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# Determinants and rates of land degradation: Application of stationary time-series model to data from a semi-arid environment in Kenya

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**Abstract:** The causes of land degradation in the African drylands have been shown to vary. Some researchers consider climate to be the major contributor to degradation, with anthropogenic factors playing a minor role. Others reverse the significance of these two factors. A third group attributes land degradation to climate and anthropogenic factors equally. This study was undertaken to establish the factors influencing land degradation in a semi-arid environment in southeastern Kenya and the rate of change in vegetation types for a period of 35 years (1973–2007). The reduction in grassland cover was used as an indicator of land degradation. Causes of land degradation were determined by a multiple regression analysis. A log-linear regression analysis was used to establish the rate of vegetation change. The multiple and log-linear regression analyses showed: (1) woody vegetation, livestock population and cultivated area to be the main contributors of reduction in grassland cover in the area, and (2) an increase in undesirable woody species, livestock population and cultivated area had a significant ($P<0.05$) negative effect on grassland vegetation. Increased human population, low amounts of rainfall and drought showed no significant negative effect on grassland vegetation cover. In conclusion, human and livestock population growth and increased agricultural land have contributed to intensive crop cultivation and overgrazing in the semi-arid lands. This overuse of the semi-arid rangelands has worsened the deterioration of the natural grassland vegetation.

**Keywords:** regression analysis; land degradation; grassland cover; semi-arid Kenya; Sub-Saharan Africa

## 1  Introduction

Land degradation is widely recognized as one of the most serious global challenges of our time, directly affecting over $250×10^6$ people and putting $1×10^9$ people at risk (Wessels et al., 2007). However, many observers consider land degradation to be highly variable, discontinuous, arising from different causes and affecting people differently according to their socio-economic status (Gisladottir and Stocking, 2005). It has a broad range of definitions that include, for example, soil erosion and long-term reduction in the amount or diversity of natural vegetation composition.

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However, it principally describes the reduced capacity and biological productivity of land (Wessels et al., 2004; Izzo et al., 2013). The definition of desertification by the United Nations Environmental Programme (UNEP) as 'land degradation in arid and semi-arid and dry sub-humid areas resulting from various factors, including anthropogenic factors and climatic variations' has been cited in previous studies (Wessels et al., 2004; Wang et al., 2013). Moderate to high sensitivity to land degradation because of climatic factors has also been highlighted in previous studies (Izzo et al., 2013). Land degradation is reflected not only by the reduced capacity of the land and soil to sustainably produce ecosystem services but also economic value.

Drylands provide a vital livelihood stream to people across the globe through a range of goods and ecosystems services they deliver. These ecosystems are under threat and thought to be in various degrees of degradation. The extent and impact of land degradation remains uncertain, with some sources routinely citing that up to 70% of the world's drylands are 'desertified' and others suggesting a figure of less than 17% (Gisladottir and Stocking, 2005). Amidst such discrepancies, it is generally agreed that land degradation remains a central problem to the sustainable development of drylands (Olukoye and Kinyamario, 2009). This is because degradation in the drylands threatens the subsistence of the local communities and their economic sustainability. Furthermore, degradation reduces the productivity of land, the value of ecological services and the ability to properly sustain an economy. Commercial ranches and pastoral livestock production systems are among the principal economic activities in the semi-arid environments (Nyariki, 2009).

Land degradation is a problem facing most developing countries, particularly in Sub-Saharan Africa (SSA). In Africa, up to 73% of the drylands and $268×10^6$ people (Gisladottir and Stocking, 2005) are affected by desertification. Dryland ecosystems of Africa are especially susceptible to degradation because they have a poor soil structure exacerbated by scarce vegetation cover (Lal, 2009). A drop in soil fertility, soil biodiversity loss and soil erosion by wind and water demonstrate degradation in semi-arid areas in Africa (Visser et al., 2007). In Kenya, land degradation in the arid and semi-arid lands (ASALs) has been extensively considered as a major environmental problem. Approximately 80% of Kenya is affected by land degradation (Adams and Watson, 2003). According to Nyangito et al. (2008), approximately 30–40% of Kenya's ASALs are rapidly being lost through degradation and an additional 2% have completely been denuded. Much of the soil erosion occurs when vegetation cover is removed, as this leaves the soil unprotected from water and wind. The principal degradation processes in the ASALs of Kenya are water and wind erosion, salinization, soil compaction and vegetation degradation.

Vegetation degradation is a worldwide phenomenon and is recognized as an important measure of degradation over different spatial and temporal scales in the dryland ecosystems (Visser et al., 2007). Changes in the composition of the herbaceous vegetation cover, grasses and herbs, exemplify the short-term indicators of vegetation degradation which are reversible. However, a shift in state from herbaceous to bushy dominated vegetation types is indicative of more permanent degradation (Bennett et al., 2012). Natural vegetation change from 'excellent condition' to 'poor condition' in the dryland environments triggers a subsequent but comparative increase in the dominance of unpalatable plant species over the more preferred palatable plant species (Kassahun et al., 2008; Angassa, 2014). Degradation in the ASALs of Kenya is induced by a combination of human activities such as grazing, ploughing, mining, fire and deforestation, and changes in the climate characterized by cyclical and short-term droughts and episodes of floods.

A decrease in vegetation cover to almost zero due to sustained high pressure of the grazing animals affects the soil surface. This is because bare patches increase raindrop impact and splash erosion. Erosion is often mentioned as the main cause of soil degradation (Nyangito et al., 2009). Additionally, trampling enhances soil compaction and breakdown of soil aggregates. Moreover, physical-chemical and biogenic crusts appear and the density of surface stones increases (Cerdà and Lavee, 1999). However, trampling can also improve the soil structure through incorporation of organic materials, animal manure and urine enhance soil fertility. Furthermore, only some