

1 *Type of the Paper (Article)*

2 **Survey of community livelihoods and landscape**
3 **change along the Nzhelele and Levuvhu river**
4 **catchments in the Limpopo Province, South Africa**

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28 **Abstract:** Landscape change studies have attracted increasing interest because of their importance
29 to land management and sustainable livelihoods of rural communities. However, empirical studies
30 on landscape change and its drivers are often poorly understood, particularly, in small rural
31 communities in developing countries such as South Africa. The present study surveyed local
32 community livelihoods and perceptions of landscape change in the Nzhelele and Levuvhu river
33 catchments in Limpopo Province, South Africa. These areas have experienced land reform and are
34 also characterized by environmental degradation, poverty, inequality and environmental justice
35 concerns among other issues. Land cover maps derived from Landsat satellite imagery were used
36 for purposes of correlating and validating the survey data findings and results. The survey results
37 showed that education levels, working status and marital status have statistically significant effects
38 on community livelihoods (indicated by levels of income, $p < 0.05$). Maize, fruits and vegetables are
39 the main cultivated crop varieties in the study area, and these crops are mainly used for subsistence
40 to meet household self-consumption requirements. Besides, local community members and
41 stakeholders argue that the landscape has changed over the past 20 years mainly as a result of urban
42 expansion, deforestation, agricultural diversification and forestry intensification. These landscape
43 changes were largely confirmed by the land cover change maps derived from satellite imagery. Soil
44 erosion as a result of landscape changes was identified as a major threat and hazard in the study
45 area. Political, natural, economic and cultural factors have been identified as the major underlying
46 drivers for the observed landscape changes. These results have implications for understanding
47 landscape change, coupled with human nature relationships as well as informing government

48 policy with respect to advancing land management and further promotion of sustainable
49 livelihoods of rural communities. Overall, the study proposes a multiple stakeholders' approach
50 and ecosystem-based approach to promote the sustainable management of landscapes in rural
51 areas.

52 **Keywords:** Landscape change; livelihoods; sustainable development; subsistence agriculture;
53 South Africa

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55

56 1 Introduction

57 Landscape is referred to as the prime sphere where the combined effects of society and nature
58 become visible and the interactions between spatial patterns and ecological process are reflected [1].
59 Historically, landscapes have been shaped and maintained by human activities over generations
60 including in the recent millennia [2, 3]. In the context of global environmental change, landscapes
61 worldwide have experienced changes at increased magnitudes over the past decades [4] (partly due
62 to urbanization, agricultural intensification etc.). Studies on the causes, dynamics and consequences
63 of landscape change have attracted increasing interest because of their implications with respect to
64 sustainable development, food security as well as livelihood systems and adaptation options [5].
65

66 The concept of Drivers-Pressures-State-Impact-Responses (DPSIR) has been widely used as a
67 framework for understanding the causes, dynamics, and consequences of landscape change [3, 6].
68 Among the causes of such changes are socioeconomic, political, technological, natural, and cultural
69 reasons [7-10]. However, a comprehensive understanding of the drivers of these changes remains
70 challenging, as it is difficult to quantify anthropogenic factors [3, 6, 11]. Moreover, landscape change
71 often leads to a series of positive or negative feedback effects on both social and ecological systems,
72 thus adding a further layer of complexity in quantifying the drivers of landscape changes in any area
73 [12-16]. However, enhanced knowledge and understanding of the consequences of landscape change
74 is fundamental for land administration and management. This is because such knowledge and
75 understanding acts as a tool in clarifying ecological processes and impacts on socio-ecological
76 systems, thereby providing valuable scientific indicators that can be used in suggesting steering
77 mechanisms in the quest to achieve the sustainable developmental goals (SDGs) [17, 18].
78

79 The landscape sustainability notion and concept refer to the capacity of a landscape to
80 consistently provide long-term, landscape-specific ecosystem services essential for maintaining and
81 improving human well-being. This has recently been subjected to questioning with regards to the
82 adequacy of the concept in fully unpacking the complex nature of landscape changes [19, 20]. It is
83 therefore at risk as a framework for studying and exploring landscape changes [21-26]. In South
84 Africa, the reality of the growing demand for food amidst a background in which there is rapid
85 population growth of approximately 2 % per annum has raised the question of landscape changes in
86 respect of food security and livelihoods high on the national agenda. This is because people in rural
87 areas rely mainly on land and natural resources for their livelihoods. Achieving food security and
88 guaranteeing livelihood security in the context of intensive farming, overharvesting, and land reform
89 as factors that are driving landscape changes or even degradation becomes both an opportunity and
90 challenge in land administration and management [27-30]. These issues collectively become very
91 concerning taking into account that soil erosion is also considered as a pernicious threat to land
92 productivity and water resources in South Africa [31-34]. Yet, the paradox is that empirical studies
93 on landscape change, drivers and consequences highlight how these matters are often particularly
94 poorly understood in small rural communities of South Africa. This therefore justifies the need to
95 focus on promoting the sustainable management of landscapes in rural areas.
96

97 Traditionally, studies on landscape changes usually focus on the change in spatial patterns based
98 on multi-temporal satellite imagery with little consideration of the local community's perceptions
99 [35-37]. This is despite the fact that humans actually respond to landscape changes, which acts, and
100 impact on socio-ecological systems. Consequently, combining cartographic studies and social
101 research methods leads to better comprehension of landscape change [38]. The effects of human
102 behavior on landscapes can be influenced by the community perception of landscape change [39, 40].
103 For example, human beings can modify nature through overharvesting natural resources (e.g.,
104 because of agricultural expansion, deforestation, water extraction etc.). These consequences are a
105 manifestation of the need for survival and development by a community. In this livelihoods interplay
106 set-up, it is not uncommon for negative environmental issues and outcomes to emerge that threaten
107 rural livelihoods[41]. This is despite concerted attempts by human beings to promote environmental
108 protection and ecological restoration through behavioral stimuli aimed at rational actions and
109 interventions [42, 43]. Hypothetically, in order to unify nature and human interactions, it is important
110 to synthesize local community perceptions of landscape change and its drivers with the broader
111 sustainable environmental planning and management requirements [41, 44-49]. Therefore, a study
112 that investigates landscape changes and the possible drivers and effects from the perspective of socio-
113 psychological or community perception is particularly desirable in South Africa.

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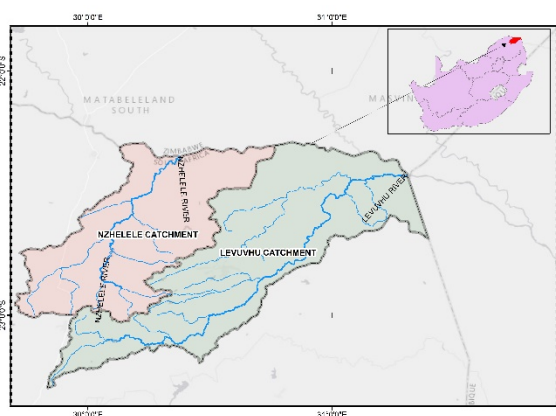
115 The present study consequently surveyed local community livelihoods and perceptions on
116 landscape change in the Nzhelele and Levuvhu river catchments in Limpopo province, South Africa.
117 Our study has the following specific objectives: (1) to survey local community livelihoods; (2) to learn
118 about the perceptions of local communities to landscape change including identifying the drivers for
119 such change and comparing these results with land cover maps derived from satellite imagery; (3) to
120 understand the ecosystem services provided by nature and (4), to glean the impacts of climate change
121 on the landscape, ecosystem services and livelihoods. By this, we aimed to identify knowledge gaps
122 on how local community perceptions contributes to the understanding and management of
123 landscape change for rural land use planning and administration.

124

125 2 Materials and Methods

126 2.1 Site selection and sampling procedures

127 The data collection was conducted in Nzhelele and Levuvhu river catchments in Limpopo
128 province, which is located in the northern tip of South Africa (refer to Figure. 1). The Nzhelele and
129 Levuvhu river catchments were specifically selected because of their significant agricultural and
130 economic importance and because they have experienced land reform and agricultural expansion
131 leading to landscape changes [32, 50]. Thus, the study area is a very typical and representative
132 example for investigating landscape change and its drivers in South Africa.



133

134 Figure. 1 Location of study area

135

136 The data was obtained by making use of a household survey. Before this, we consulted with the
137 local Chief and headman who gave us approval to conduct the survey in the Nzhelele and Levuvhu
138 catchments. During the data collection, we were always in the company of a local and community
139 stakeholder. The questionnaire was designed and piloted in April 2019, and adjustments were based
140 on feedback from the pilot tests. Face-to-face questionnaire interviews were conducted with 160
141 randomly selected people during July 2019. Ninety-one females (57%) and 69 males (43 %) with ages
142 ranging from 18 years to above 60 years took part in the survey. From the Levuvhu catchment, we
143 selected households in the Mulenzhe, Tshakhuma, Ha-Peitboy and Mutele communities and
144 surrounding areas whereas for the Nzhelele we sampled the Musekwa, Ha-Mandiwana, Ha-Rabali
145 communities and surrounding areas. Ninety respondents were selected from the Levuvhu catchment
146 and seventy from the Nzhelele catchment. In collecting data, we were assisted by a community
147 gatekeeper who would explain the aims and objectives to potential respondents so that we could
148 identify the respondents with knowledge on the four themes of our study namely, livelihoods,
149 landscape change, ecosystem services and climate change in the area. Hence conducting of the
150 interview would only commence when a potential respondent would confirm their knowledge on
151 the themes of the study. Ten local research assistants were recruited and trained, and they assisted in
152 collecting the data since the questions were asked in Venda, the local vernacular language to glean
153 better information. The research assistants would explain what livelihoods, landscape change and its
154 drivers, ecosystem services and climate change are, to foster better comprehension by the
155 respondents. Furthermore, the assistants would give examples when explaining the various themes.
156 Before the survey was carried out, ethical clearance, community approval and informed consent
157 forms were secured from the respondents. In addition, all respondents were informed that the
158 research was an academic project, and that information they gave would be kept confidential and
159 anonymous at all times. The interview questionnaire contained items in which respondents were
160 asked about their demographic and socio-economic characteristics, livelihoods and their perceptions
161 on landscape change and its drivers. They were also questioned about climate change and its impacts,
162 the availability and quality of ecosystem services, their views on soil erosion, and local people's
163 willingness to participate in initiatives to mitigate and combat negative landscape changes in their
164 areas. Completing the thirty-three questions in the questionnaire took on average thirty minutes with
165 each respondent.

166 2.2 Statistical analysis

167 All statistical analysis was performed in SPSS 19.0 software. We assumed income as a measure
168 of livelihood. Data were subjected to both analysis of variance (ANOVA) and descriptive statistical
169 analyses. Where ANOVA showed significant differences, means were separated by Tukey's Honestly
170 Significant Difference (HSD) test at 5 % significance level. ANOVA was used to detect significant
171 differences in income between males and females, and amongst different age groups, marital status,
172 working status and educational levels [51, 52].

173

174 2.3 Land cover mapping and analysis

175 Landsat 6 and Landsat 8 satellite imagery for 1999, 2008 and 2018 were obtained from The United
176 States Geological Services (USGS). Landsat was chosen because it is the satellite with the longest earth
177 observing history. The satellite images were ortho-rectified and subjected to atmospheric and
178 radiometric corrections using ArcGIS 10.5 [53, 54]. Land cover for both images was classified and
179 quantified using a pixel-based random forest supervised classification in ArcGIS 10.5. Random forest
180 was chosen because it is robust, efficient, and produces better results as demonstrated in other studies
181 [53, 54]. Training samples were used to train the images for classification. The images were classified
182 into six land use types namely: water, bare land, vegetation, settlements, grassland and cropland. The

183 classification was verified by extensive field visits and the use of Google Earth [55]. The overall
 184 accuracy of the classification was 82%, with a producer accuracy of 84% and a user accuracy of 81%.

185

186 After the land cover mapping, the following step was calculating the landscape change index
 187 (LCI) [38, 56-58]. To do this we had to calculate the transformation of each land cover type in
 188 percentages as shown in equation (1) below.

$$CA = 100 \times (A_{t+1} - A_t)/TA \quad (1)$$

189 wherein CA_i signifies changes in percentage share of areas covered by each land cover class in
 190 relation to the total area of study area (%); A_{t+1} is the area covered with each type of land cover during
 191 the time interval $t + 1$ (ha); A_t represents the area covered with each type of land cover during the
 192 time interval t (ha); and TA represents the total study area (ha). The CA enabled us to compute the
 193 Landscape Change Index for each time-period. The LCI shows the absolute change for each land
 194 cover type during separate time intervals[58]. The LCI was calculated by multiplying a factor of one-
 195 half by the sum of the absolute values of change in percentage share of areas covered by each land
 196 type cover in relation to the whole analyzed for each period of time. The formula for LCI is given
 197 below [38, 56, 57].

$$(LCI = \frac{1}{2} \times \sum_{i=1}^n |CA_i|$$

wherein LCI_t is the landscape change index at a given time period; and $|CA_i|$ signifies changes (2)
 in percentage share of areas covered by each land cover class in relation to the total area of study
 area

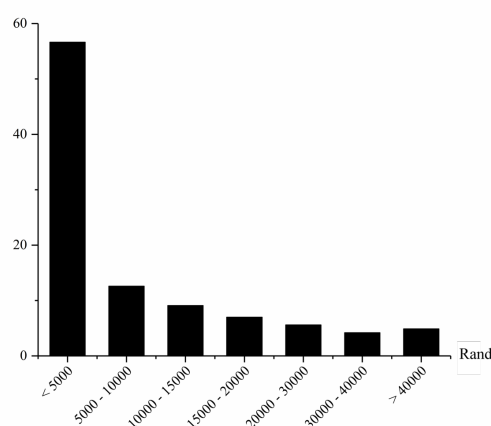
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200 3 Results and discussion

201 3.1 'Socio-demographic characteristics and livelihoods

202 Figure 2 shows that the Nzhelele and Levuvhu river catchments are characterized by poverty,
 203 where the majority of the people earn less than 5 000 South African Rand (ZAR) a month (equivalent
 204 to United States Dollars \$ 350) with an overall household income of ZAR 50000 per annum [59] which
 205 is classified as poor [59]. The low incomes are as a result of unemployment in the study area (Figure
 206 3).



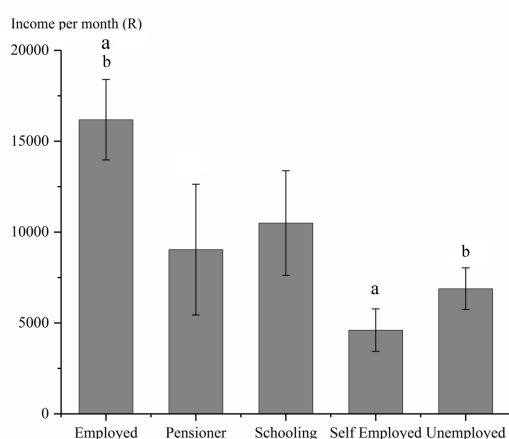
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Figure. 2 Income levels in the Nzhelele and Levuvhu river catchments

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Figure 3 Relationship between income and employment levels in the Nzhelele and Levuvhu river catchments

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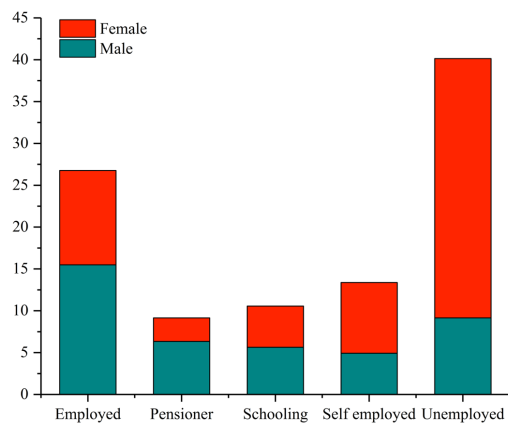
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Furthermore, the rest of the residents either depend on pensions, are currently in schools or depend on social grants (Figure 3). This points to high poverty levels that still persist in South Africa 25 years into democracy. These high poverty levels are a threat to the attainment of social cohesion and the SDG 1 goal of achieving no poverty by 2030 [29]. The high levels of poverty and lack of meaningful livelihoods often lead to the exploitation of the natural environment as a means of livelihood, and this shows the link between society and nature. For example, overfishing and cutting down of trees for purposes of selling firewood is a common practice in the Nzhelele and Levuvhu river catchments. Overall, employment status has a significant effect on people's income based on the ANOVA analysis, especially among employed, self-employed and unemployed ($p < 0.05$, Figure 3). Poverty in the area also has a gender bias, meaning that gender significantly affects people's income (Figure 5). There are fewer females who are employed, who are pensioners, who are in schooling and who are more self-employed compared to males (Figure 4). Females also earn less than males (Figure 5). This predicament reinforces the local patriarchal culture prevalent in the area, where males are often afforded education and other opportunities at the expense of females [29, 60] (Figure 6).

What is encouraging is that there are more females with secondary education. However, there are more males with a diploma, undergraduate degree and postgraduate degree compared to females. The high gender inequality is a serious threat to the attainment of SDG 4 on quality education as well as SDG 5 on gender equality. The ANOVA analysis also indicates that people's income has significant differences among different educational levels and there is a strong correspondence between better education and higher incomes ($p < 0.05$, Figure 7). Income levels rise to above ZAR 15 000 if one has a diploma, undergraduate degree or postgraduate degree. Education in South Africa is often cited as a conduit to escape poverty; hence the need to promote quality education in the study area. However, the educational levels in the Nzhelele and Levuvhu catchments are quite low with very few of the respondents having a degree or postgraduate degree.

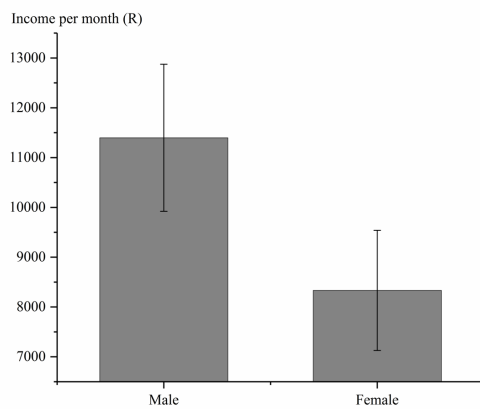


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Figure. 4 Employment levels according to gender levels in the Nzhelele and Levuvhu river catchments



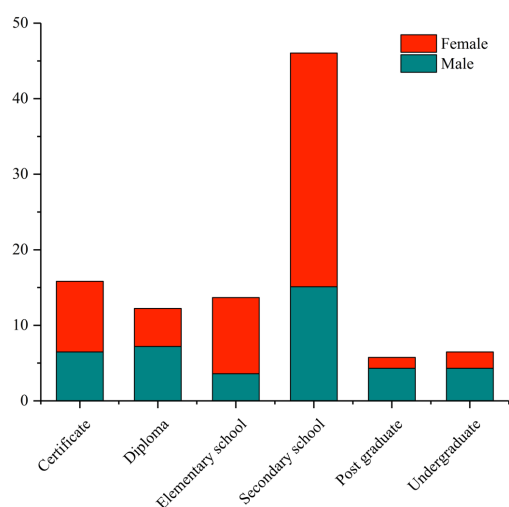
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Figure. 5 Correspondence between income levels and gender in the Nzhelele and Levuvhu river catchments

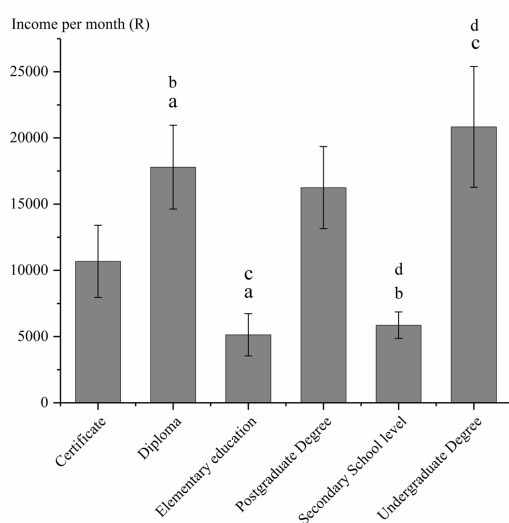
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Figure. 6 Education levels according to gender in the Nzhelele and Levuvhu river catchments



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Figure. 7 Correspondence between education levels and income in the Nzhelele and Levuvhu river catchments

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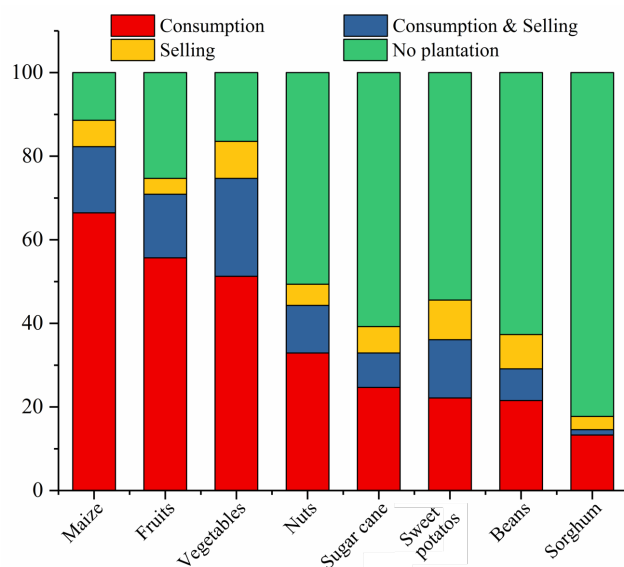
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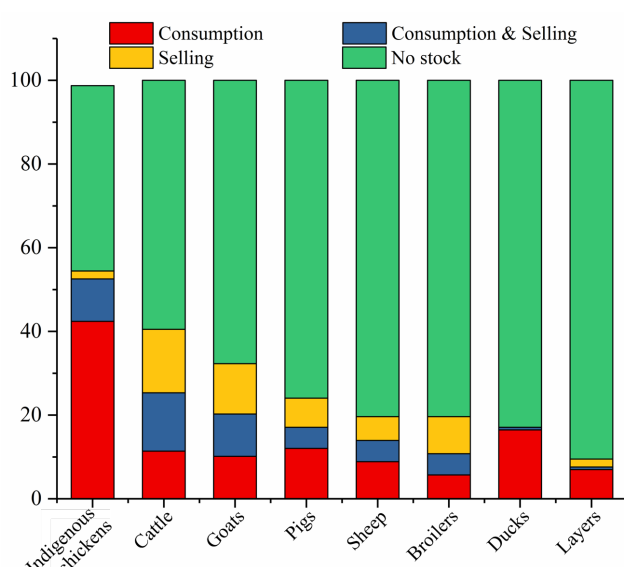
Pertaining to livelihoods, the respondents mostly depend on subsistence agriculture wherein the main crops cultivated are maize, fruits and vegetables (Figure 8). Most of the agricultural produce is for self-consumption with little for sale. Moreover, residents pointed to a decline in maize crop production due to the erratic rainfall, hence they now resort to indigenous irrigation systems such as canal irrigation or the bucket system for vegetable farming. Residents in the Nzhelele and Levuvhu catchments also keep livestock; mostly indigenous chickens, goats and cattle for subsistence with little finding its way to the market for commercial purposes (Figure 9). However, the majority of the respondents indicated that they do not own livestock.



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Figure. 8 Common crops cultivated in the Nzhelele and Levuvhu river catchments



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Figure. 9 Livestock reared in the Nzhelele and Levuvhu river catchments

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Agriculture is a major source of livelihood. However, the residents face challenges such as a lack of finance and agricultural knowledge, poor and inadequate infrastructure (roads, irrigation to propel their agriculture to be more productive) (Figure 10). Furthermore, due to a lack of water and challenges in agriculture and failure of South Africa’s national agricultural initiatives such as Land Redistribution for Agricultural Development, Integrated Sustainable Rural Development Programme, Comprehensive Agricultural Support Programme, and the Comprehensive Rural Development Programme [60, 61], it emerges that the respondents, particularly the youth, require better employment opportunities more than anything which is a sign that can be attributed to deagrarianization. Consequently, our study concurs with [60] who argues that the youth are disinterested and disconnected, with a marginal agrarian lifestyle.



277
278 **Figure. 10** Common challenges faced by communities in the Nzhelele and Levuvhu river catchments

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280 3.2 Landscape change and its drivers

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282 Figure 11 shows that the residents agree that their landscape has changed over the past twenty

283 years (1998-2018). However, the respondents argue that the change is positive. This is despite the

284 results indicating that most of the change has been detrimental to the environmental. For example,

285 the residents agree that there has been urban growth and an increase in buildings constructed. The

286 increase in buildings has led to an increase in western type houses being built as opposed to

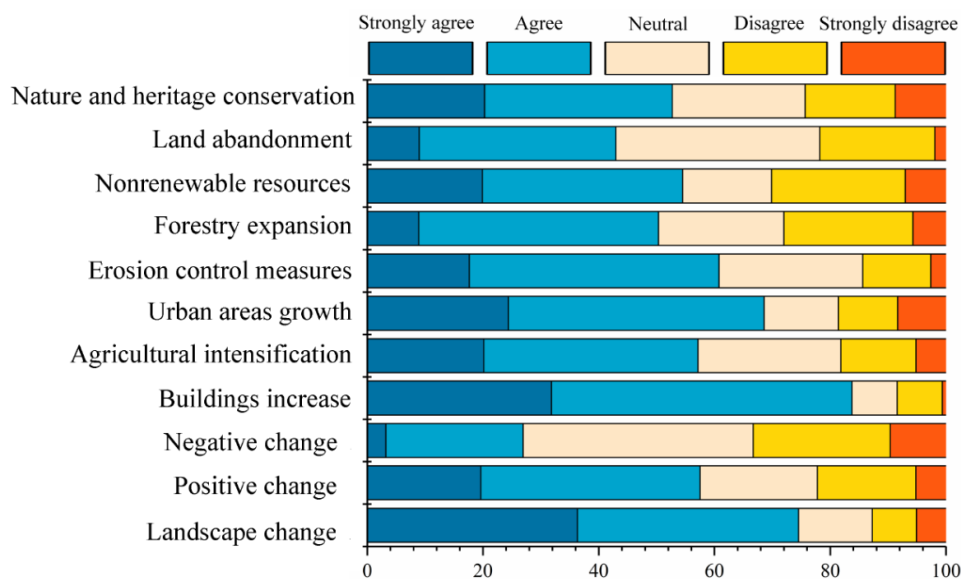
287 traditional rondavel huts[62]. Urban growth and the increase in buildings are often at the expense of

288 pristine natural resources and agricultural land. For example, urban development along the banks of

289 the Nandoni dam is occurring at a rapid rate, leading to soil erosion and destruction of wetlands.

290 Urban growth in Thohoyandou, the major town in the study area is the fastest in Limpopo province

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Figure. 11 Landscape change perceptions by communities in the Nzhelele and Levuvhu river catchments

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The other major change in the area is the prevalent soil mining and extraction of stones. Stones and rocks are mined and sold for decorative and construction purposes. Soil is often mined for construction purposes as well as for the lucrative brick making industry along the Nandoni dam and Levuvhu riverbanks. This has led to massive soil erosion, a decline in soil nutrients, siltation, and destruction of wetlands, which threatens agriculture, and water supply in the study area. Soil erosion is most severe along the riverbanks, wetlands and agricultural plots thus threatening the residents' water supply and agricultural land use-based livelihood activities. Consequently, the residents in the study area strongly pleaded for the implementation and enforcement of soil erosion curbing mechanisms in the Nzhelele and Levuvhu river catchments. This is because soil erosion has led to ecosystem disservices such as decline in water quality, and quantity, which negatively affects the agricultural livelihood practices and systems. Residents strongly concur that soil erosion needs to be curbed in order to restore soil fertility and for a return to better crop production in the study area (Figure 12). Consequently, soil is identified as a major ecosystem service that has to be managed well if agricultural livelihood practices and systems are to prosper in the study area. Some of the suggested measures to curb soil erosion include planting more trees, adoption of crop rotation, strong enforcement of laws to discourage soil mining, terracing when planting on steep slopes, destocking of livestock and placing stone barriers along gully's to prevent further erosion.



314

315 **Figure 12.** Perceptions on the benefits of controlling soil erosion by communities in the Nzhelele and
 316 Levuvhu river catchments

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318 A key change in the agricultural sector has been an increase in agricultural intensification in
 319 terms of an increase in agricultural production per unit of inputs [64]. The residents favored form of
 320 agricultural intensification, which is gaining traction, is ecosystem based agricultural intensification
 321 [29]. This includes water harvesting and irrigation, mulching, nutrient recycling for crop production,
 322 intercropping, and crop rotation. Despite attempts at ecosystems-based intensification, forms of crop
 323 production that utilize agricultural chemicals such as, fertilizers and pesticides, are still prevalent in
 324 the study areas. However, the residents in the Nzhelele and Levuvhu river catchments argue that
 325 lack of finance, government support and inadequate farming knowledge hampers their attempts at
 326 agricultural intensification.

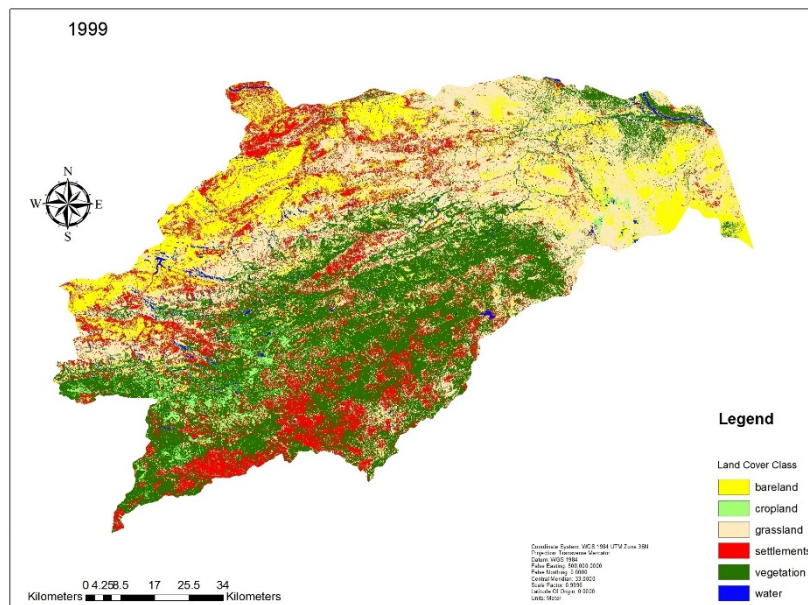
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328 The abandonment of agricultural land was also identified as a change in the landscape. This
 329 points to de-agrarianization and declining crop yields as a result of the effects of climate change
 330 (drought, erratic rainfall) and migration of youths to urban areas seeking better opportunities [60].
 331 Commercial forestry expansion is also another major change often at the expense of indigenous
 332 natural forests leading to ecosystem disservices such as a decline in soil quality [65]. Remote sensing
 333 studies have also confirmed an increase in forest plantations [66]. These are mostly commercial
 334 ventures as well as community owned ventures, producing timber and tea in the Nzhelele and
 335 Levuvhu river catchments.

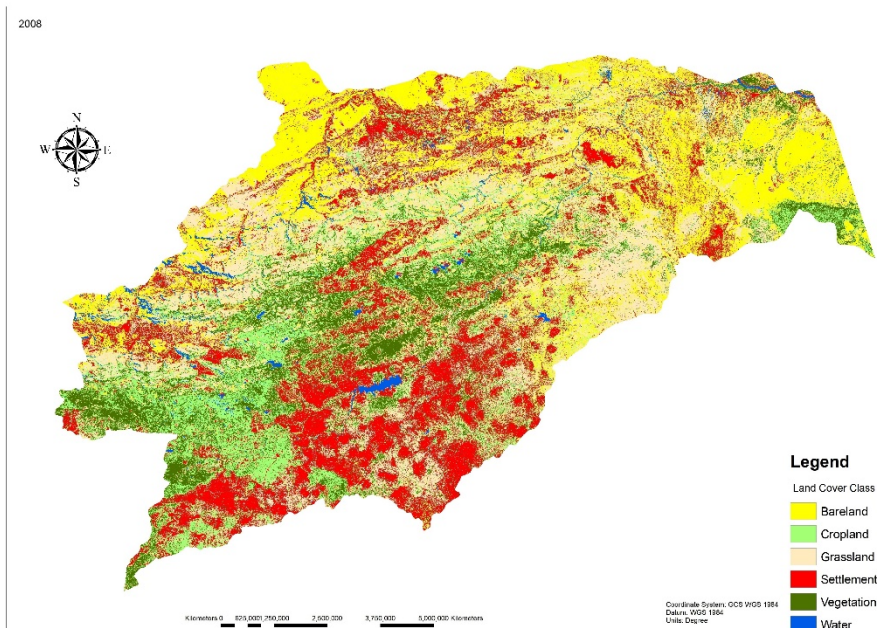
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337 The residents in the Nzhelele and Levuvhu catchments are also engaging in nature and heritage
 338 conservation owing to their cultural beliefs so that they ensure that cultural ecosystem services are
 339 transferred to future generations. For example, there is the practice of preserving indigenous ‘holy
 340 forests’ [67] where the local people communicate with their ancestors. These practices preserve local
 341 pristine indigenous forests. Similarly, there have been attempts to promote tourism and heritage
 342 conservation along the “holy forest”, sacred sites, and along dams in the river catchments.
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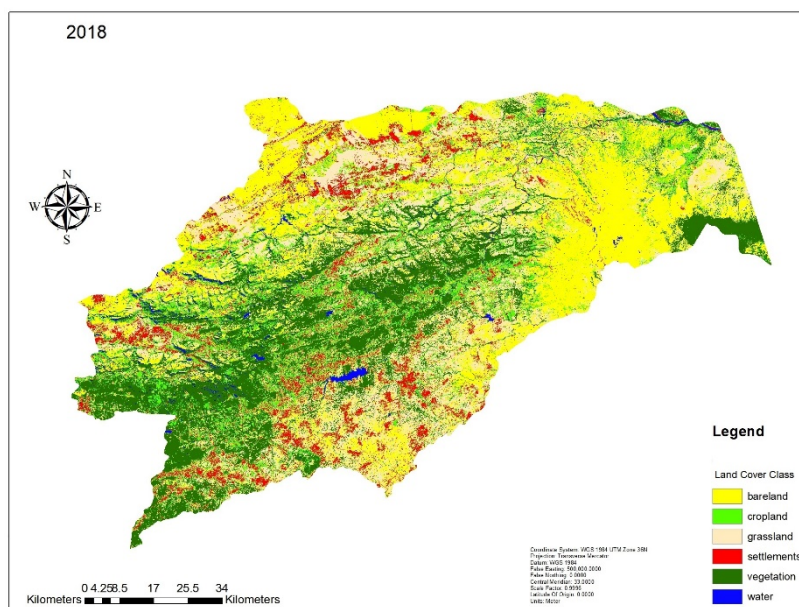
345 Figure 13 shows the land cover changes in the study area between 1998, 2008 and 2018 whereas
 346 table 1 shows the change in area in land cover classes according to CA and LCI.
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Figure 13. Land cover maps for the Nzhelele and Levuvhu river catchments for 1999, 2008 and 2018

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Table 1. Land cover change in Nzhelele and Levuvhu river catchments between 1999 and 2018.

Land Cover class	Area 1999 (ha ¹)	Area 2008 (ha)	Area 2018 (ha)	Change in (ha) 1999 - 2008	Change in (ha) 2008 - 2018	Area in % ² 1999	Area in % 2008	Area in % 2018	CA ³ 1999 - 2008	CA 2008 - 2018	
Bare land	180507,1	195890,0	207242,9	15382,9	11352,9	17,8	19,4	20,4	1,5	1,1	
Cropland	41211,9	99966,0	150637,1	58754,1	50671,1	4,1	9,9	14,9	5,8	5,0	
Grassland	301414,2	260409,0	221743,5	41005,2	38665,5	29,7	25,8	21,9	-4,0	-3,8	
Settlements	169651,5	176452,0	190803,8	6800,5	14351,8	16,7	17,5	18,8	0,7	1,4	
Vegetation	307255,6	263404,0	228034,2	43851,6	35369,8	30,3	26,1	22,5	-4,3	-3,5	
Water	14125,4	14268,0	14962,1	142,6	694,1	1,4	1,4	1,5	0,0	0,1	
									LCI⁴	8,1	7,4

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¹Hectares; ² percent; ³ changes in percentage share of areas covered by each land cover class in relation to the total area

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of study area; ⁴ landscape change index

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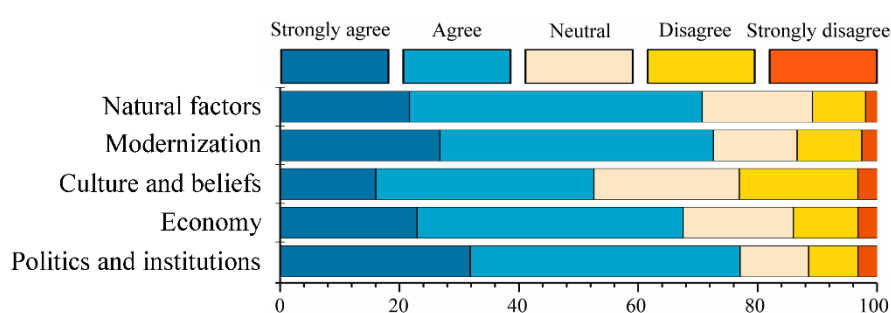
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The first step was to calculate the magnitude of change (CA) between 1999-2008 and 2008-2018 for each land cover type. Between 1999-2008 and 2008-2018, vegetation and grasslands had the highest negative transformation of 4, 3 and -3, 5 and -4, 0 and -3, 8 respectively. These declines correspond with the survey results, where the residents argue that there was an increase in settlements, agricultural intensification and expansion, and extraction of non-renewable resources such as sand and granite for construction. However, pristine forests and grasslands were destroyed in the process. During the time intervals of 1999-2008 and 2008-2018, settlements and bare land show a transformation CA of 0, 7 and 1, 4 whereas bare land was 1, 5 and 1, 1 respectively. The extraction of natural resources such as sand and stones, and brick making along the river catchments are drivers explaining the increase of bare land and settlements as confirmed by the land cover analysis. Furthermore, as highlighted in the survey, the bare land areas are very prone to soil erosion, and the residents in the study area confirmed that soil erosion is a huge problem that needs to be urgently addressed. Croplands experienced major transformation as its CA was 5, 8 and 5, 0 for time intervals

369 of 1999-2008 and 2008-2018. The increase in croplands coincides with a decline in vegetation and
 370 grasslands as communities' clear land to increase agricultural output. The change (CA) of 0, 0 and 0,
 371 1 in water between time periods of 1999-2008 and 2008-2018 was minimal and it was mostly due to
 372 the building of the Nandoni dam in 2005. However, discussions with the community during the
 373 survey revealed that although dams are present, water reticulation and irrigation water is not readily
 374 available for community members. From calculating the magnitude of change for each land cover
 375 type the next stage was computing the landscape change index. The landscape change index was 8,
 376 1 and 7, 4 for the time intervals 1999-2008 and 2008-2018. Therefore, we can argue that most of the
 377 land transformation occurred between 1999-2008. Although the land cover analysis is useful in
 378 showing the magnitude of landscape change, it is difficult to identify its salient drivers. However,
 379 the survey does highlight that for example land abandonment is a critical driving factor explaining
 380 landscape change in the study area. Nevertheless, despite this insight, more studies are required to
 381 comprehend the drivers of land abandonment in the Nzhelele and Levuvhu river catchments.
 382

383 The proximate drivers of landscape change in the study area are shown in Figure 14. Firstly,
 384 politics and legislation are cited as a major driver of landscape change. For example, the land reform
 385 policy has led to ceding of plantations to the local people. However, the current ceded plantations to
 386 the community are not being well maintained. Land is also governed traditionally, where the Chiefs
 387 and Headman allocate land parcels and give households 'permission to occupy land' certificates
 388 without giving full title ownership. It has been argued that such ownership leads to the so called
 389 'tragedy of the commons', because when no one owns the land, environmental degradation will be
 390 common and difficult to resolve. To some extent, it is true in the study area, as soil erosion due to soil
 391 mining, overgrazing and cutting down of trees is common. The existing challenge is that the
 392 traditional land governance practices and systems is often in conflict with modern or western type of
 393 land use planning, administration and management[62]. Perhaps a market-based system of land
 394 ownership of issuing ownership and titles to land is often cited as a solution. However, it also has its
 395 own challenges such as the fear that title will be given to men, the administrative modalities
 396 associated with change of ownership and it can give rise to market speculation
 397



398

399 **Figure 14.** Proximate drivers of landscape change in the Nzhelele and Levuvhu river catchments

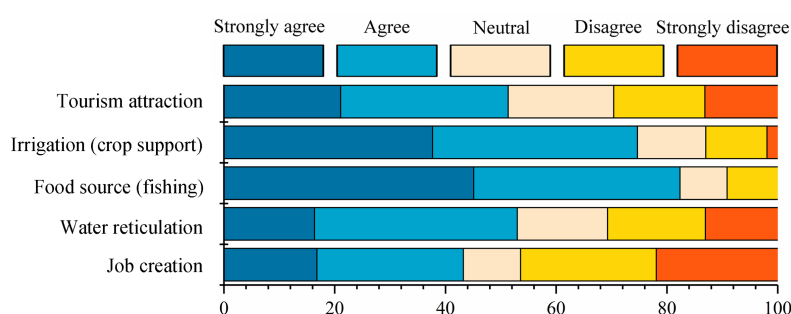
400

401 The economy and markets are also a major driver of landscape change. For example, because of
 402 the search for quick profits and higher market prices, residents in the study area are increasingly
 403 turning into cash cropping (e.g. market gardening, vegetables and growing of cash crops such as
 404 sunflowers, mangoes and avocados). Culture is also cited as a major driver of landscape change
 405 through preservation and reverence of 'holy forests'. Other local practices such as harvesting wild
 406 fruits and vegetables (without cultivation) as well as insects (e.g. mopane worms) are strong drivers
 407 of landscape change and a serious threat to biodiversity [68]. Modernization in agriculture, in
 408 particular by the smallholder farmers, is also a major driver of landscape change in the study area.
 409 For example, the use of tilling equipment means that more land is used for agriculture. Furthermore,
 410 increased use of fertilizers, pesticides, and irrigation, being adopted by farmers is a threat to the

411 environment. Lastly, natural forces such as recurring droughts and cyclones are also cited as
 412 significant drivers of landscape changes. Droughts have led to land degradation, while flooding, for
 413 example cyclone Dineo in 2017 [69] led to destruction of property, infrastructure, crops and
 414 vegetation.
 415

416 3.3 Ecosystems services

417 From an ecosystems services point of view the residents in the catchment's areas agree that the
 418 river catchments provide fresh water for irrigation purposes (Figure 15). The villagers have turned
 419 to traditional methods of irrigation such as using trenches to supplement rain fed agriculture.
 420 Villagers have been able to implement vegetable farming and also irrigate their crops despite the
 421 erratic rainfall. The two major dams (Nzhelele and Nandoni) are the main sources of irrigation water.
 422 Nevertheless, the villagers strongly argue that drinking water from the dams is hardly possible owing
 423 to lack of water processing and pumping infrastructure. Furthermore, some villagers in the northern
 424 parts of the catchment areas such as Madangani argue that, although the government have drilled
 425 boreholes, the water is salty and unsuitable for drinking. As a consequence, some villages in the
 426 northern parts of the catchment area still obtain water from rivers thereby exposing them to water-
 427 borne diseases. The unavailability of safe drinking water is a major threat to the attainment of SDG 6
 428 of Clean Water and Sanitation. Likewise, the residents are dissatisfied with the service provision of
 429 clean water by the municipality in the river catchments, which is also confirmed by other studies [30,
 430 70, 71]. Hence, the district municipality, provincial government, and national government need to
 431 provide lasting water resilient solutions, especially given the frequency of droughts and erratic
 432 rainfall in the study area.
 433



434

435 **Figure 15.** Perceptions of ecosystem services in the Nzhelele and Levuvhu river catchments

436

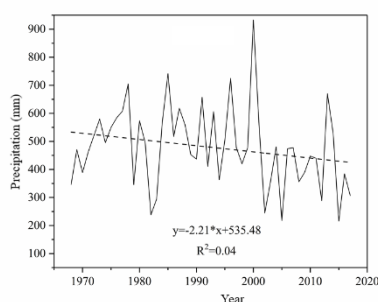
437 The river catchments are also an important source of food through fishing (Figure 15). However,
 438 overfishing which threatens the survival of fish species in the river catchments is a concern in the
 439 area. Moreover, if the unsustainable fishing continues, the catchments runs the risk of having no fish
 440 in the future. In addition, there has been reports of safety issues because of overfishing, where
 441 villagers venture into deeper waters and several drowning reports have been noted in the areas. Some
 442 villagers suggested fish farming as a solution to overfishing. However, this requires training and
 443 financial resources that are not readily available.
 444

445 However, the cultural ecosystem services provided by the river catchments is thriving and has
 446 potential (Figure 15). For example, there are various tourist resorts along the Vondo and Nandoni
 447 Dams and the river catchments. These support recreational activities (fishing and picnicking) that
 448 that are common at various sites in the river catchments and are an important source of employment
 449 to the villagers and local economy. The river catchments are also an important source of cultural
 450 ecosystem services, as some places are considered sacred (Figure 15). For example, Lake Funduzi is
 451 a sacred place, home to the python god. It is a place where local people go to worship their ancestors

452 and chiefs are buried there. Similarly, the sacred Phiphidi falls, Mahovhovo falls and the sacred
 453 forests are places where the local people communicate with their ancestors. There are many sacred
 454 sites dotted along the Nzhelele and Levuvhu rivers used by the Venda people to practice their
 455 traditions. Nevertheless, some of these sacred sites are under threat as a result of tourism, soil erosion,
 456 soil mining and agricultural expansion. A major threat to the water system and sacred places is the
 457 impending construction of the Makhado Mine which is along the Nzhelele catchment. The new mine
 458 threatens to destroy sacred sites as well as deplete water resources, which are already under threat
 459 owing to drought. The development of an integrated mining and heritage plan is therefore a critical
 460 component in updating the Spatial Development Plan (SDF), Special Economic Zones (SEZ) and
 461 Municipal Integrated Development Plans (MIDP) covering the study area catchment areas.

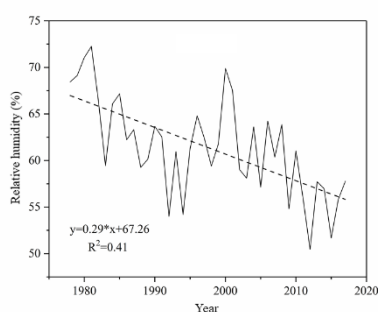
462 3.4 Climate change and its impacts

463 From a climate change perspective, since 1968 the overall trend is a decline in precipitation
 464 (Figure 16), and relative humidity in the river catchments (Figure 17). This decline is problematic,
 465 because the majority of residents in the river catchments depend on rain fed agriculture. Of note was
 466 the spike in precipitation in 2000 as a result of the extreme weather event Cyclone Leon-Eline [72].
 467 However, despite the decline in overall precipitation, there has been an increase in extreme weather
 468 events such as, Cyclone Domonia in 1984 [73], Tropical Storm Irina in 2011-2012 [72] and Cyclone
 469 Dineo in 2017 [69]. These cyclones and tropical storms have high speed winds and precipitate large
 470 rain downpours in a short period of time which destroys infrastructure, causes loss of life, displaces
 471 people and causes flooding [74]. For example, the cultivation on slopes and the clearing of vegetation
 472 exacerbated the flooding in the study area as a result of Cyclone Leon-Eline [72]. Consequently,
 473 people, settlements and agricultural plots are vulnerable, and this calls for better disaster
 474 preparedness and coping strategies to mitigate the impact of cyclones in the study areas.



475

476 **Figure 16.** Trends in rainfall from 1968-2017 in the Nzhelele and Levuvhu river catchments

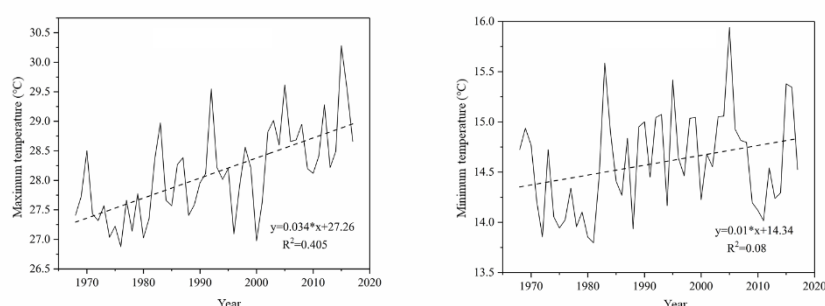


477

478 **Figure 17.** Trends in humidity from 1968-2017 in the Nzhelele and Levuvhu river catchments

479 The decline in precipitation has also been met with an overall increase in average maximum and
 480 minimum temperatures, which has caused droughts in the river catchments (Figure 18). These

481 droughts are normally associated with El Nino events and occurred in the early 1980s, early 1990s,
 482 2004-2005 and in the 2015-2016 seasons [57]. The droughts in the river catchment areas largely
 483 affected the agricultural livelihood systems and activities that depend on rain fed agriculture in the
 484 study areas. As a result, there has been a decline in crop production leading to families diversifying
 485 their livelihood systems and practices. One adaptation strategy is that people migrate to cities in
 486 search of better opportunities as a result of declining agricultural yields. They support family
 487 members through remittances, among other coping mechanisms.



488

489 **Figure 18.** Trends in temperature from 1968-2017 in the Nzhelele and Levuvhu river catchments

490 The erratic rainfall and high temperature have changed the length in seasons. Farmers have
 491 adapted to the climate changes through planting varieties that have a short growing season and also
 492 by farming drought resistant crops such as sorghum and millet. However, although the residents can
 493 clearly see the decline in maize production as a result of droughts, maize is still their preferred crop
 494 as it is an essential constituent of their staple food. Thus, changing to other drought resistant crops
 495 such as sorghum and millet requires a mindset shift and a concerted effort. There is thus a strong
 496 drive by the government to change to other rapidly maturing maize crop varieties, as well as to plant
 497 cereals such as sorghum and millet. Other impacts of the droughts include loss of livestock (cattle,
 498 sheep and goats) because of shrinking grazing land. Consequently, farmers are being urged to
 499 destock and sell their livestock to minimize losses during droughts as a result of lack of grazing.
 500 Climate change also has increased disease outbreaks such as malaria, since mosquitos thrive in
 501 warmer areas. However, scholars argue that an increase in temperature alone is not the only reason
 502 that explains an increase in malaria incidence. Drug resistance, inadequate mosquito control
 503 programs, inadequate public health facilities, and low living standards are also factors that strongly
 504 explain the resurgence in malarial incidences in the northern parts of South Africa [75].
 505

506 4 Summary and conclusions

507 The point of departure for the study was to survey the local community and comprehend their
 508 perceptions on landscape change. An objective of the study was to survey community livelihoods.
 509 Accordingly, the study results and findings have showed that there is poverty with a gender bias in
 510 the Nzhelele and Levuvhu river catchments. Poverty often compels communities to engage in
 511 livelihood systems and practices that are detrimental to the environment, such as soil mining and
 512 over-harvesting of natural resources. Consequently, if poverty is addressed through agricultural
 513 support and value adding employment opportunities, harm to the environment will be reduced. The
 514 results also show that the communities in the Nzhelele and Levuvhu River practice subsistence
 515 farming that is largely rainfed dependent. However, due to droughts and erratic rainfall, some
 516 farmers have shifted to irrigation-based farming as a coping mechanism. Others have diversified into
 517 market gardening and growing fruits, which offer better returns. Despite the decline in rainfall, the
 518 communities still find it difficult to shift from farming maize to drought resistant crops such as
 519 sorghum and millet. Similarly, the droughts, overgrazing and lack of pastures has also meant loss of

520 livestock and destocking of animals to guard against future losses. Overall, poverty hinders the
521 community's response, mitigation and adaptation attempts to climate change.

522

523 The communities in the Nzhelele and Levuvhu river catchment areas face challenges such as
524 lack of finance, lack of stakeholder support and poor government support for agriculture as well as
525 poor comprehension of rural development realities by the government. Consequently, for the
526 government policies and support systems to work better, such actions and measures should integrate
527 the local communities and culture. This will increase the chance of landscape change reversal
528 interventions being a success in the study area, in similar areas in South Africa and elsewhere in
529 developing countries generally.

530

531 Another objective of the study was to learn about the perceptions of local communities to
532 landscape change including identifying the drivers for such change and comparing these results with
533 land cover maps derived from satellite imagery. The perception that the landscape has changed is
534 unanimous in the study area, and this is confirmed by the land cover change analysis. However, most
535 of the change has been detrimental to the environment. The major drivers are climate change,
536 increased urbanization, agriculture, and forestry. Proximate drivers of changes are politics (land
537 reform and traditional land authorities), the economy (markets) and culture. The study also sought
538 to comprehend the ecosystem services provided by nature and to identify the impacts of climate
539 change on the landscape, ecosystem services and livelihoods. The results also show that the
540 communities in the Nzhelele and Levuvhu river catchments, practice subsistence farming that is
541 largely rain fed dependent. However, due to droughts and erratic rainfall, some farmers have shifted
542 to irrigation-based farming as a coping mechanism. Others have diversified into market gardening
543 and growing fruits, which offer better returns. Despite the decline in rainfall, the communities still
544 find it difficult to shift from farming maize to drought resistant crops such as sorghum and millet.
545 Similarly, the droughts, overgrazing and lack of pastures has also meant loss of livestock and
546 destocking of animals to guard against future losses. Overall, poverty hinders the community's
547 response, mitigation and adaptation attempts to climate change. In the study, we gleaned that, the
548 changes in the landscape affect the provision in ecosystem services and livelihoods. For example, the
549 landscape change has led to ecosystem disservices such as a decline in soil quality as a result of soil
550 erosion, damage to wetlands, overgrazing, inadequate and poor-quality water, deforestation, and
551 over-harvesting of natural resources. As a result, the communities' livelihood systems and practices
552 are affected negatively. Owing to erratic rainfall and the realization that returns in agriculture are
553 low, there is de-agrarianization with most residents arguing that they want better employment
554 opportunities.

555

556 The study highlights the nexus between landscape change, climate change ecosystems services
557 and livelihood systems and practices. Climate change impacts landscape change, which is driven by
558 other factors such as agriculture, urbanization and forestry. Besides these direct drivers, other
559 underlying drivers such as politics and culture need to be considered in the study area. In turn, the
560 landscape change affects provision of ecosystem services (water, soils, vegetation, crops) which
561 consequently affects people's livelihood. Consequently, when proposing agricultural policies and
562 strategies as well as land management policies in rural areas such as the Nzhelele and Levuvhu river
563 catchments, government and other stakeholders should take cognizance of peoples' culture and
564 knowledge and propose ecosystem services-based land management practices.

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 591

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