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Trends in Vegetation Degradation in Relation to Land Tenure, Rainfall, and Population Changes in Peddie District, Eastern Cape, South Africa

VINCENT KAKEMBO*
Department of Geographical Sciences
Vista University, Port Elizabeth Campus
Private Bag X613
Port Elizabeth, 6000, South Africa

ABSTRACT / Spatial and temporal variations in vegetation are examined in relation to land tenure, population increase, and rainfall variation in a part of Peddie district, Eastern Cape. Sequential aerial photographs between 1938 and 1988 are analyzed to determine trends in vegetation and population change in three different land-tenure units. The areal extent at each date of four distinct vegetation categories is determined using PC ARC/INFO GIS. Long-term annual rainfall trends for the area are analyzed and juxtaposed with vegetation changes. Extensive ground-truthing exercises are carried out to verify the present condition of vegetation condition in terms of cover and species composition. Differences in land-tenure systems are discerned as the dominant factor controlling variations in vegetation degradation. The study also reveals that neither population changes nor rainfall variations can explain the observed trends in vegetation degradation. Earlier injudicious land-use practices, sustained since the turn of the last century, may provide plausible explanations for the trends and present status of vegetation degradation in the area.

Vegetation degradation in the form of diminution of cover and changes in species composition is one of the major environmental problems plaguing many parts of South Africa, particularly the former "homelands" (the marginal lands reserved for blacks during apartheid). More often than not, this problem is attributed to injudicious land-use practices, for instance, overgrazing concomitant with increasing population pressure. However, there is a need to examine the problem in a spatial and temporal context before directly and simplistically linking it to population growth. Changes in vegetation are responses to different variables, which range from adaptive ones, such as those imposed by the cyclicity of rainfall, to negative conditions resulting from sustained anthropogenic activity (Ringrose and others 1995). It is thus important to distinguish human-induced change from natural variability as well as short-term reversible changes from long-term impacts (Pickup and others 1994).

This paper examines the spatial and temporal variation of vegetation in a part of the Eastern Cape, South Africa, in relation to population changes, rainfall variation, and land tenure. The study provides a basis for understanding the interaction of vegetation with human and climatic factors. The dramatic response of vegetation to rainfall variations is noted in the literature (Rowntree 1988, Brinkate and Hanvey 1996), as is its vulnerability to human manipulation (Trimble 1990). Whether trends in vegetation change in the study area are a response to the one or both of these factors is the focus of this investigation.

Study Area

The study area is part of the dividing ridge between the Great Fish and Keiskamma rivers, in the Peddie district of the former Ciskei, Eastern Cape (Figure 1). It extends from 33°3′S, 27°0′E to 33°13′S, 27°12′E and has a surface area of 178.2 km^2. It was selected on the basis of its ecological homogeneity—it has topographic and geologic continuity and, according to the South African Weather Bureau (1972) and Acocks (1975), it falls within a homogeneous rainfall and vegetation zone. The area consists of three contiguous land-tenure units namely: former commercial farms and traditional and betterment villages.

The area is predominantly covered by shallow Mispah form soils (the equivalent of Entisols in the USDA classification) and is underlain by sandstone, shale, and red mudstone of the Beaufort and Ecca groups of the Karoo Supergroup. It lies in the semiarid plateau of the

KEY WORDS: Vegetation degradation; Land tenure; Population changes; Spatial and temporal variability; Rainfall variations; Riparian vegetation

*Author to whom correspondence should be addressed.

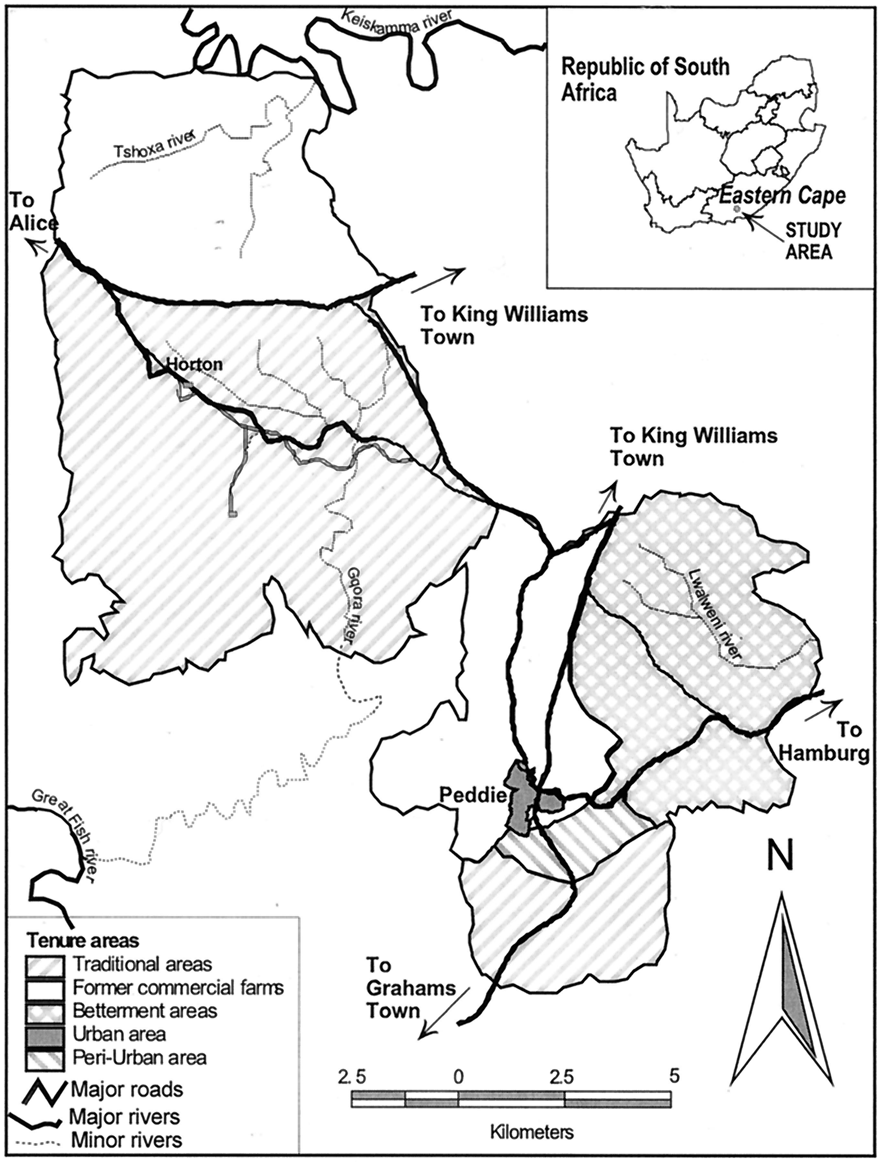


Figure 1. Study area.

Eastern Cape. Long-term rainfall data for the area were obtained from the Computing Centre for Water Research (CCWR) of the University of Natal, Pietermaritzburg. According to the data, the area's mean annual rainfall of 488 mm is erratically distributed with a coefficient of variation of 32%. A well-defined peak is experienced during the summer months from October to April. The mean temperatures range between 29 and 31°C in summer and between 7 and 9°C in winter. The vegetation classification for South Africa by Acocks (1975) categorizes the study area as the Eastern Province Thornveld, fringed by the Valley Bushveld of the Keiskamma and Great Fish river valleys to the north and south, respectively. The climax vegetation for this veld type would be short and scrub forest, but it essentially remains Thornveld dominated by *Acacia karoo* (Weaver 1988). This has been considerably modified by a long history of human occupancy and overutilization.

Distinct land-tenure units—African traditional villages and white commercial farmlands—have existed side by side in the area since the turn of last century. Both are discernible from the earliest set of aerial photographs of the area taken in 1938. The former are characterized by communal ownership of land. The phenomenon of "betterment" was introduced in the early 1960s in part of the region of traditional villages to arrest what were perceived then to be deteriorating environmental conditions. Grazing and crop cultivation are noticeable from the 1938 set of aerial photographs as the main land-use practices in the traditional villages. Presently, widespread abandonment of cultivation is a significant aspect of land-use change in both the traditional and betterment villages. On the other hand, grazing on the commercial farms is noted as the consistently predominant land-use type. The farms were expropriated in the early 1980s on the eve of the creation of the former Ciskei "black homeland." The territory was reincorporated into the Republic of South Africa in April 1994. To date, the former commercial farms remain unutilized state land onto which communal farmers from the traditional and betterment villages are gradually encroaching. Such spatial variation of tenure systems would thus permit a comparative assessment of their impact on vegetation.

Methodology

Sequential aerial photographs of the area for 1938, 1954, 1965, 1975, and 1988 were analyzed using a mirror stereoscope with 3× magnification lenses. This technique has successfully and reliably been used in several studies elsewhere (Keech 1969, Stromquist and others 1985, Marker 1988, Ntsaba 1989, Rowntree and others 1991, Garg and Harrison 1992, Whitlow 1994, Rowntree and Dollar 1995, 1996, Watson 1995, 1996). Four categories of vegetated surfaces were clearly discernible from the different sets of aerial photographs. These were specified as open woodland, wooded grassland, moderate grass cover, and scanty grass cover. Dominance by woodland was the basis upon which the open woodland vegetation textural surface was designated. Vegetated surfaces with a very variable and scattered woody component were categorized as wooded grassland. Textural surfaces where the woody component was absent were designated as grass cover. The presence or absence of extensive light-toned areas as a proxy for bare surfaces marked the line that was drawn between moderate and scanty grass cover. Changes in these textural surfaces were mapped from the photographs at each date.

The process of designating polygons for each vegetation class at the different dates could be a highly subjective one. Subjectivity may then give rise to overlaps between the classes from the respective sets of aerial photographs, hence constituting a considerable source of error. In order to minimize the margin of such an error, consistency was exercised by adhering to the criteria outlined above for designating vegetation categories and polygons.

Table 1. Scale of aerial photographs and rainfall status of months during which they were taken

Year	Scale	Month	Rainfall status
1938	1:25,000	December	Fairly wet
1954	1:36,000	April	Fairly wet
1965	1:36,000	April	Dry
1975	1:15,000	August	Dry
1988	1:15,000	April	Wet

Variations in the density of riparian vegetation—another conspicuous feature of the vegetation cover in the area—were mapped. Individual stream courses were analyzed and differences in the density of vegetation along them were designated as dense, moderate, and scanty. Thick woody riparian vegetation, interspersed with shrubs was designated as dense. The discernibly open woody vegetation along some of the stream courses constituted the moderate category. Visibly eroding streambanks with very sparse riparian vegetation were a surrogate for the scanty category. The variation pattern of riparian vegetation remained consistent throughout the period of study. Hence, its mapping was not done at each date.

Details mapped from sequential aerial photographs ranging in scale from 1:20,000 to 1:50,000 contain a number of inherent sources of error (Watson 1995). These errors were eliminated by transposing the mapped details to transparent overlays superimposed onto orthophoto maps, drawn at a uniform scale of 1:10,000. Besides serving as a measure against scale and areal distortion, this technique facilitated the capture of the data onto a GIS in PC ARC/INFO format. It was thus possible to calculate the areal extent of the vegetation categories at each date from the PC ARC/INFO database. The present status of vegetation degradation in terms of cover and changes in species composition were verified by means of extensive field surveys.

The spatial and temporal variability of vegetation in response to rainfall variations was alluded to earlier. As observed by Rowntree (1988), aerial photographs taken in high rainfall years or seasons indicate better vegetation cover than is the case during dry years. Hence, in the present study, cognizance was taken of the time of the year at which the area was flown. The long-term rainfall data for the area obtained from the CCWR were based on the Peddie town gauging station. The data were therefore considered adequately representative of the study area. The scales of the sequential aerial photographs and the rainfall status of the period of the year during which they were taken are given in Table 1. Comparisons between the status of rainfall and vegeta-

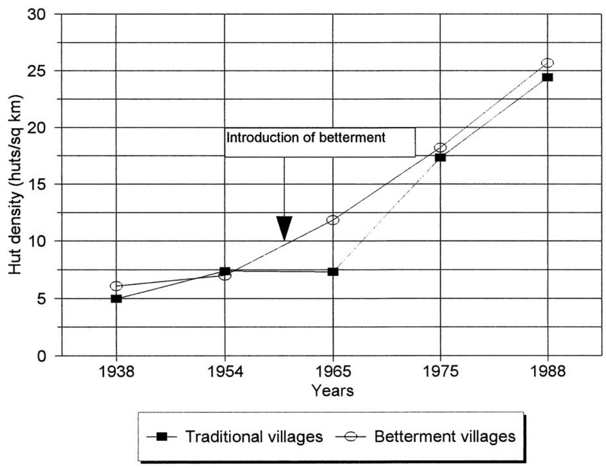


Figure 2. Trends in population change.

tion at each date were also made. To this end, long-term annual rainfall trends for the area were obtained using the z score, which is computed as follows:

$$z = \frac{\text{raw value} - \text{mean rainfall of station (1920–1990)}}{\text{standard deviation of rainfall (1920–1990)}}$$

Distinct dry and wet periods between 1920 and 1990 were identified using a five-year running mean of the z scores. These trends were then juxtaposed with vegetation changes in the three land-tenure units (Figure 3 below).

To assess population changes, individual dwelling units in the traditional and betterment villages were counted at each date as surrogates for population increase. This technique was inapplicable to the former commercial farms, where the tenure system was such that a single farmer could own extensive farmland. An increase in the number of farm houses is thus irrelevant as an indicator of population increase. Rather, participatory interviews with elderly local residents were conducted to gain an insight into population changes on the commercial farms. An historical perspective of stocking rates in the traditional and betterment villages was also gained using the same technique.

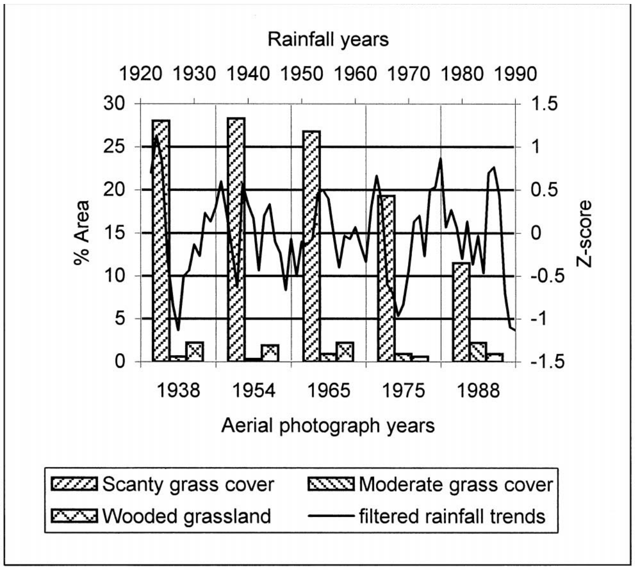
Results and Discussion

Trends in population change expressed as hut density per square kilometer at each date are depicted in Figure 2. A sharp rise in the density of dwelling units after 1954 and 1965 in the betterment and traditional villages, respectively, is noticeable. In the betterment areas, the increase coincided with the introduction of the betterment program in the early 1960s. According to information obtained from participatory interviews, the population of workers on the former commercial farms remained more or less consistent.

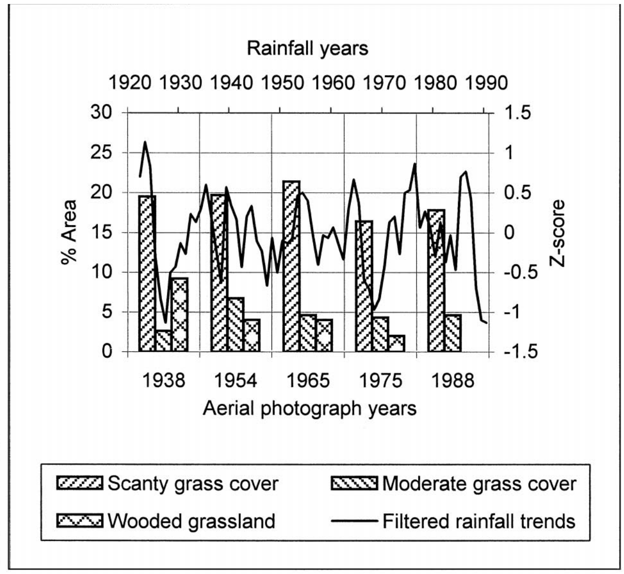
Changes in the areal extent of the four vegetation categories with respect to land-tenure units and long-term rainfall trends are presented in Figure 3. It can be seen that certain vegetation categories are confined to specific land-tenure units. Scanty grass cover is the consistently dominant vegetation category in both the traditional and betterment villages for the whole study period (Figure 3A and 3B). A reduction in the areal extent of this vegetation category is noticeable in the traditional villages between 1975 and 1988. This is a result of the opening up of additional land for cultivation. The small land area under wooded grassland diminishes gradually in both tenure units. The increased demand in wood fuel concomitant with population increase could explain this. Open woodland is confined to the former commercial farms at each date (Figure 3C). The greater representation of wooded grassland in the latter tenure unit is also readily noticeable. Its shrinkage in the same tenure unit between 1975 and 1988 is noted to coincide with a 17% increase in open woodland.

Juxtaposed with long-term filtered annual rainfall trends for the area (Figure 3), the vegetation categories in the traditional and betterment villages do not show any significant changes that may denote a response to rainfall variations. No improvement in vegetation condition was observed even during the wet phases. The dominance of sparse grass cover in these areas at each date thus signifies permanent damage to vegetation. This is in keeping with Dube's (1995) observation that below average or poor performance of vegetation even during good rainfall years indicates long-term damage. Conversely, the considerable increase in woody species observed on the former commercial farms between 1975 and 1988 could be a reciprocal response to the 1974–1989 wet phase. This probably gave the woody shrubs a competitive advantage over grass species. Therefore, to some extent, vegetation condition in the former commercial farms provides a benchmark against which deviation from the normal can be determined.

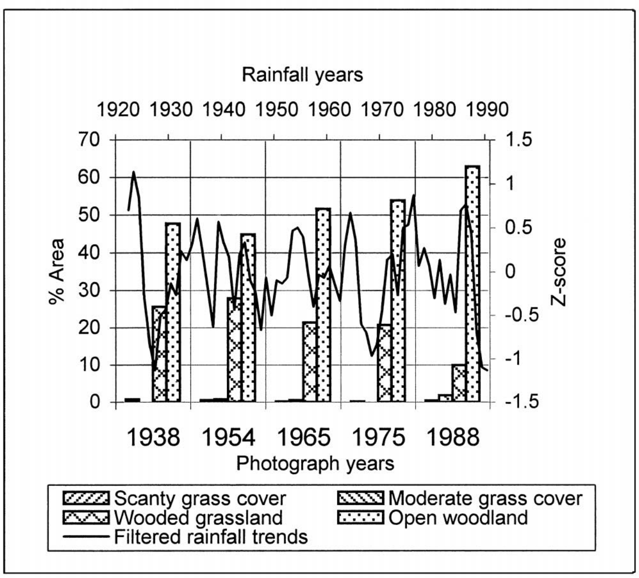
Figure 4 vividly portrays that riparian vegetation density varies with land-tenure systems. Whereas stream courses in the former commercial farms have dense riparian vegetation along them, almost all stream courses in the traditional and betterment villages have had vegetation along them removed. A close link between scanty riparian vegetation and streambank erosion was established during field surveys. Such channel degradation has given rise to excessive stream sedimentation. This is evidenced by valley-fill, which character-



A Traditional villages



B Betterment villages



C Former commercial farms

Figure 3. Vegetation changes in the three land-tenure units juxtaposed with filtered rainfall trends.

izes most stream reaches with scanty riparian vegetation. That this distributional pattern was observed throughout the study period indicates that riparian vegetation removal from these villages began much earlier than 1938. Such a marked change in vegetation gradient from the traditional and betterment villages to the former commercial farms over the entire period clearly denotes the direct impact of different tenure related land management practices on vegetation.

The persistence of scanty vegetation cover, the absence of open woodland, and the sparseness of riparian vegetation at each date in both the traditional and betterment villages indicate that the detrimental impact on vegetation is not a recent phenomenon. It also signifies the dismal failure of the betterment program in regard to achieving its aim as spelled out earlier in this paper. It would thus be erroneous to ascribe such vegetation conditions to trends in population change, since that was the status quo long before the observed exponential rise in population. By implication, vegeta-

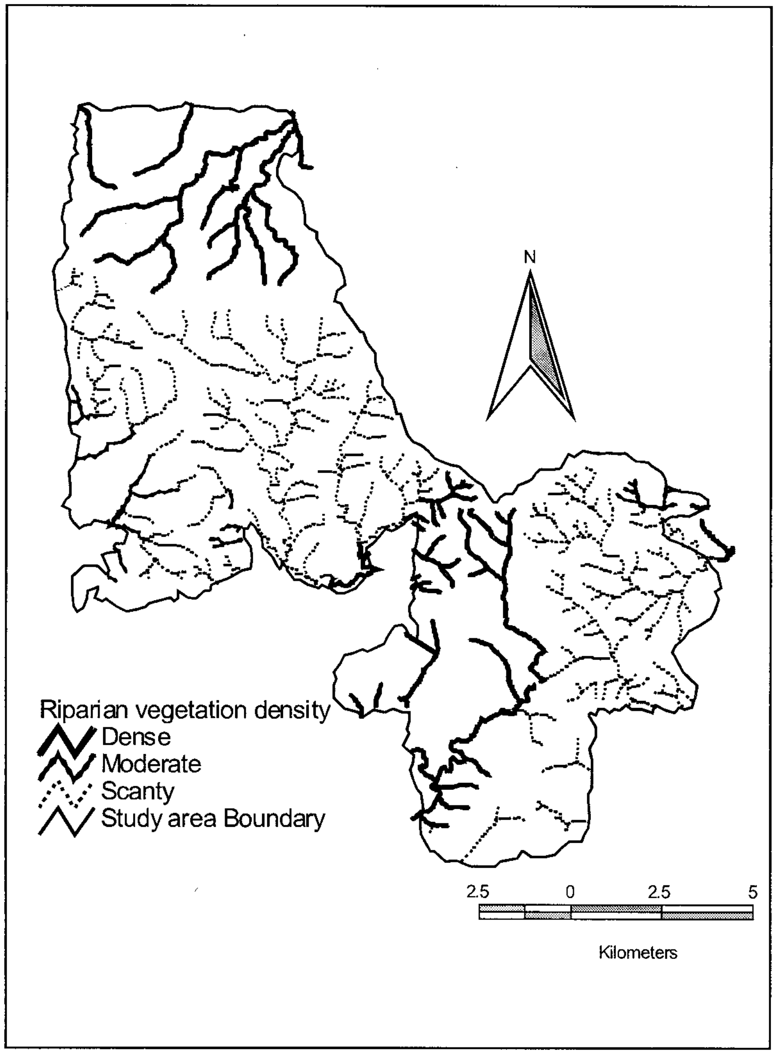


Figure 4. Variations in riparian vegetation density.

tion degradation in the area is more a product of earlier injudicious use rather than an increase in population.

A pertinent question arises as to how vegetation in both the traditional and betterment villages was destroyed at the time when both areas were still sparsely settled. Information obtained by way of participatory interviews indicates that in these areas, stocking rates well above the veld carrying capacity have been maintained throughout the study period. The participants referred to the first quarter of the 20th century as the era of the ox-drawn plow and wooden cart. This era essentially had a two-pronged negative impact on vegetation: prolonged overgrazing and wood depletion due to ox-drawn wooden cart construction. Despite the drastic reduction in stock numbers due to the late 1960s acute drought as reported by Brown (1971), no improvement in vegetation condition was recorded.

Another facet of vegetation degradation observed during field surveys is the widespread invasion of the traditional and betterment villages by inferior vegetation species. *Pteronia incana* (blue bush), an unpalatable dwarf shrub of Karoo origin is spreading rapidly from the stream valley bottoms onto grazing lands and some of the abandoned cultivation fields (Figure 5). Its effects on the ecosystem are manifest in its spatial correlation with soil crusting and different forms of soil erosion (Kakembo 2000). It is increasingly becoming the dominant species at the expense of the indigenous *Themeda triandra* and *Digitaria eriantha*, which are steadily being depleted by browsers. This phenomenon must be taken into account in future studies of vegeta-

Figure 5. Invasion by *Pteronia incana* (blue bush).

tion condition from aerial photographs as well as from satellite imagery. Such inferior invader species can create an impression of a healthier and improved cover, giving misleading results in regard to vegetation condition.

Conclusion and Recommendations

This study has demonstrated that the observed vegetation degradation can be explained in terms of neither population increase nor short-term impacts linked to rainfall cyclicity. It is rather a product of long-term sustained injudicious anthropogenic activity. Differences in land management practices that vary with land-tenure systems emerge as the main controlling factor to the spatial and temporal variations in vegetation degradation identified in this study. It is in this context that restoration measures could be undertaken.

Given such crisis levels of vegetation degradation, there is a need to adopt new grazing strategies so as to relieve the pressure on the communal lands. It is suggested that farmers should be allocated grazing land in the former commercial farmlands. This would enable the desired plant species in the affected areas to recover and improve their competitiveness. The use of the former commercial farmlands to date remains undefined since their expropriation from white farmers. The allocation of grazing land would halt the uncontrolled encroachment on these areas by the communal farmers.

In order to avoid a repeat of the appalling situation in the traditional villages, sound land management strategies have to be adopted in the allocated lands. Controlled grazing practices and realistic stocking rates commensurate with the veld carrying capacity should be adhered to. These ideals can only be realized with the full participation of the concerned communities in the process of defining suitable land management strategies.

Regulated burning could also be used as a control measure against invader vegetation species. *Pteronia incana* was particularly noted to be highly combustible due to its oily leaves and stem. It could possibly be eliminated by controlled burning. There is also an urgent need to reestablish suitable riparian vegetation along the banks of stream channels. This would assist in halting the widespread channel degradation observed in the traditional and betterment villages. Its impact is already evident in the form of excessive stream sedimentation.

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