

1 **The strategically located land index support system for human settlements land reform** 2 **in South Africa**

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4
5 Creating sustainable human settlements is fundamental in fostering spatial and socio-economic
6 integration in South Africa. Policy makers are often faced with the problem of identifying strategically
7 located land for human settlements land reform in South Africa. To date there is no tool or standard
8 framework that assists the government to identify land that is strategically located for land reform. This
9 study proposes the use of Geographic Information Systems (GIS), and Multi-Criteria Decision Making
10 (MCDM) to develop a Strategically Located Land Index (SLLI) deployed in a web viewer to identify
11 land that is smart for human settlements land reform. The study demonstrates that GIS, MCDM and the
12 SLLI are invaluable tools in facilitating streamlined, coordinated, standardised and evidence-based
13 decisions for human settlements land reform. However, there is need for capacity building in
14 government departments responsible for land reform and development planning for the SLLI to be fully
15 utilised.

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18
19 Key words. GIS-MCDA, land reform, located, SLLI, Human settlements,

20 21 22 **1 INTRODUCTION**

23 The development of cities and nations is underpinned by the existence of sustainable human
24 settlements. The quality and aesthetics of housing as well as its proximity to other related urban
25 amenities such as schools, road networks, places of worship and open spaces, and economic
26 opportunities form the bedrock of sustainable human settlements. In building houses, land
27 becomes ‘an up-front component’ (Huchzermeyer, 2003, Harrison, Huchzermeyer, &
28 Mayekiso, 2003). The availability and accessibility of land as well as its proximity or distance
29 from other supporting physical, social and environmental infrastructure determines both the
30 functionality as well as the desirability of cities.

31
32 In South Africa, the colonial and apartheid spatial planning practices deliberately created cities,
33 towns and homelands (Bantustans) fragmented on racial and ethnic lines (Harrison,
34 Huchzermeyer, & Mayekiso, 2003). The Natives Land Act No. 27 of 1913 and the Group Areas
35 Act 41 of 1950 prohibited Africans from purchasing or leasing land outside the homelands. As
36 a result, Africans were located in townships and hostels far removed from urban amenities such
37 as water, electricity, schools and places of entertainment. The so-called ‘white cities’ (i.e.
38 where white people resided) were well positioned spatially, and well serviced with amenities
39 needed for a fulfilled urban life. The fact that black townships were located far from areas with
40 economic potential rendered them not strategically located from a service delivery point of
41 view. Consequently, the current urban and housing challenges in South Africa have its roots in
42 the history of land dispossession and segregatory policies. Williams (2000) therefore argues
43 that the cumulative impact of these racially contrived planning frameworks resulted in South
44 Africa having “Islands of Spatial Affluence” in a “Sea of Geographical Misery. Therefore,
45 there is a strong need to identify land that is strategically located to ensure spatial and social
46 integration.

47 South Africa’s skewed land ownership patterns are further complicated by the global and local
48 calls for sustainable environmental planning (World Commission of Environment and
49 Development, 1986). The realities of climate change and the subsequent threats to food security
50 and development at large, requires the state and its developmental partners to preserve natural

51 capital. South Africa therefore finds itself in a space where demands for social justice at times
52 compete with international obligations for protecting environmental assets. Balancing the
53 relationship between poverty, inequitable access to resources, land reform and the protection
54 of biodiversity, remains a challenge to the South African government (Crane, 2006). The
55 creation of biodiversity and mega-reserves on one hand, and the demands for developments in
56 the built environment requires a scientific approach that can assist the state to ascertain the
57 best-possible land for these competing activities (Ramutsindela, 2003). Hence, the significance
58 of a geographic multi-criteria approach to land identification proposed herein.

59
60 A number of frameworks and legislations to support government developmental strategies
61 including land restitution and redistribution were introduced since the dawn of democracy in
62 1994 (Kepe & Tessaro, 2014). To accelerate the rate of land redistribution and restitution in
63 South Africa, the South African government seeks to follow a structured approach to land
64 acquisition. Cabinet decided in 2009 to implement the Comprehensive Rural Development
65 Programme (CRDP), and use it as a blueprint for land development and use. It was determined
66 that quality of land and its location are critical when acquiring land. Sector departments such
67 as, The Department of Rural Development and Land Reform (DRDLR) does not have a
68 guideline or framework that clearly outlines what land is referred to as “strategically located”
69 for establishing human settlements. Likewise, The Minister in the then Department of Land
70 Affairs noted that at least 50 per cent of government land reform projects have failed to make
71 their beneficiaries permanently better off (Centre for Development and Enterprise (CDE),
72 2008). Furthermore, the land reform had a rural bias without making a significant impact in
73 improving spatial integration in urban areas. Moreover, according to the National Development
74 Plan, there is a strong desire to create smart and sustainable human settlements. Similarly, some
75 land acquisitions where people have resettled have been un-strategic as there are little amenities
76 present (Bradstock, 2006). Identifying this strategically located land is more than formal,
77 nominal or constitutional validity (Williams, 2000). Therefore, the aim of this paper is to
78 propose a Strategically Located Land Index (SLLI) using Geographic Information Systems
79 (GIS) and Multi Criteria Decision Analysis (MCDA). This provides a powerful and smart
80 spatial decision support system that makes it possible to identify land that is strategically
81 located for human settlements land reform.

82
83 The remainder of the paper is structured as follows: a look into the state of Geographic
84 Information Systems and Multi Criteria Decision Analysis (GIS-MCDA) in spatial decision
85 support systems for land suitability followed by the methods, results and discussion on the
86 usefulness of the SLLI.

87 88 **2 GIS-MCDA IN SPATIAL PLANNING**

89 Various methods to identify land suitable for establishing smart human settlements exist. These
90 tools are even more useful in the 21st century where there are global problems such as climate
91 change, sustainable development, urbanisation and land reform in the developing world.
92 Numerous studies show that the lack of carrying out of land suitability analysis especially for
93 human settlements can result in degradable land and settlements not being smart (La Rosa et
94 al., 2014; Malczewski, 2006b; Pinto-Correia & Carvalho-Ribeiro, 2012; Puertas, Henríquez,
95 & Meza, 2014; Thapa & Murayama, 2008; Zhou, 2015). Using land unsuitable for such use
96 results in negative environmental costs (Lui et al., 2014). Assessing land suitability is crucial
97 as every portion of the landscape is characterised by a different set of features that render it
98 more suitable for certain uses than other uses (Heacock & Hollander, 2011; Kliskey, 2000;
99 Marull et al., 2007; Park et al., 2011; Pourebrahim, Hadipour, & Mokhtar, 2011).

101 Urban Planners have leveraged the use of GIS-MCDA in identifying land that is suitable to
102 establish communities and urban amenities (Hamzeh et al., 2015; Jelokhani-Niaraki &
103 Malczewski, 2015; Malczewski, 2006b). It is essential to combine GIS and MCDA in
104 developing Spatial Decision Support Systems (SDSS). Conventional MCDA techniques are
105 often non-spatial and assume that the area under analysis is spatially uniform. Consequently,
106 this makes MCDA unsuitable for spatial analysis and thus it is not suitable for urban planning.
107 Despite MCDA's potential to be integrated into solving urban planning problems related to
108 spatial entities, multi-criteria decision analysis remained in operational research and
109 management fields for a substantial period of time as decision support systems (Phua &
110 Minowa, 2005). It is only recently (last two decades 1990's and 2000's) as a result of improved
111 technological capabilities that MCDA has addressed spatial problems.

112

113 Similarly, GIS technology is inadequate in decision-making capabilities (Malczewski, 1999;
114 2003). It cannot fully address complexities associated with resource management issues such
115 as identifying strategic land for human settlements land reform (Laskar, 2003). Moreover GIS
116 has limitations in representing judgements, values, arguments, combining the decision maker's
117 preferences and heuristics into the problem-solving process (Jelokhani-Niaraki & Malczewski,
118 2015; Malczewski, 1999, 2006a, 2006b; Malczewski, 2006b). However, GIS remains a useful
119 tool for handling physical suitability analysis. Consequently, there is need of combining GIS
120 with other approaches used during land suitability analysis to create smart human settlements.

121

122 Concerning the specific literature on MCDA, a Scopus search returned 1286 articles whereas
123 when limited to GIS-MCDA 39 articles were found (Figure 1). There has been a significant
124 increase in the GIS-MCDA research since 1996 as a result of advances in the field of GIS and
125 MCDA, which makes integration possible. Integration frameworks combine GIS capabilities
126 of data acquisition, storage, retrieval, manipulation and analysis and the capabilities of MCDA
127 techniques for aggregating geographical data (spatial) data and the decision maker's
128 preferences into a one-dimensional value to make a decision (Hamzeh et al., 2015; Jelokhani-
129 Niaraki & Malczewski, 2015; Pourebrahim et al., 2011). Combining MCDA and GIS
130 techniques reduces complexity in the decision-making process. Effective multi-criteria
131 decision analysis in solving complex problems such as land reform is only possible with input
132 from GIS analysts, decision makers, and professionals in the spatial planning domain (Van
133 Niekerk, 2008).

134

135 [Insert Figure 1 here]

136

137 The increase in the volume of GIS-MCDA research can also be attributed to a number of
138 reasons. According to (Malczewski, 2006a), this was because of, first, a wider recognition of
139 decision analysis and support as an essential element of GI science initiatives on 'Spatial
140 Decision Support Systems (SDSS)', secondly the availability of low-cost and easy-to-use
141 MCDA software and mathematical programming techniques and thirdly, the proliferation and
142 availability of MCDA modules in such systems as IDRISI (Eastman et al. 1993).

143

144 Studies in which spatial decision support systems technology has been used for land
145 management are well documented in the literature. Arnold et al. (2000) designed specific tools
146 to address urban sprawl. These tools were designed to understand what effect land use change
147 has on water quality. Sanders and Tabuchi (2000) provided local planners in the United
148 Kingdom with an SDSS to analyse flood risk. Some spatial decision systems have been
149 developed as standalone programs, while others are solely web-based. These include the 'What

150 If?’ system (Klosterman, 2008) and the Wide Bay-Burnet Regional Information System
151 (WBBRIS) respectively (Pettit, Shy & Stimson, 2002). Petit et al., (2015) extended the ‘What
152 If?’ as an online tool that can be used for scenario building as well as a tool for walkability
153 analysis in neighbourhoods for Australian cities. Other systems have been developed mainly
154 to visualise potential spatial developments. Such systems include GAME and Key to Virtual
155 Insight (K2vi) (Geertman & Stillwell, 2004). GAME was developed to evaluate plan-based
156 scenarios on land development in New Jersey USA, whereas K2vi allows users to manipulate
157 and analyse two-dimensional and three-dimensional data within a virtual reality environment
158 to assist in sustainable urban design in Auckland, New Zealand. Likewise, Abdullahi et al
159 (2015) designed a GIS-MCDA to evaluate mixed land use development for a compact city in
160 Malaysia. Van Niekerk et al., (2016) used GIS-MCDA to develop a planning support system
161 to model growth potential in towns of the Western Cape province in South, Africa. Despite the
162 proliferation of GIS-MCDA tools in land suitability there are limited GIS-MCDA studies and
163 tools that have been explicitly developed to support and inform decisions regarding land
164 reform. Although esteemed institutes such as the Gauteng City Region Observatory (GCRO)
165 and African Centre for Cities (ACC) in South Africa have GIS systems, they hardly do focus
166 on land suitability and urban land reform in particular. Notwithstanding this, the GCRO, ACC
167 and Todes et al., (2015) are instrumental in stimulating robust debate in urban policy issues.

168

169 **3 APPROACH AND METHODOLOGY**

170 This section provides a step-by-step approach on how the SLLI for human settlements land
171 reform in South Africa was developed. Identifying land suitable for land reform is a complex
172 process. The approach taken to develop the SLLI involves using GIS-MCDA. A consultative,
173 participatory, anticipatory and collaborative approach was employed to improve user
174 acceptance within the DRDLR (Figure 2). The process involved criteria identification, criteria
175 weighting, mapping and assigning rule sets and generating the strategically located index. The
176 mapping, assigning of rule sets and computing of the SLLI was done using ArcGIS 10.2 and
177 the model builder tool in ArcGIS 10.2

178

179 [Insert Figure 2 here]

180

181 **3.1 CRITERIA IDENTIFICATION**

182 Criteria identification for identifying strategically located land was carried out through
183 participatory planning workshops (Figure 2). An initial workshop was conducted in September
184 2013, which consisted of professionals in government departments, consultants, and policy
185 makers. Most of these were officials from various sector departments such as DRDLR,
186 Economic Development, Human Settlements, Agriculture and Cooperative Governance and
187 Traditional Affairs. Selection of the criteria was guided mainly by national legislation and
188 policy documents such as the National Development Plan. The workshop resulted in criteria
189 which were grouped into seven broad themes namely proximity to Economic Development
190 Corridors (EDCs), proximity to Strategic Infrastructure Projects (SIP), proximity to
191 infrastructure, linkages to social amenities and markets, land with unique resources features
192 that provide a competitive advantage, vital infrastructure for social and economic development.
193 These themes produced over 60 criteria, which would make it impossible and complex to
194 develop a GIS tool. Accordingly, a core team comprising academic experts in GIS and town
195 planning, professionals such as Town Planners, GIS professionals, Environmentalists, built
196 environment professionals, Agronomists, Economists from various government departments
197 together with civil society were appointed to streamline the criteria. Literature and human
198 settlement guidelines were also consulted extensively in criteria selection (Bradstock, 2006;

199 Jelokhani-Niaraki & Malczewski, 2015; Marquet & Miralles-Guasch, 2015; Marull et al.,
200 2007; UNHABITAT, 2010; Van Niekerk et al., 2010). Consequently, the number of criteria
201 was reduced to 14 (Table 1) to make a well-informed decision and also to reduce complexity
202 and redundancy. Table 1 clearly shows that criteria relating to proximity have greater weight
203 because proximity dynamics have a wide array of positive outcomes which include; reduction
204 in vehicle emissions and improving the wellbeing of citizens (Marquet & Miralles-Guasch,
205 2015). Similarly, the criteria have to be logically sound and consistently relate to the objective
206 of identifying strategically located spaces for human settlements land reform. Likewise, the
207 workshop deliberations also made sure that criteria are realistic, transparent and simple (Saaty
208 1987).

209
210 [Insert Table 1 here]

211

212

3.2 CRITERIA WEIGHTING

213 During a sequel set of workshops with the core team¹ participants engaged in an Group
214 Analytical Hierarchy Process (GAHP) for weighting each criterion using a pair wise
215 comparison matrix for the 14 criteria (Malczewski, 2006b; Saaty, 1987; Satty, 1980). The
216 GAHP was chosen for comparing criteria, because it is a comprehensive method of
217 multicriteria decision analysis (Malczewski & Rinner, 2015). Consequently, the pair wise
218 comparison matrix asks how important one criterion is relative to another based on a 1-9 scale
219 (Table 2).

220

221 [Insert Table 2 here]

222

223 Workshop participants were given a template with 105 pairwise comparisons of the 14 criteria
224 to complete. This template was computed using the GAHP calculator by Goepel (2014).
225 Consequently, the participants used the GAHP calculator software to create an overall
226 weighting matrix, which involves synthesizing each of the individual's judgments and
227 combining the resulting priorities using a geometric mean (Malczewski & Rinner 2015). This
228 approach is better than the group consensus-reaching model because it relieves the group² of
229 the need for a moderator who may be biased, through the use of an automatic feedback
230 mechanism (Dong & Cooper, 2016; Grošelj et al., 2015). The pairwise matrix had a consistency
231 ratio of 0.025, which implies that there were no logical inconsistencies in the matrix. Similarly,
232 the sum of the weight for all the criteria should add up to 1(one) to ensure consistency.

233

234

3.3 MAPPING AND ASSIGNING OF RULE SETS

235 Mapping of the 14 criteria was divided into two parts (1) data collection and geodatabase
236 development and (2) developing rule sets for the each criterion. The spatial data was collected
237 from the DRDLR, the National Geospatial Inspectorate and other government departments.
238 This data was stored into a geodatabase, which was divided into themes, namely
239 environmental/physical and socio-economic GIS layers. This data was assigned
240 Hartebeesthoek_1994 Geographic Coordinates Systems. Rule-sets for each criterion were
241 identified from literature (Durand & Gonzalez-Feliu, 2012; Fafchamps & Wahba, 2006; Leite
242 et al., 2014; Marquet & Miralles-Guasch, 2014, 2015). Accordingly, maps for each criterion
243 were classified using suitability scale of -1 to 2 where 2 is highly suitable, 1 moderately suitable,

¹ Experts in GIS and town planning, professionals such as Town Planners, GIS professionals, Environmentalists, built environment professionals, Agronomists, Economists from various government departments together with civil society y.

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

244 0 marginally suitable and -1 unsuitable (Table 3). Assigning these rule sets enabled statistical
245 analysis using the Weighted Linear Combination (WLC) to derive the strategically located
246 index. In addition, the classification scale of -1 to 2 enables comparisons, normalisation and
247 simplifies interpretation of the results.

248

249 [Insert Table 3 here]

250

251 **3.4 GENERATING THE STRATEGICALLY LOCATED INDEX**

252 The WLC was chosen to calculate the (SLLI) where S_i total score of strategically located land
253 for a land unit is calculated using the following equation (1)³.

254

$$255 S_i = \sum_{i=1}^n W_i P_i \quad \text{Equation 1}$$

256

257 Where W_i of each criterion is calculated using GAHP, P_i represents value of each criterion
258 based on corresponding standards and n is the number of criterion. This approach was selected
259 because it is a risk averse and full trade off solution (Van Niekerk et al. 2016). Nevertheless,
260 when more control is required over the trade off one can apply the Ordered Weighted Average
261 (OWA) (Van Niekerk et al. 2016).

262

263 The final SLLI was a raster; however, for ease of use the SLLI values were extracted to points
264 and accompanying criteria justifying each point was attached using structured querying
265 language. The points were also converted to theisen polygons of 500m X 500m containing the
266 SLLI and accompany criteria to improve visualization. Lastly, these polygons were calibrated
267 or reclassified to improve usability using a range of 1-100 where 0-25 represents unstrategic
268 locations, 26-50 marginally strategic, 51-75 moderately strategic and 76-100 highly strategic
269 land to establish human settlements. Extensive validation and accuracy assessments were also
270 carried out to determine if the SLLI and accompanying criterion corresponds. The theisen
271 polygons were later plugged into the SLLI web viewer that managers could use as a SDSS.

272

273

274 **4 RESULTS AND DISCUSSION**

275 Figure 3 shows the strategically located land index for human settlements land reform while
276 Figure 4 shows strategic location for human settlements land reform according to strategic
277 location (suitability classes). From Figure 3 it is clear that land strategic for human settlements
278 (SLLI of 60-100) is mostly located along activity corridors and close to urban areas. Gauteng
279 and Mpumalanga provinces possess the majority of land; however they are also the two
280 smallest provinces in the country. It is necessary for the DRDLR and managers to identify land
281 for human settlements using the SLLI so as to ensure that people are resettled where there are
282 necessary supporting services and also avoid mistakes of the past where people were settled
283 far away from economic opportunities. Moreover, the SLLI can be used to make comparisons
284 and motivate decisions objectively, unlike the current ad-hoc and subjective manner of
285 acquiring land.

286

287 [Insert Figure 3 here]

288

³ The summation using weighted linear combination (WLC) was chosen because it can easily be applied within a GIS environment using map algebra operations and the approach is also intuitively appealing to decision makers (Malczewski & Rinner 2015).

289 In Kwa-Zulu Natal (KZN) the highly strategic land in a dark green shade (SLLI 90-100) is also
290 along development corridors. Likewise, the most strategic land in the Eastern Cape is in the
291 central Eastern Cape. Similarly, in the Western Cape the most strategic land is on the Western
292 Cape seaboard and in the South Western Cape known for their picturesque vineyards.

293

294 [Insert Figure 4 here]

295

296 Table 4 gives an overview of the amount of strategic land available to establish human
297 settlements in South Africa. Only 7% of the country is highly suitable (SLLI of > 75) for human
298 settlements and 18% moderately suitable. These areas have to be targeted, as they are highly
299 accessible, already contain infrastructure and services as well as supporting land uses. This also
300 confirms the high disparity in South Africa as only few areas are well endowed (Bradstock,
301 2006). This will most likely lead to further densification and congestion in already established
302 areas, which can ultimately lead to inability to promote sustainability and smart cities. The
303 question therefore becomes, can more growth in these areas be sustained or should growth be
304 channelled elsewhere? Perhaps a paradigm shift in the county is required which focuses on
305 high-rise and high-density buildings as opposed to owning a land parcel.

306

307 Forty six per cent of the country is largely unsuitable for human settlements. This poses a
308 challenge in distribution of resources and can have implications in migration patterns as well
309 as hampering plans of creating smart cities. As a result, areas such as Cape Town, Durban and
310 Johannesburg continue to receive migrants and are plagued with service delivery issues and
311 these cities are known to be hotspots for service delivery protests (Tapela, 2013). This may as
312 well suggest that metropolitan cities in South Africa have reached a tipping point.

313

314 [Insert table 4 here]

315

316 It should be noted that the suitability for human settlements land reform is not evenly
317 distributed within the provinces (Table 5) further highlighting the inequalities in South Africa
318 20 years after independence.

319

320 [Insert Table 5 here]

321

322 Gauteng contains the largest (69%) of highly suitable land for human settlements per province,
323 because it is the country's economic hub, highly urbanised area and yet it is the smallest
324 province in land size (Statistics South Africa, 2011). Continued resettling of people in Gauteng
325 is less costly as Gauteng contains infrastructure and services suitable for human habitation.
326 However, there should be caution as pressure on Gauteng will result in congestion,
327 overcrowding, and damage to the environment and strain on services which can lead to reduced
328 carrying capacity if necessary improvements and adjustments are not made. Gauteng is also
329 identified as highly suitable for agriculture (Musakwa et al. 2014); therefore there is conflict
330 between resettling for agriculture and or human settlements. Consequently, there has to be a
331 tool that facilitates decision-making amongst competing objectives.

332

333 Kwa Zulu-Natal contains 30% of highly suitable land and offers a better solution than Gauteng,
334 as it is much larger and also contains infrastructure and services necessary for human
335 habitation, particularly along the coast. The Eastern Cape, Western Cape and Northern Cape
336 are generally harsh environments mainly due to climatic reasons as they have 53%, 57% and
337 70% of unsuitable land. The highly suitable land in the Cape provinces is mostly along activity
338 corridors and already established towns along the coastline. For example, the City of Cape

339 Town receives migrants from the Cape provinces as a result of its suitability and strategic
340 location (Kok & Collinson, 2006). This is mainly because the neighbouring provinces
341 (Northern Cape and Eastern Cape contain only 1% and 2 % of highly suitable land. Perhaps
342 there is need to attract investment and to channel development in these areas to improve
343 suitability for human settlements and minimise migration to other provinces.
344

345 It is important to note that the above statistics and maps are indicative of where to target areas
346 for land reform to establish human settlements. The SLLI therefore provides a scientific
347 procedure of targeting land for human settlements as opposed to the current ad hoc systems
348 (Hall, 2009). The objective of this study is to propose using GIS-MCDA, a technique that is
349 scientifically grounded in systematically identifying land for human settlements. This is unlike
350 the current systems available at the Housing Development Agency (HDA) that are small scale,
351 which do not employ a structured GIS-MCDA. Furthermore, with the SLLI undesirable and
352 disastrous consequences under the Reconstruction and Development Program (RDP) that
353 established human settlements far away from infrastructure, economic opportunities and
354 services can be avoided. Land reform ultimately needs to make its beneficiaries better off
355 (CDE, 2008). Little or nothing is gained in the long run if justice turns out to be purely
356 symbolic, leave people poorer, or even worse off (CDE, 2008). Accordingly, the SLLI is crucial
357 to complement the political aspect of land reform as it makes sure that land used is suitable for
358 human settlements land reform, leads to spatial integration, densification, does not perpetuate
359 poverty as well as enabling access to opportunities. Tshikotshi, (2009) notes that the post-
360 apartheid government's resettlement programme still locates the urban poor households on the
361 peripheries of the cities, a pattern similar to the apartheid era. Therefore, in light of this, the
362 SLLI can be viewed not only as a technical tool but an enabler that ensures that mistakes of the
363 past in land identification and settlement creation are not repeated as well as ensuring the
364 potential of urban areas is maximised when people, jobs, livelihood opportunities and services
365 are aligned (Integrated Urban Development Framework, 2014).

366

367 It should be recognised however that deciding on a piece of land is an optimising procedure,
368 as other factors have to be taken into account. For example the carrying capacity, land uses,
369 dolomite status, conservation, spatial targeting and issues of global climatic changes.
370 Accordingly, the SLLI was deployed on an ArcGIS server to aid in decision-making.

371

372 **4.1 SLLI VIEWER**

373 The SLLI was deployed as a web application, developed in Adobe Flex and works across
374 browsers with a flash plug-in. This is the first step in centralising and coordination of
375 information within the DRDLR and across government departments. Unlike the raster-based
376 information it is vector based and it is meant to simplify information to facilitate decision-
377 making and increase usability. Moreover, most managers at provincial level are familiar and
378 work with vector (cadastral data) in their day-to-day activities. The SLLI viewer consists of
379 two main layers containing both the agricultural index (Musakwa et al., 2014) and human
380 settlements index with supporting criterion. The purpose of the SLLI viewer is to simplify the
381 daunting task of searching relative information on what land can be best used for. The solution
382 makes available answers to key questions to be asked in order to make the decision on land
383 use.
384

385 Figure 5 shows the SLLI viewer-landing page.

386

387 [Insert Figure 5 here]

388

389 The main functionality of the SLLI viewer is the search function and reporting function. There
390 are two main functions, namely the search by parcel key, and detailed search (Figure 6). For
391 this function Land Managers can search for the index overlaid on national cadastre wherein
392 decision makers can search for a land parcel using the unique land parcel key known as the 21
393 digit code (Figure 7). Once the search is completed it collates the average index for that
394 particular parcel as well as accompanying criteria. The viewer also has a reporting functionality
395 that allows users to generate pdf reports and Excel file for further analysis (Figure 8).

396

397 [Insert Figure 6 here]

398 [Insert Figure 7 here]

399

400 In addition, the detailed search allows users to search for SLLI for human settlements using
401 attributes that are used to filter to the necessary land parcel. This also allows minimizing the
402 results to be returned for reporting and to improve performance on the viewer. Province,
403 District Municipality, Local Municipality are compulsory fields to select before a user can
404 search. These fields are also used to narrow the search to a subset of data and zoom into the
405 area selected.

406

407 [Insert Figure 8 here]

408

409 The SLLI viewer also contains standard functions such as, identification and measuring tools
410 that can enhance the decision-making process. The SLLI viewer compares well with planning
411 support systems such as the What If? (Petit et al, 2015) in that it is built for Planners. However,
412 the SLLI does not support scenario building like the What If? system. Therefore, in future,
413 there is potential to include scenario building, which would improve the functionality of the
414 tool. Furthermore, both systems (SLLI and What If?, are policy oriented, collaborative systems
415 and utilise cadastral data at a local level which most Planners are familiar with. Additionally,
416 the interface of the SLLI viewer is simple and developed in consultation with the planners to
417 improve user acceptance (Geertman, 2008). Unlike other sophisticated systems such as
418 WBBRIS, the SLLI has potential to be deployed in other developing countries battling with
419 land reform as the SLLI employs replicable standard GIS-MCDA processes. Likewise, there
420 is scope for use of the SLLI not only in human settlements land reform but also as an enabler
421 in sound land use management as what the Spatial Planning and Land Use Management Act
422 (SPLUMA Act of 2013) envisages.

423

424

425 **4.2 LESSONS LEARNT AND CHALLENGES**

426 The SLLI viewer has several limitations. Firstly it is a web-based application, only accessible
427 at the DRDLR head office. This can lead to the SLLI system not being readily used throughout
428 the country. A solution is packaging all the data used, the SLLI grids, and supporting data that
429 can be used for querying into a geodatabase digital video disk (DVD). This can then be
430 distributed to managers at provincial level to start using the SLLI tool to assist them in
431 identifying strategically located land. Moreover, the geodatabase requires only ArcGIS
432 software that is available within the DRDLR and other government departments. This will
433 mean that the SLLI will be employed more for day-to-day decision-making, as it will not be
434 dependent on the viewer, and it also requires minimal capital outlay, which is often an

435 impediment to the use of GIS in developing countries (Klosterman, 2001). Further training
436 perhaps is needed to train particularly non-GIS experts on how to navigate and query the SLLI
437 geodatabase. Distributing, training and usage of the SLLI geodatabase will mean
438 decentralisation of functionally and it will also be part of capacity building. Managers will be
439 able to make quick decisions instead of relying on the head office.

440

441 Potential users of the SLLI pointed out that the criteria are broad as they are to be utilised for
442 a national geospatial tool to identify strategically located land for land reform for human
443 settlements. However, it was established that there is potential to develop specific sub-criteria
444 for various land uses in cities such as industrial uses and recreational uses. Consequently, there
445 would be a need to develop new tools or viewers that are context specific such as for industry
446 use or recreation. Nevertheless, there was broad consensus that the SLLI is a huge step towards
447 improving identification of strategically located land. Another challenge common to
448 developing countries is the access and availability of data. As a result users are advised not to
449 alter the current state of the SLLI viewer or the desktop package. Users can only query and
450 obtain results for use. However, with time, when required the SLLI index can be updated using
451 new data obtained. For example, it is anticipated that in the future data such as roads and towns
452 are to change, therefore it becomes critical that the index be updated using such data.

453

454 Similarly, it also emerged that there were over-expectations as some users deemed the SLLI as
455 a tool that is supposed to make the decision for them. It should be cautioned that the SLLI
456 viewer is supposed to aid or facilitate decision-making not making the decision for the user
457 (Geertman & Stillwell, 2004). As a result many supporting datasets that enhances querying
458 were included. The SLLI is not the panacea to land acquisition. However, it goes a long way
459 towards making sure that correct, appropriate, smart and suitable land parcels are acquired. It
460 also ensures consistency and objectivity in land acquisition

461

462 An additional challenge faced was creating a common ground as well as the need to provide a
463 history of how the SLLI was developed, explaining what it can and what it cannot do. Overall,
464 the users generally acknowledged the utility of the SLLI during the training workshops.
465 However, key issues that have to be solved are capacity and management constraints. Some
466 users indicated that they are not familiar with spatial decision support systems and GIS.
467 Consequently, they found the system intimidating which may hamper its use. This scenario is
468 not only common within DRDLR, but in other government departments and developing
469 countries (Göçmen & Ventura, 2010)

470

471 Another issue that was identified is the issue of propriety where it was identified by users that
472 the SLLI could be useful for various government departments with a stake in planning for
473 cities, as the SLLI would add value in their operations. The SLLI viewer has been
474 identified that it could be potentially useful for the Housing Development Agency (HDA).
475 However, at present, functionality across government departments is not available as it is
476 strictly proprietary to one department. Sharing information across departments has been cited
477 as an impediment to the development process (Klosterman, 1995, 2001). Perhaps other
478 departments can make arrangements, as this will greatly facilitate coordination and
479 streamlining of decision-making, which will ultimately lead to efficient utilisation of resources
480 and creation of smart cities. Similarly, a challenge with the SLLI is that it was developed at
481 national level, which possibly implies that municipal powers are usurped and it may mean
482 unwillingness of local government to utilize the SLLI. Therefore, it requires coordination
483 between national and local governments for successful implementation and buy-in.
484 Nevertheless, the political, administration and operational challenges of universal use in

485 government departments is hampered by political interest, operational deficiencies, and general
486 lack of tools to ensure meaningful coordination and successful implementation of land use
487 management tools in South Africa and Africa in general. Ultimately the successful
488 implementation of the SLLI depends on the interaction of macro-level processes with local-
489 level factors, overlapping legal and governance frameworks and, power relations (Lombard,
490 2015)

491

492 Despite the identified technical, operational and political challenges, the SLLI has been
493 generally accepted as a useful tool in identifying land for land reform. However, the success of
494 the land reform program goes beyond using a tool, as concerns of pressure groups with vested
495 interests have to be navigated. The continued success and implementation of the SLLI rests on
496 political buy-in from various stakeholders. Currently, it appears that the SLLI has weathered
497 some of the political storms as it is used as a standard tool within the DRDLR to identify land
498 for acquisition and as a general land use management tool. We also acknowledge that
499 politically connected people who can delay the adaptation of sound land use management tools
500 to their advantage may hamper the universal use of the SLLI.

501

502 **5 CONCLUSION**

503 This study aimed to develop tools that help identify land suitable for human settlements land
504 reform. A consultative and participatory process using GIS-MCDA was utilised to develop the
505 SLLI. A key component of the SLLI is that it enables streamlining and better decision making
506 based on a scientific basis, unlike the current systems. Consequently, the SLLI can assist
507 through acquisition of appropriate land, which enables creation of smart cities. The SLLI can
508 also be adapted and applied in countries with land reform problems. Similarly, the SLLI can
509 be applied to solve other problems such as identifying land potential. However, the SLLI
510 viewer only guides but does not make the decision. Other factors such as government policy,
511 human judgment and internal process have to be taken into cognisance. Lastly, a multitude of
512 challenges such as capacity issues and political interests have to be navigated for the SLLI to
513 be fully used in practice. Nevertheless, it is a step in the right direction towards a more
514 structured process in establishing human settlements to ensure that cities are smart and liveable
515 for all.

516

517

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