, there are islands of strategically located land as a result of infrastructure projects in the eastern zone of the Northern Cape

Table 3 Agricultural criteria and rule sets

Group	Agriculture criteria	Highly suitable	Moderately suitable	Marginally unsuitable	Unsuitable
Environmental and Physical criteria	Normalised difference vegetation index (NDVI)	>0.75	0.5–0.75	0.25–0.49	<0.25
	Soil PH	7.5–8.4	6.5–7.4	5.5–6.4	0–5.5 or >8.5
	Proximity to rivers and dams	<5 kilometres (km)	5–7 km	8–10 km	>10 km
	Soil texture[a]	Favourable structure	Somewhat favourable	Unsuitable	Water bodies
	Elevation	1600–2500	800–1600	200–800	0–200 or >2500
	Groundwater quality	<70	70–300	301–1000	>1000
Climatic criteria	Average annual rainfall	601–800 mm	201–600 mm	800–1000 mm	<0–200 or >1000 mm
	Average temperature min)	>8 degree Celsius (°C)	4.1–8 °C	0.1–4 °C	−1.9 to 0 or <−2 (°C)
	Average temperature max	0–25 or 25.1–29 °C	27.1–31 °C	31.1–35 °C	>35 °C
Socio-economic criteria	Proximity to roads	<3 km	3–6 km	6–10 km	>10 km
	Proximity to cities &town	<7 km	7–14 km	14–21 km	>21 km
	Proximity to economic development corridors (EDC)	<15 km	15–30 km	31–45 km	>45
	Proximity to railway line	<5 km	5–10 km	11–15 km	>15 km
	Proximity to strategic infrastructure projects (SIP)	<15 km	15–30 km	31–45 km	>45
	Proximity to mining/deposits	>90 km	61–90 km	30–60 km	>30

[a] The soil texture dataset already classified by Council for geosciences in terms of suitability

commonly referred to as the green zone in agro-ecological studies (Fig. 5). Classifying the suitability per province also assists in showing the suitability distribution and variances across a province.

Only 15% of the country is pristine agricultural land (SLLI >75) (Fig. 6), which is highly strategically located, whereas 32% is moderately suitable, 31% marginally suitable and 22% unsuitable (Table 4). Therefore, there is scarce land to resettle land for farming purposes, which is further complicated by ownership, and current land use patterns, which needs to be ascertained first. Hence, achieving food security through land reform will likely remain a challenge, as there would be competing interests. It is also important to note that the 15% of pristine agricultural land (SLLI >75) is not distributed evenly across the country, which further exacerbates inequality in South Africa (Table 5).

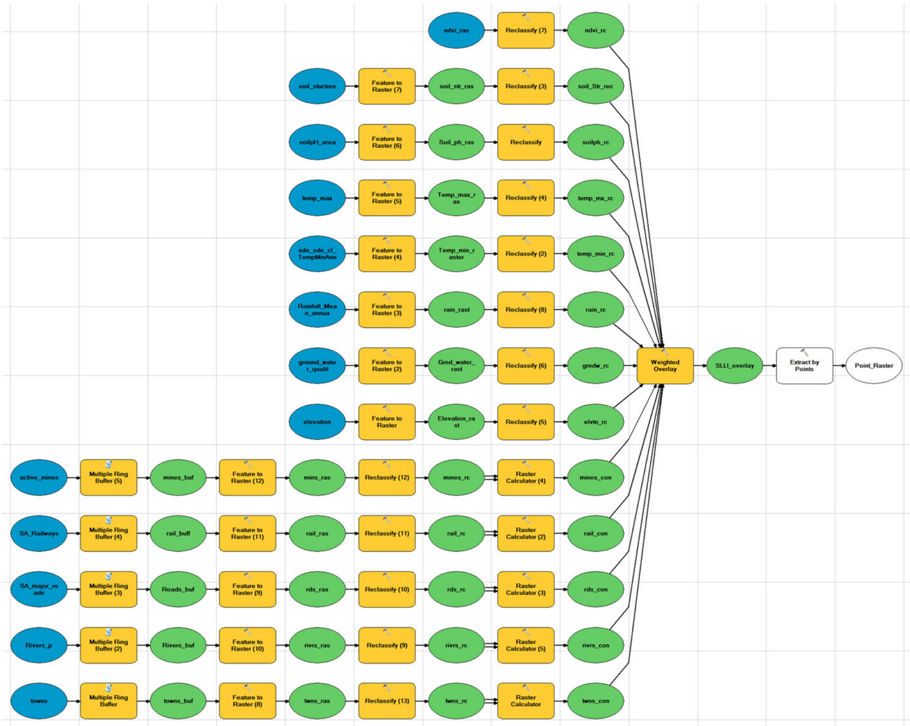

Fig. 3 ArcGIS model to derive the strategically located land index

Gauteng province contains the largest proportion per province (68%) of highly suitable land; however, it is the smallest province and it is highly urbanised which proves a challenge for agricultural land reform. Similarly, it is affected by acid mine drainage which can impact negatively on agriculture and it has also been identified as highly suitable for human settlements land reform (Mbugwa et al. 2015). Therefore, multi-objective analyses to decide between competing uses of agriculture and human settlements need to be undertaken. Mpumalanga and the Free State provinces have 37 and 33% of highly suitable land; therefore, they offer a better option for agricultural land reform, as well as the North West (23%) and Limpopo (21%) as they are not highly urbanised and largely rural. However, the North West province is a mining province, which further complicates possibilities of acquiring land for agricultural purposes. The Eastern Cape, Western Cape and Northern Cape only possess 7, 9 and 6% of highly suitable land, respectively. Therefore, resettling communities in these provinces would not necessarily lead to food security and poverty reduction, as they are largely unsuitable.

Figure 7 shows the most unsuitable and 'unstrategic' pieces of land in South Africa which the government should not target as they would not lead to food security and poverty alleviation. Yet at times land acquisitions have occurred in areas unsuitable for agriculture (Bradstock 2006; Kepe and Tessaro 2014). This points to lack of sound land use management principles. It is often argued that South Africa focuses more on land use control as opposed to sound land use management principles informed by sustainable land use suitability practices. For example, the current policy of the Comprehensive Rural Development Programme (CRDP) to establish one mega agri-park per district is not guided by

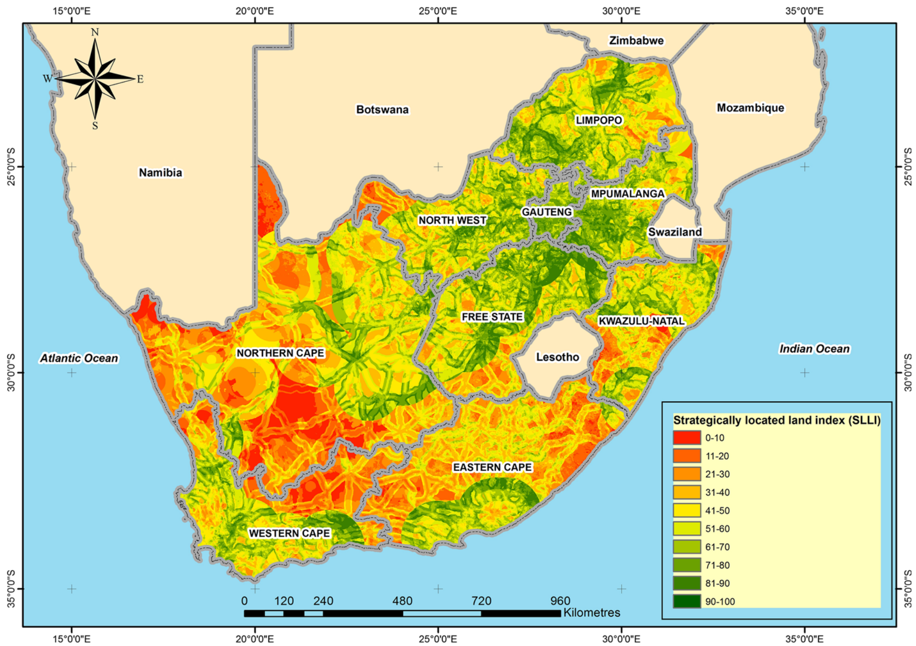

Fig. 4 Strategically located land index (SLLI) for agricultural land reform

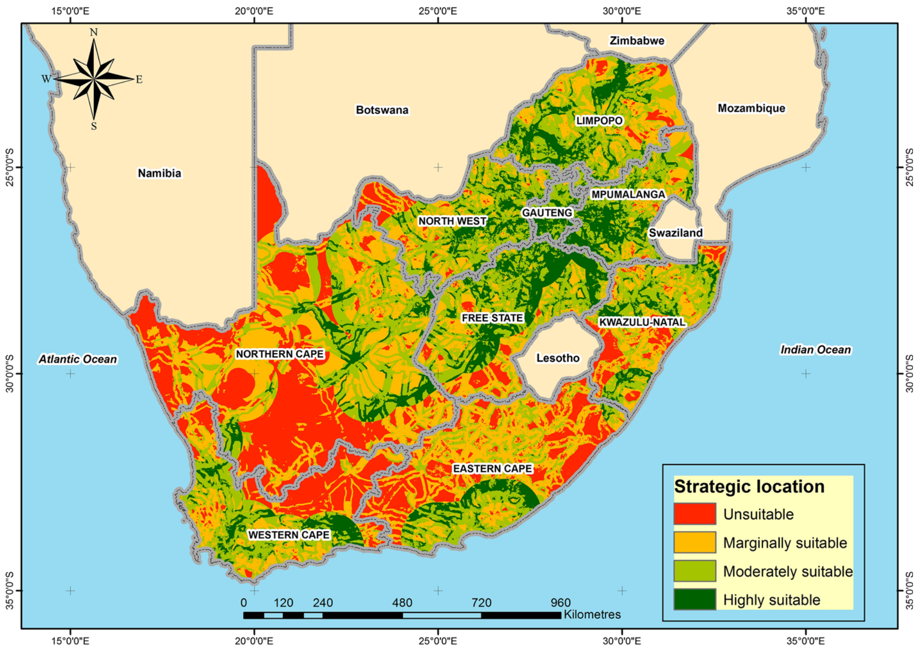

Fig. 5 Strategically located land index (SLLI) for agriculture according to suitability classes

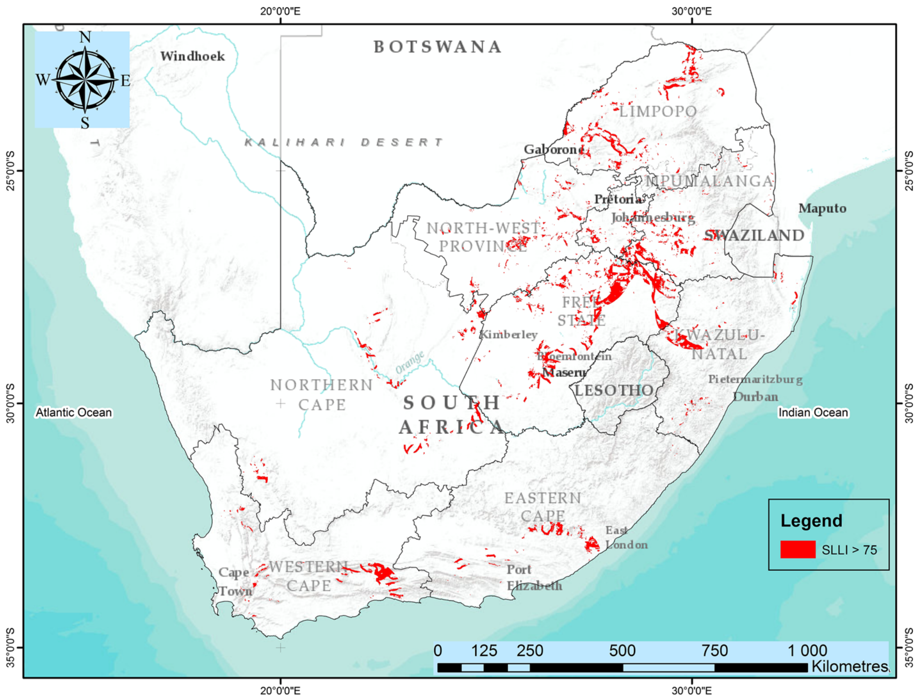

Fig. 6 Highly strategically located land for agricultural land reform (SLLI of >75)

Table 4 Agricultural suitability in South Africa

Suitability	Area (ha)	% Area
Highly suitable (SSLI <75)	23,288,299	15
Moderately suitable (SLLI 51–75)	50,085,499	32
Marginally suitable (SLLI 25–50)	48,443,104	31
Unsuitable (SLLI >25)	36,515,206	22

land suitability and management principles but loosely defined geographic and economic analysis that is largely desktop.

It should be noted that the SLLI only broadly classifies suitability for agriculture without specifying the type of agricultural activity. Therefore, there is need for further suitability analysis based on specific agricultural commodities such as wheat, livestock or fisheries. Nevertheless, the SLLI is a step in the right direction as it is objective unlike the current ad-hoc land identification strategies, which have not led to food security and poverty alleviation. Hall (2009) notes that land reform planning will ultimately need to be refined using maps that have the advantage of showing where redistribution is to happen and provide a guide for officials responsible for acquisition planning. Similarly, Bradstock (2006) notes that land being offered for resettlement is unattractive due to its poor productive potential. Therefore, the DRDLR and other government departments can use the SLLI as a tool for sustainable land use planning and land use management. Furthermore,

Table 5 Distribution of agricultural suitability per province

	Gauteng (% area)	Limpopo (% area)	Mpumalanga (% area)	North West (% area)	Free State (% area)	Eastern Cape (% area)	Western Cape (% area)	Northern Cape (% area)	KwaZulu-Natal (% area)
Highly suitable	67	21	37	23	33	7	9	6	14
Marginally suitable	3	30	20	26	24	43	32	35	32
Moderately suitable	29	44	38	42	36	20	24	21	34
Unsuitable	1	5	5	9	6	30	35	38	20
Total	100	100	100	100	100	100	100	100	100

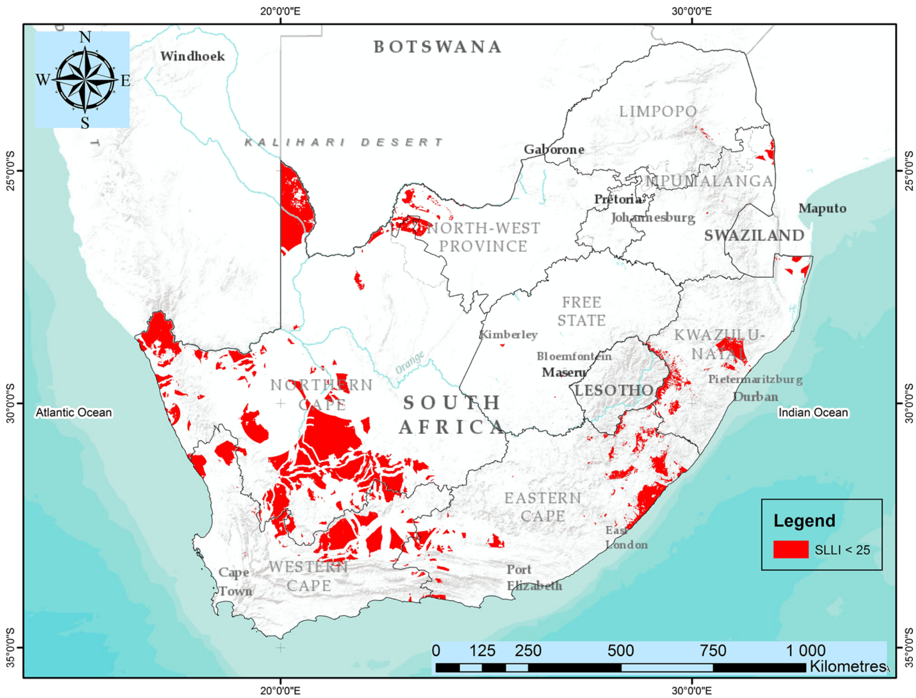

Fig. 7 Highly unstrategic land for agricultural land reform (SLLI <25)

the SLLI can be incorporated into policies and plans such as the National Development Plan as it broadly defines suitability and capacity of land based on physical and socio-economic factors. Perhaps, the time is nigh for the ruling government to realise that land reform as the panacea to food security and poverty alleviation, should not be politicised but based on sound objective criteria such as the SLLI and sound land use management principles. Similarly, instead of being consumed and aggressively creating wall-to-wall layout plans in rural areas under the recently promulgated Spatial Planning and Land Use Management Act (SPLUMA) which creates policy overload and often hampers development, the focus should rather be on suitability assessment using the SLLI which can inform what form of sustainable agricultural practices can be undertaken. Lastly, the SLLI creates a framework that enables the willing buyer (The State) to be a better informed and it can be used as a decision-making tool to guide expropriation as defined by the Expropriation Bill of 2016. Therefore, the SLLI is a useful tool in supporting the implementation of various legislation. The SLLI empowers the national government to be in a better position to negotiate with landowners to sell their land, and particularly to approach absentee landowners to negotiate leases and land-sharing agreements since the national government will be well informed on the suitability of particular piece of land. It should be noted that the SLLI is not a magic bullet and panacea in identifying land for land reform because land is such a contested space with many vested interests. For example, people can claim land that belonged to their ancestors irrespective of the land not being suitable for agriculture. In this case, land is viewed as a form of identity not for its potential for agriculture (Kepe and Tessaro 2014).

5.1 Strategically located land index viewer

The SLLI grid index was also deployed as a web application, developed in Adobe Flex. The landing page for the SLLI viewer is shown in Fig. 8.

The viewer unlike the raster-based information is vector based and it simplifies information to facilitate decision-making and increase usability. Furthermore, most managers at provincial level are familiar and work with vector (cadastral data) in their day-to-day activities. The SLLI viewer consists of two main layers containing both the agricultural index and human settlements index with supporting criterion (Musakwa et al. 2014). The main functionality of the SLLI viewer is the search function and reporting function. There are two main functions, namely the search by parcel key and detailed search. For the search by land parcel function, land managers search for a land parcel using the unique land parcel key. This search function collates the average index for a particular parcel as well as accompanying criteria that can be exported (pdf or excel) for further analysis (Fig. 9). The SLLI viewer also contains other constraint layers such as rocks, protected areas and servitudes that can be used to decide on the suitability of a land parcel.

Consequently, the SLLI viewer simplifies the daunting task of searching relative information on what land can be best used for. It makes available answers to key questions to be asked in order to make the decision on land use as it also contains supplementary datasets such as protected areas that can be used to query, overlay analysis and inform decision-making on land acquisition. Therefore, not only is the viewer useful in identifying land for land reform but it can be used as a standard tool in land use planning and management, thereby ensuring that government departments follow standard defined procedures unlike the current procedures which are not uniform across government departments.

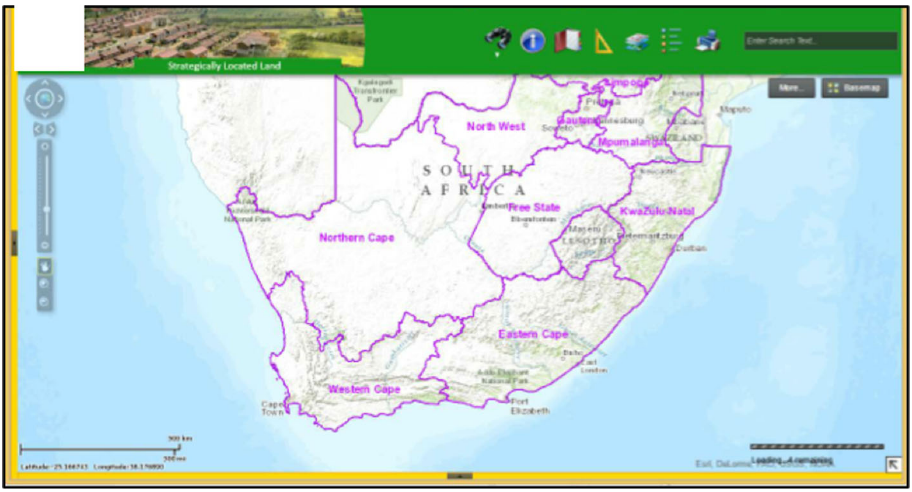

Fig. 8 SLLI viewer landing page

6 Lessons learnt, challenges and conclusion

Several challenges during the design and implementation of the SLLI also emerged. Firstly the SLLI viewer is a web-based application that is not readily available at provincial level, which could potentially lead to limited use of the SLLI as a land use management tool. Nevertheless, the SLLI grid, criterion used and ancillary data that can be used for querying were packaged into a geodatabase digital video disk (DVD) that was distributed to provincial managers and staff within the DRDLR. The geodatabase requires only ArcGIS software, which is readily available within the DRDLR, hence ensuring the SLLI will be utilised as a day-to-day land use management tool and the DVD requires minimal capital outlay, as capital is often an impediment to the use of GIS in developing countries (Klosterman 2001). In addition, further training particularly for non-GIS experts is required on how to navigate and query the SLLI geodatabase.

PARCEL KEY:	0000T0JR000000000549000120
PROVINCE:	GAUTENG
DISTRICT MUNICIPAITY:	City of Tshwane
LOCAL MUNICIPALITY:	City of Tshwane
WARD:	404

AVERAGE RAINFALL	601 - 800mm
AVERAGE MAXIMUM TEMPERATURE	31.1 - 35
AVERAGE MINIMUM TEMPERATURE	0.1 - 4
ELEVATION	800 - 1600 m
SOIL CLASSES	8
UNDERGROUND WATER QUALITY	< 70
NDVI (VEGETATION)	0.25 - 0.49
PROXIMITY TO RIVERS	< 5 km
PROXIMITY TO DAMS	> 10km
PROXIMITY TO MAJOR ROADS	< 3km
PROXIMITY TO RAILWAY LINE	< 5km
PROXIMITY TO SIPS	> 45 km
PROXIMITY TO EDC	< 15km
PROXIMITY TO ACTIVE MINES	< 30km

Fig. 9 Sample SLLI land parcel report

Similarly, users of the SLLI noted that criteria used to derive the SLLI broadly define agricultural suitability nationally. Nevertheless, future works that can delve into developing crop and/or sub-sector SLLI's such as livestock's or cereal are required. Another challenge is that the SLLI does not support scenario building at present as users can only query and obtain results for use. To improve functionally and relevance, the SLLI can be recomputed and updated regularly. For example, it is anticipated that data such as roads and vegetation change frequently; therefore, it becomes critical that the index be updated using such data.

It should be noted that the SLLI viewer is supposed to aid or facilitate decision-making not making the decision for the user (Geertman and Stillwell 2004; Geertman 2008). As a result, many supporting datasets that enhances querying were included. The SLLI is not the panacea to land acquisition and land use management; however, it goes a long way towards making sure that correct, appropriate, sustainable and suitable land parcels are acquired. It also ensures consistency and objectivity in land acquisition. Similarly, the success and application of the SLLI is heavily dependent on political will.

In conclusion, the suitability analysis shows that land strategic suitable for resettling people for agriculture is scarce. There are also competing objectives and interest (agriculture, mining and urban) as well as ownership that have to be circumvented first if land reform is to succeed in increasing agricultural production and promoting poverty alleviation. The study also demonstrates that the SLLI is particularly useful as a means to promote evidence-based land use management decisions and it can be tool used to support implementation of legislation. However, this is dependent on political support. Finally, the SLLI is a positive step in the right direction in entrenching sustainable land use management practices. However, it still requires undergoing a process of refinement and continuous updating so to remain relevant. Most importantly land suitability analysis for specific agricultural crops such as maize, sorghum and wheat which ensure should be developed.

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