Restoring Degraded Rangelands in Northern Kenya Using Buffel Grass

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Abstract— *This review paper seeks to explore the potential of buffel grass (Cenchrus ciliaris L.) in the fight against land degradation within arid and semiarid areas of the world, especially Kenya. Soil degradation impacts 1. 5 billion people globally and more than 60% of the Earth's land surface experience poverty, hunger, and environmental pollution. The current drought cases in ASAL countries, including Kenya, exhibit the need to develop effective land restoration approaches. Several studies have reported that Buffel grass has improved germination and initial growth rates, improved disease control, improved water use efficiency, and increased resistance to weeds, which makes it a tool that could significantly alleviate problems related to soil erosion, low soil fertility, and land degradation. This review integrates the literature and case study evidence and presents practical recommendations for policy makers, land owners and managers and all interested in land restoration. This study highlights how buffel grass can be incorporated into sustainable land management practices while considering risks to the environment.*

Keywords— Cenchrus ciliaris L., Drought tolerance, Controlled burns, Selective grazing, Carbon credits, Ecological stability.

I. INTRODUCTION

Currently, more than 40% of the Earth's land surface is experiencing degradation, and this percentage is increasing (Shao *et al*., 2024). Land degradation refers to the ongoing or prolonged depletion of natural resources on land. This poses a direct danger to the well-being of almost half of the world's population that depend on these land resources (UNCCD, 2022). Persistent land degradation will amplify the occurrence of poverty, hunger, and environmental pollution (Jiang *et al*., 2022). Areas that have been degraded will become more susceptible to disasters such as disease outbreaks, droughts, floods, or wildfires (UNCCD, 2022). As the world continues to suffers the impacts of climate change, a cyclical relationship between land degradation and poverty will become prevalent in several regions, particularly in arid environments (UNCCD, 2017). Degradation affects 12 million hectares of land each year, with estimates ranging from 10% to 20% of the world's drylands (James *et al.* 2013). A larger population in the Africa will be affected by this phenomenon as nearly half of Africa's population lives in dry and semiarid rangelands, which make up approximately 43% of the continent's total area according to James *et al*. (2013).

Approximately 65–70% of the rangelands in Sub-Saharan Africa are categorized as moderately to severely degraded, meaning that they have experienced a large decrease in plant cover, an increase in undesirable species, or both (Tamene and Le 2015). Kenya is among the nations most impacted by land degradation in terms of its degree, severity, and economic situation, as more than 80% of her landmass is inarable (Mganag *et al*., 2022). The North Kenya region is characterized by dry and semiarid conditions and has experienced delayed growth and underdeveloped economic conditions. Despite being the habit for 30% and 70% of humans and livestock, respectively, the area has long been plagued by poverty and drought which will be worsened by the continued degradation (Mganga *et al*., 2022). Land degradation in these areas is caused by climate change and poorly managed human activities, which accelerate desertification in these regions. Figure 1 below shows the land degradation status of drylands according to the USDA Natural Resources Conservation Service, highlighting the critical need for targeted conservation efforts in these areas, including Kenya.

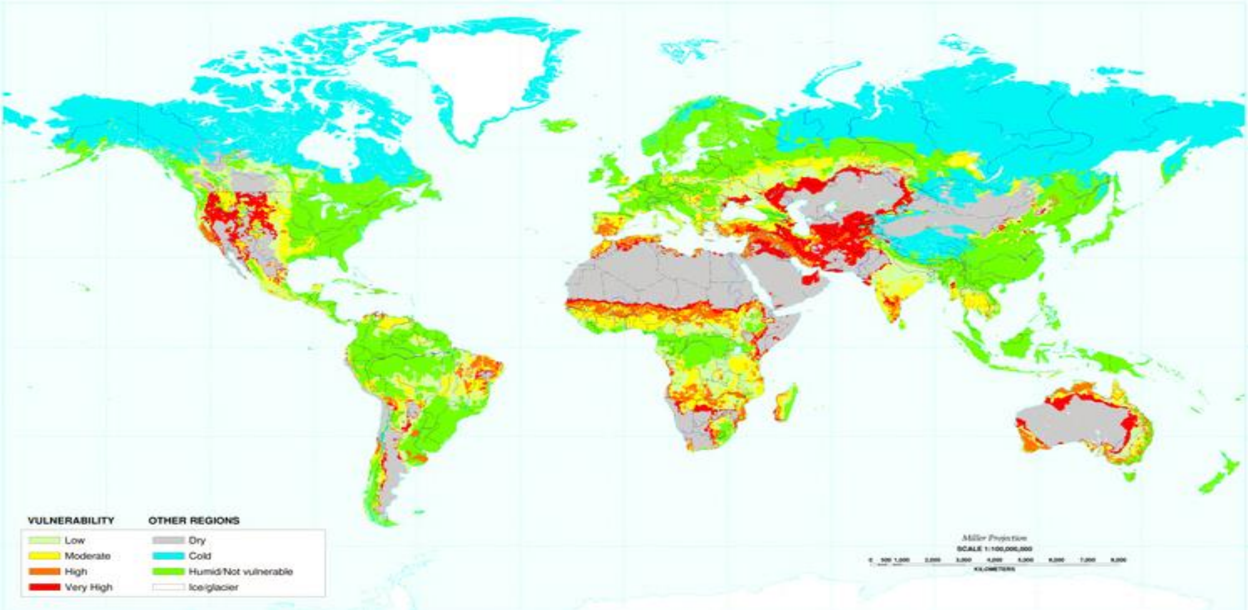

FIGURE 1: Vulnerability of Drylands to Land Degradation (Source: USDA Natural Resources Conservation Service)

In 2022, the Arid and Semi-Arid Lands (ASALs) counties of Kenya experienced unprecedented drought. This drought, which began at the end of 2020 and continued with five consecutive below-average rainy seasons, led to a significant increase in humanitarian needs according to the Office for the Coordination of Humanitarian Affairs (OCHA) ("Kenya 2022 drought response in review," 2023. The capacity of communities in the ASAL areas to cope was weakened by successive droughts, which led to a dramatic increase in food insecurity and severe malnutrition throughout the year. From January to December 2022, the number of individuals experiencing high acute food insecurity jumped eighty percent, rising from a projected 2.4 million in crisis (IPC Phase 3) or worse to approximately 4.4 million, with 1.2 million falling into emergency (IPC Phase 4) ("Kenya 2022 drought response in review," 2023. By December 2022, 2.5 million cattle had died due to the drought according to OCHA.

Approximately 885,000 children under five years of age and older than 115,700 women who were pregnant or nursing were projected to be acutely malnourished and in dire need of treatment by October 2022 ("Kenya 2022 drought response in review," 2023. In some regions, the incidence of acute malnutrition exceeds the emergency threshold. In addition to having to travel further to obtain food and water, women and girls saw an upsurge in gender-based violence, including sexual assault, early marriage, and female genital mutilation ("Kenya 2022 drought response in review," 2023. Reports of individuals seeking new livelihoods and aid in urban and peri-urban regions of the ASAL region increased, mostly from pastoralist groups. Additionally, in 2022, the United Nations High Commissioner for Refugees (UNHCR) reported that approximately 45,000 people seeking refuge in Kenya came from neighboring Somalia ("Kenya 2022 drought response in review," 2023. The socioeconomic dynamics of the ASAL regions are influenced to a greater extent by the adverse effects of severe climate events and droughts. Hence, finding appropriate strategies to reverse this trend and establish a thriving ecosystem is necessary.

Due to its extreme drought tolerance and ability to endure severe grazing, buffel grass (*Cenchrus ciliaris L.*) is extensively cultivated in tropical and subtropical dry rangelands worldwide. Buffel grass has been shown to have significant potential to mitigate soil erosion, enhance soil fertility, and restore degraded landscapes (Nkombe, 2016; Lebbink *et al.*, 2021). This review explores the mechanisms through which buffel grass contributes to land restoration and the best practices for its management to reverse the land degradation problem in the Kenyan rangelands. Here, we review the available literature to explore the role of buffel grass in restoring degraded rangelands and highlights the socioeconomic benefits of Buffel grass cultivation, including its impact on local communities' livelihoods and resilience against climate change. By synthesizing the current research and case studies, this review aims to provide actionable insights for policymakers, land managers, and stakeholders involved in land restoration efforts in these fragile landscapes.

II. LITERATURE REVIEW

2.1 Extent and Impacts of Land Degradation:

Although the exact percentage of degraded land varies from country to country, 67% (16.1 million km2) of Sub-Saharan Africa's total land area is shown by FAO TERRASTAT data. Kenya experienced 13% land degradation, and the variations among counties are considerable (FAO, 2000; Kirui *et al*., 2021). Approximately 14 percent of Kenya's landmass is considered degraded according to GLASOD data (FAO, 2000). The estimates of land degradation in Kenya differ based on the source and calculation methodology (FAO, 2000). Approximately 17% of the nation and 30% of its arable land might be at risk of land degradation, according to a 2006 study by Bai and Dent. This degradation could be characterized as "places where both net primary production and rain-use efficiency are diminishing" (Kirui *et al*., 2021). More land is degraded in the east and northeast regions of Kenya; 12.3% of the land is severely degraded, 52% is moderately degraded, and 33% is susceptible to land degradation (UNEP 2022). According to Bai *et al*. (2008), in 1997, moderate land degradation affected approximately 64% of Kenya's total land area, while extremely severe degradation affected approximately 23%. The latter rose to almost 30% at the turn of the 2000s (Bai *et al*. 2008). A more recent study by Le *et al.* (2014) indicated that 31% of croplands, 46% of forested land, 42% of shrub lands, and 18% of grasslands in Kenya degraded from 1982 to 2006. The Kenya Soil Survey reported land degradation hazard areas, as shown in the figure below.

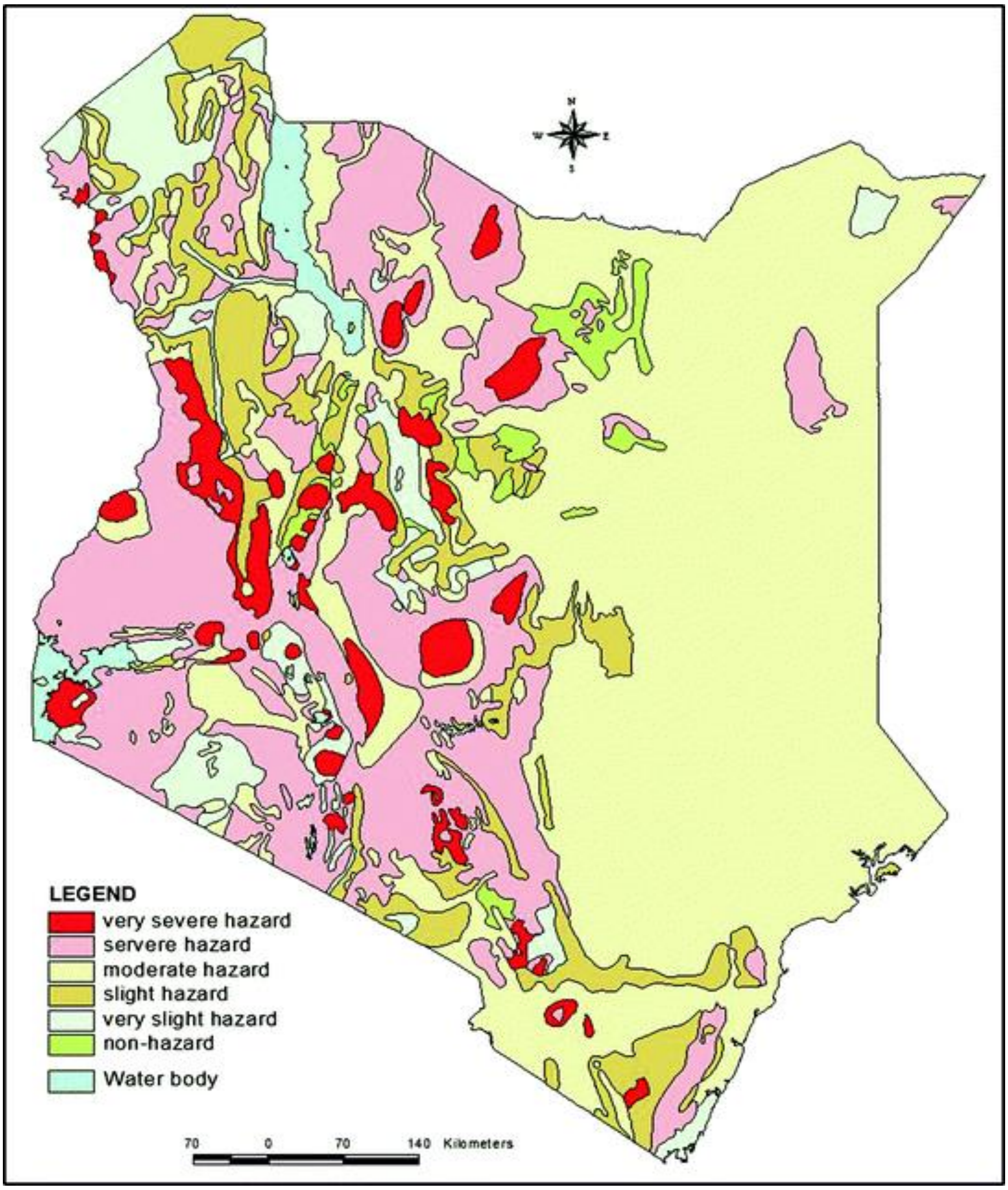

FIGURE 2: Land degradation hazard areas in Kenya. Source Based on Kenya soil survey

Figure 3 below shows some of the major causes of land degradation. Deforestation, desertification, rangeland degradation, wind and water erosion, soil fertility loss due to "soil nutrient mining," and soil erosion overall are the most significant land degradation issues in Kenya (UNEP 2022). In Kenya, the expansion of farming into marginal lands, such as in the drylands close to Lake Turkana and marginal agricultural land in the Eastern Regions, was a major contributor to land degradation. This degradation not only affects the ecosystem service supply, food security, and food pricing downstream but also affects other regions far from their sources.

Droughts impact the availability of water and feed, which hinders most livestock development operations in rangelands. During droughts, livestock productivity is severely limited due to insufficient conservation efforts and a lack of strategic feed reserve facilities. Prolonged drought events act together with other factors, such as the subdivision of pasture lands, and unsustainable land practices accelerate land degradation in these areas. Additionally, rangeland ecosystems are susceptible to a number of negative impacts caused by overgrazing (UNEP 2022). Many of the impacts are obvious right away, but others are subtle and may linger for a while. Soil, forage, water, and livestock interactions are all negatively impacted by overgrazing, which in turn disrupts rangeland systems. In only one year, overgrazing may cause tremendous damage to rangeland ecosystems (Gebrehiwot *et al*., 2022). In the long run, climate change will have detrimental effects on soil quality, native plant species, fodder production, weaning weights, and breeding rates, among other factors.

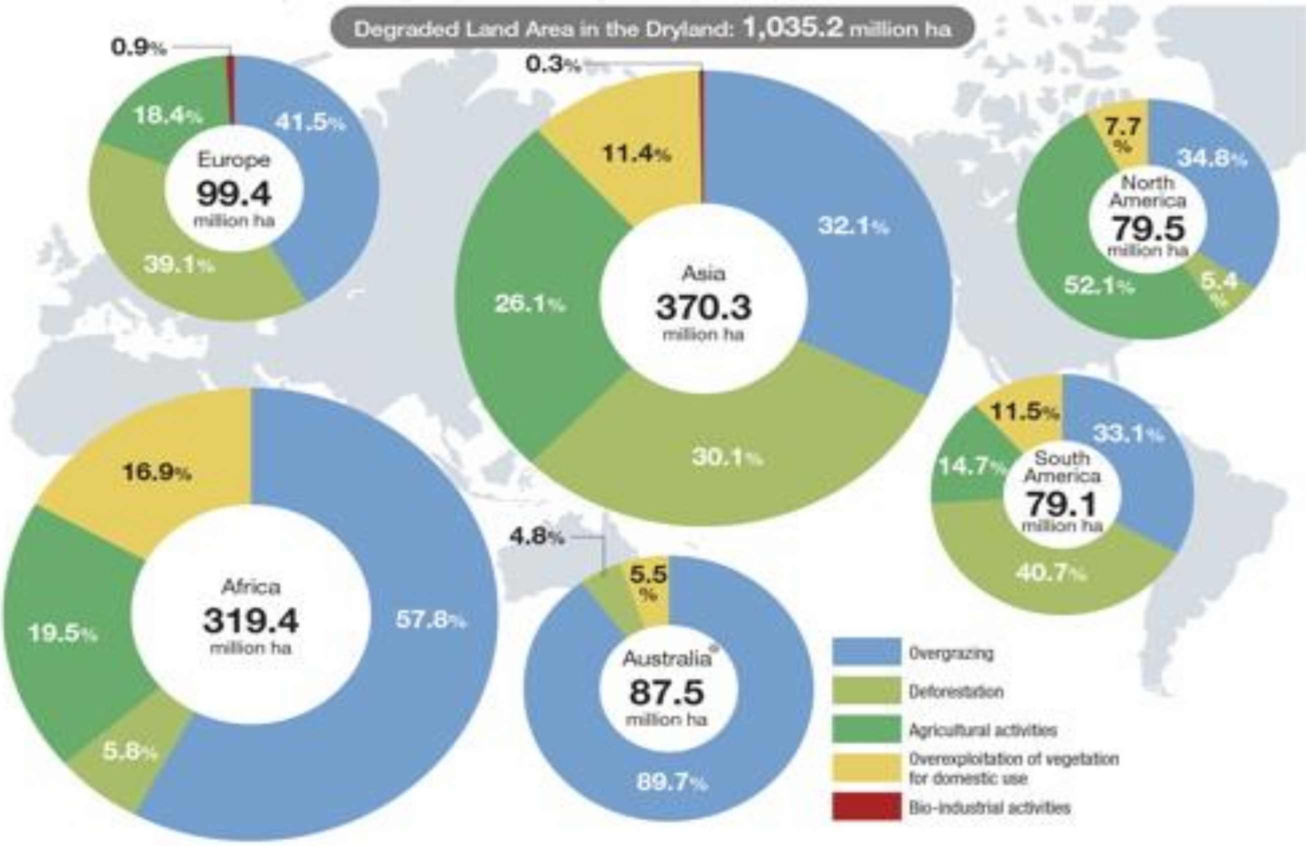

FIGURE 3: Causes of Land Degradation in Global Dry Ranges

The capacity for vegetation to absorb carbon decreases as landscapes degrade. Vegetation grows as a result of restoration strategies such as regenerative agriculture, natural forest regeneration, river restoration, regenerative grazing, reseeding with indigenous species, habitat conservation, and restoration of biodiversity. Soil organic carbon absorption increased by more than 10% after 20 years of landscape restoration, according to one Ethiopian study (Gebrehiwot *et al*., 2022). Because degraded land covers 75% of the world's usable land, restoration has a great chance of boosting carbon sequestration, which is an important measure in the fight against climate change. Additionally, restoring optimum pasture conditions is an important social and environmental goal for many governments, NGOs, and local community organizations. In the Kenyan rangelands, Buffel grass has the potential to act as a tool for pasture production and land restoration, hence enhancing the capacity of formerly degraded lands to sequester more carbon. Therefore, this species can be used to reseed disturbed areas as a native species owing to its adaptive nature and improve primary productivity in these rangelands.

2.2 Origin and distribution of Buffel Grass:

Buffel grass covers a large portion of the Earth's surface between 45 degrees north and south of the equator. Figure 4 shows the occurrence of these species throughout regions and nations. The grass was originally from the dry tropical and subtropical zones of western Asia and Africa, but it has since spread exotically to parts of Australia, the United States, Mexico, and South America (Marshal *et al.*, 2012). Buffel grass is native to Kenya and other sub-Saharan Africa countries.

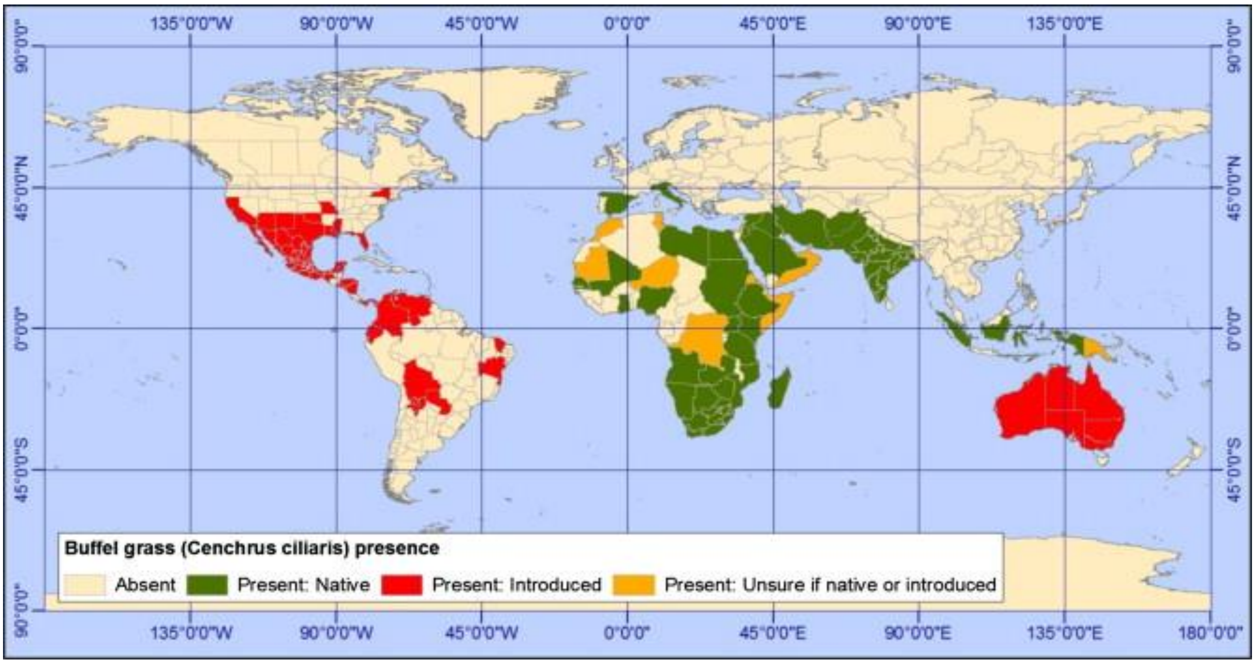

FIGURE 4: Buffel grass distribution according to Marshal et al., 2012

2.3 Nomenclature and morphology:

Buffel grass, scientifically known as *Cenchrus ciliaris L.*, is a resistant perennial tussock grass that grows in dry tropical and subtropical regions. There is considerable taxonomic uncertainty surrounding this species due to its diverse morphological and physiological traits and extensive geographic range; thus, several synonyms have emerged. The physiological and morphological variations among buffel grass types have been the subject of several studies. For instance, height, leaf area, number of leaves on the main tiller, number of internodes covered by leaf sheaths, number of branches per plant, and number of reproductive branches per plant accounted for the majority (38.7%) of the morphological variance among the 20 Buffel grass accessions studied in a Pakistani study (Arshad *et al.*, 2007).

TABLE 1
The physiological and morphological variations among Buffel grass types according to Arshad *et al*. (2007)

Trait	Dimension
Height	20-150 cm
Stem thickness	1-3 mm
Leaf	1.5–30 cm long
	3–8 mm wide
Roots	Max 2.4 m deep
Flowering	3 months after germination
Ligules	0.5-2 mm
Inflorescences	Yellow–purple–gray

Both natural selection and the commercial introduction of novel strains to increase pastoral land production have contributed to the emergence of intraspecific diversity. Improvements in disease resistance, improved growth rates, and tolerance to various environmental circumstances have led to the development of cultivars with these traits (Arshad *et al*., 2007). As a result, it may be crucial for efficient land restoration to have knowledge about which strains are suitable for which conditions. However, there is a dearth of research in this area, particularly in the Kenyan context. It is possible to classify commercial cultivars as tall, medium, or short. Cattle production often involves tall cultivars, which may reach a height of 1.5 m because they thrive in environments with richer soils and more rainfall. Rhizomes form, and the leaves often exhibit a bluish-green hue (Arshad *et al*., 2007). Typically, smaller types (<90 cm) are better suited to soils with a lighter texture, less tolerance of floods, and poor rhizome growth (Arshad *et al*., 2007). These materials are often utilized for sheep production and erosion prevention. The majority of Buffel grass species are apomictic (Bray, 1978), yet there are a small number of sexually active species (Akiyama *et al*., 2005). Wind, waterways, and foot and animal movements are ideal routes for the rapid dissemination of seeds. Additionally, rhizomes and stolons are capable of vegetative reproduction in certain plant varieties (Arshad *et al*., 2007). Because of this, one may see a wide variety of plant types throughout the landscape, from thick monotypic stands to tiny groupings or even lone tussocks.

2.4 Establishment and Environmental Requirements for Growth:

The most basic requirements for a species' conditions may be determined by learning about its germination, growth, and development needs. The germination of seeds and seedling emergence are the most important life history phases for every plant community in dry environments (Hardegree *et al*., 2018). The germination rates and lifetime of Buffel grass seeds have been the subject of a great deal of research because of the widespread use of this species as a pasture. For seeds to germinate, the soil must be moist (Ward *et al.,* 2006). A minimum of 6.3 mm of rainfall, spread out over two days, is required for Buffel grass seeds to sprout from loam soils. Ward *et al*. (2006) conducted a greenhouse investigation meant to mimic the summer wet season in Tucson, Arizona, where buffel grass is common. The results showed that seedlings exposed to three or four days of continuous simulated precipitation had the greatest chance of fresh emergence on days three and four. After the fourth day, the likelihood of fresh emergence decreased significantly. The results showed that during the summer wet season in one of two years in Tucson, the factors needed for the development of 50% viable buffel grass occurred (Ward *et al*., 2006).

On average, the optimal duration for perennial grasses to germinate in central Australia is thought to be approximately every twelve months (Jensen *et al*., 2022). The enormous lifetime of Buffel grass's seed bank—which ranges from 2 to 30 years—helps the grass endure rare germination opportunities (Friedel *et al*., 2007). It is possible for seeds to remain viable even after 8 months of dormancy on earth (Marshal *et al*., 2012). Germination rates for buffel seeds are best achieved at approximately 30 °C/20 °C day/night, yet they can sprout at temperatures as low as 10-40 °C. These numbers were derived for light/dark changes, continuous darkness, and continuous light (Innes, 2022). Research on germination in potting mix, clay, and paper towelling environments revealed that germination rates were greater for the former two substrates (Bhattarai *et al*., 2008).

Like tropical C4 grasses, Buffel grass plants exhibit superior growth performance; greater biomass; greater height; and greater leaf length and breadth when exposed to higher levels of CO2 (Bhattarai *et al*., 2008). According to Innes (2022), a plant's CO_2 absorption and water usage efficiency peak at 30/20°C day/night air temperatures, and they decline with increasing temperature until they die at 45/35°C day/night. According to Innes (2022), the ideal temperature for photosynthesis is 35°C. Buffel grass is tolerant of nutrient-poor soils. Nonetheless, there is evidence that higher nitrogen levels enhance water use efficacy (WUE), crude protein yields, and dry fodder production, whereas higher phosphorus levels widen the shoot/root ratio (Marshall *et al*., 2012).

2.5 Adaptations of Buffel Grass:

The tropical savanna is a typical habitat for C4 grasses such as buffel grass, which thrive in the summer when temperatures are high and rainfall is heavy (Marshall *et al*., 2012). Further characteristics of this biome include open canopies and thick understorys of grass that provide fuel for fires. Extremely low soil moisture levels prevent seedling emergence and subsequent plant growth, leading to sparse vegetation in dry and semiarid habitats as well as low, unpredictable, and occasional rainfall (Innes, 2022). For a number of reasons, Buffel grass is the only grass in this category that can thrive in extremely dry environments (Marsh *et al.*, 2012). Its deep root system (which can reach depths of up to 2.5 meters in some soils) allows it to reach water sources more quickly and for longer than other native herbs and forbs (Ines, 2022). It has a number of other interesting traits, such as the ability to store carbohydrates at the base of its stems for later use, longer seed longevity, and opportunistic germination (Mganga *et al*., 2021). There may be less competition, disease, and predation for buffel grass in dry areas. In regard to water, light, and nutrients, for instance, anecdotal data suggest that native plants are outcompeted by buffel grass in their habitat (Mganga *et al*., 2021). Paralid moths, which contribute to the decline of the species in tropical regions, as well as tropical diseases such as buffel blight (Magnaporte grisea), ergot, smut, rust, and blast, may have less of an impact on buffel grass in dry climates (FAO, 2011). In addition, the establishment and growth of this grass are affected by other factors, including climate, edaphic factors, topography and fire/disturbance.

2.5.1 Climate:

The climates in which buffel grass thrives are very varied. According to Innes (2022), it can withstand temperatures as high as 50 °C. However, Marshall *et al*. (2012) reported that these faults will not settle in areas where the mean yearly minimum temperature dips below 5°C. It can thrive in areas with yearly rainfall ranging from 250 mm to 2670 mm, and it can withstand a wide range of average rainfall (Innes, 2022). Compared to average yearly rainfall, temperature seems to be a more important constraint on the species' worldwide range. The impact of rainfall seasonality on the distribution of Buffel grass should not be examined in isolation from other factors, such as the likelihood of drought, tree survival, growth rates of woody vegetation, and disturbance probability.

2.5.2 Edaphic Factors:

Although Buffel grass may be grown in a variety of soils, it seems that certain types of textures are necessary for its long-term survival (Marshall *et al*., 2012). Soil types such as sandy, silty, and clayey soil promote seedling emergence; however, the rate of emergence decreases when the percentage of sand, silt, or clay approaches 100% (Marshall *et al*., 2012). Moreover, when planted in clay, silt, loam, or silty clay soils, plants progressively wilt and die (Mganga *et al*., 2021). Centre for Arid Zone Research (2001) and Van Devender and Dimmitt (2006) found that sandy and sandy loam soils are the favorites of grasses, although they can colonize loam soils as long as they have 90 days of summer growth and reasonably warm and dry winters (Cox *et al*., 1988).

According to Hoover *et al*. (2022), the ability of soil to hold moisture is usually associated with the significance of soil texture on plant development. Some Buffel cultivars have been engineered to resist floods, making them more suitable for heavy soils that contain moisture. When tropical regions' thick clay soils become too waterlogged for Buffel grass, they adapt to dry locations' lighter soils (Innes, 2022). As long as there is an adequate supply of nitrogen and phosphorus, the species may thrive even in less fertile soils (Mganga *et al*., 2021). According to Hoover *et al*. (2022), soil fertility might differ significantly depending on rainfall. In dry areas, Buffel grass may require particularly fertile soil to grow. When there is an abundance of manganese and aluminum in the soil, Buffel grass will not grow (Smith *et al*., 2021). Soils with a pH between 7 and 8 work best for seed dispersal according to research conducted in Tanzania (Cook, 2007).

2.5.3 Topography:

The elevation range of Buffel grass may be anywhere from sea level to 2,000 meters. Grass often takes root in landscape depressions on a smaller scale (Marshall *et al*., 2012). Depressions provide a moist place for establishment and shelter from grazing, which is especially important in dry regions. C4 species, on the other hand, are physically unable to dominate closed-canopy ecosystems and instead prefer open, light-filled environments.

2.5.4 Fire and disturbances:

According to Innes (2022), buffel grass contributes to a higher fuel load, which in turn causes more frequent and powerful fires than what dry landscapes normally experience. Resurfacing initially on ash beds creates a self-reinforcing feedback loop that permanently changes the invading system (Mganga *et al*., 2021). The deep-penetrating root system and long lifespan of individual tussocks allow Buffel grass to resprout from preexisting tussocks after fire, which is one of several physiological traits that allows it to react so rapidly to rain and fire (Novak *et al*., 2021). One study showed that Buffel grass cover doubles following a fire (Marshall *et al*., 2012), and there is some evidence suggesting that aboveground biomass recovers faster after more severe fires (Innes, 2022). According to Innes (2022), the amount of disturbance needed for establishment could be influenced by the competitiveness of nearby flora. The initial effect of fire is to lessen competition from nearby plants and to slow the recruitment of young woody plants; this prevents the landscape from recovering and leaves it open to quick colonization by fast-growing species such as buffel grass. According to Mganga *et al.* (2021), after a fire, Buffel grass may be able to quickly take advantage of the soil's temporarily increased available phosphorus. While further study is needed to corroborate this, we have shown that once established, it may not need disruption to spread, and we think that rhizomes might play a role in this.

III. RESULTS AND DISCUSSIONS

3.1 Ecological Benefits:

The capacity of buffel grass to adapt to higher temperatures, endure, and provide profitable grazing makes it an essential pasture species for rangeland regions, and this ability may become even more significant under climate change conditions. Given the potential decline of other plant species due to climate change, biochar has the potential to become a significant soil stabilizer in arid regions. One documented application of grass in rangelands is erosion prevention and soil stabilization (Marshall *et al*. 2012). By stabilizing the soil through its extensive root system, Buffel grass decreases the likelihood of wind and water erosion. The large root network of this species helps bind soil particles, which in turn prevents soil loss and keeps the soil fertile, according to studies by Kimiti *et al*. (2017). By restocking native seed banks, boosting carrying capacity, improving primary production, and increasing plant cover, active restoration approaches may help mitigate soil erosion in semiarid rangelands of Africa (Mganga *et al*., 2021).

For instance, prior research has shown that seeding *C. ciliaris* seeds into a degraded African rangeland results in low-cost erosion barrier grass restoration (Kimiti *et al*., 2017). Therefore, herbaceous cover was greater even in areas where other types of grass were unable to take root. Enclosures reseeded with *Euphausia superba* and *C. ciliaris* in a semiarid rangeland in Kenya boosted biomass output by a factor of up to 10 (Mganga *et al*., 2021). Because of its high biomass output, sorghum leaves behind an abundance of litter, which breaks down and enriches the soil with nutrients. Soil organic carbon levels and general soil health are both enhanced by this procedure.

Perennial grasses native to rangelands in Africa can be used for ecological restoration for several reasons. First, they are already well adapted to their environment. Second, they are efficient seeders and dispersers of seeds (Wright *et al.*, 2021). Third, these plants undergo high tillering and nutrient translocation to protect themselves from herbivory and fires. Finally, they can be used as a source of additional income by selling hay and seeds. Grazing exaptation is an adaptation that occurs in C4 perennial grasses found in African rangelands because these grasses are drought resistant (Wright *et al*., 2021). A thicker root rhizosheath and a widespread network of fine roots are the techniques by which C4 grasses withstand drought (Mganga *et al*., 2021). An abundance of roots in the top 0–30 cm of soil allows these grasses to make the most of the infrequent and light rainfall (Marshall *et al*., 2012). The extensive root structure of grass increases soil porosity, which in turn promotes water penetration and retention. In dry areas, when water is scarce, this is very helpful. During dry seasons, improved water retention helps to retain plant cover and ecosystem production. Because C. ciliaris L. can root up to 2.4 meters deep, it is able to access deeper layers of soil for water intake (Marshall *et al*., 2012).

The reclamation of degraded pasture areas has led to extensive and fruitful use of buffel grass. For instance, mechanical treatments and the introduction of kapok bush (*Aerva javanica*), buffel grass, and birdwood grass (*Cenchrus setiger* Vahl) during restoration in the 1960s greatly improved conditions in the Ord River watershed in western Australia (Friedel *et al*., 2006). Active soil erosion had mostly eased by 2002, large gully systems had stabilized to some extent and were anticipated to improve further as ground cover increased, and large colonies of introduced *Cenchrus spp*. dominated the most vulnerable and severely degraded regions. Perennial grasses, both native and imported, formed a thick ground cover throughout much of the region. There have been effective uses of buffel grass for land reclamation on pastoral land in central Australia, where rainfall is much lower, as was the case for Bastin in 1991 according to Friedel *et al*. (2006). The article mentions its usage for revegetation and erosion control in parks and reserves, as well as for dust control at the Alice Springs airport and in the vicinity of many Aboriginal communities. After being rehabilitated using Buffel grass, central Queensland's postmining area has been put back into pastoral use (Bisrat *et al*. 2004). These case examples indicate the successful utilization of buffel to restore and reclaim degraded lands, resulting in ecologically thriving landscapes with substantial economic and social benefits.

3.2 Management Practices:

3.2.1 Establishment Techniques:

The successful establishment of Buffel grass involves site preparation, seed selection, and planting methods. Planting Buffel grass requires the same soil preparation as planting any other crop, plus an additional procedure of ensuring that the seedbed is either mechanically firmed or has settled down (Wied *et al.,* 2020). It is sufficient to use relatively shallow tillage to obtain soil aggregates with a medium texture, absorb organic matter residues, and eradicate weeds (Cook, 2007). To compact loose seedbeds, one might use a roller or be "cultipacked." Additionally, it has been established that buffel grass can be effectively grown in a variety of planters. Used on very uneven terrain, track-type tractor exhaust tack seeders disperse the material in a random fashion. If not overgrazed, six or seven harvests may continue to occur on well-fertilized buffel grass (Cook, 2007). Fertilizer is effective on Buffel grass, as it is effective on the majority of grass species. Soil analysis is necessary prior to implementing a fertility program. Potassium is seldom necessary in Buffel grass regions due to the high levels of natural potassium in most soils.

3.2.2 Grazing Management:

Buffel grass is a valuable forage resource for livestock. However, overgrazing can lead to its decline and consequent land degradation. In regard to livestock and environmental goals, grazing management is key for achieving a balance between pasture quantity and quality. The profitability of farms that rely on pasture for animal feed will also improve. Compared to a poorly grazed pasture, a well-grazed pasture has greater productivity, lifespan, and feed quality (Rhodes *et al*., 2023). Grazing managers need to be able to time the movement of animals between paddocks, evaluate the different phases of pasture development, and set significant benchmarks for pasture. Overgrazing or selective grazing may eliminate valuable species from a paddock, and leaving livestock there for too long can lead to erosion and deterioration of the pasture. However, a shift in pasture composition, poor utilization rates, or an increase in waste may result from undergrazing or excessive rest, which in turn reduce feed quality (digestibility and protein content). One beneficial management strategy that is gaining popularity is regenerative grazing, which typically entails a combination of rotational grazing and selective rest to hasten landscape regeneration.

Multiple studies conducted in Australia in the last few years have shown that regenerative grazing strategies may enhance ecological conditions, including plant richness and variety. According to McDonald *et al*. (2019), strategic-rest grazing resulted in considerably greater total ground cover and animal output per hectare than did continuous grazing management. According to McDonald *et al*. (2019), compared to continuous grazing, increasing the amount of rest relative to grazing time resulted in increased plant biomass, vegetation cover, animal weight growth, and animal output per hectare. Lawrence *et al*. (2019) noted that under short-duration grazing, there was an approximately 19% increase in the ground cover of perennial species, with higher-value forage species being more abundant. Research conducted by Kisambo *et al*. (2023) on buffel grass highlighted the substantial impact of clipping management on important morphological and production parameters across rangeland grass ecotypes. The findings of the present study also indicated that the grass ecotype produced the best results when clipped at 10- and 15-centimeter intervals and with 4-week and 12-week delays between cuts. In grazing fields with native grasses, the most productive defoliation strategies occur either moderately or at low frequencies.

3.3 Potential Challenges:

Buffel grass has been linked to a decline in native plant diversity and abundance, a reduction in tree recruitment, and an increase in fire severity that alters the structure of woodlands in the rangeland region. Invertebrates, reptiles, and native mammals all exhibit a decrease in variety because of this change (Marshall *et al*. 2012). These issues will likely worsen as a result of increased density and the use of buffel grass as an infill material due to climate change. Compared to fire and unpredictable rainfall, Buffel grass competition was the strongest predictor of native biodiversity loss in 28-year-long studies (Mganga *et al*. 2021). Buffel has a direct impact on the survival of several native plant species, including those that are at risk of extinction. In addition to influencing species and faunal assemblages, buffer invasion alters the structure and composition of vegetation, which may increase the likelihood of extinction (Innes, 2022). Buffel planting in dry and semiarid areas has had a detrimental effect on local plant and animal species diversity according to substantial evidence. Preventing the introduction of new genetic material, increasing control efforts in areas where the plant is scarce (which may include confinement), and setting up quarantine barriers to stop intrusions into nature reserves are all possible approaches to management (Innes, 2022). Controlling its proliferation and balancing its usage with the protection of local plants need effective management measures. Furthermore, the large biomass of Buffel grass might increase the vulnerability of drought-prone regions to fire (Kisambo *et al.*, 2023; Rhodes *et al*., 2023). The capacity of Buffel to change invaded habitats into dense swards and enhance fire connectivity in formerly sparsely or patchily vegetated regions allows it to increase the frequency, severity, and extent of fires; this makes it a transformer species. Controlled burns and firebreaks are two fundamental fire management methods that are vital for reducing this risk.

IV. CONCLUSION

Buffel grass (*Cenchrus ciliaris L.*) has significant potential for preventing land degradation in arid and semiarid regions, especially in Kenya. Due to its tolerance to drought and high ability to withstand overgrazing, it is useful for reestablishing degraded soils, controlling soil erosion and improving soil fertility in many rangeland landscapes. Moreover, there are socioeconomic advantages associated with growing Buffel grass, including an enhanced standard of living for people in the region in the wake of climate change. The features of high adaptability, fast growth rates, and well-developed root systems help grass establish more hostile conditions and enhance the existing stocks of carbon and ecosystem stability. However, Buffel grass should be adopted very carefully because the impact of this grass on native wildlife and the balance of ecosystems could be rather negative. Although Buffel grass can enhance the quality of degraded lands, it has certain disadvantages, such as elevating the level of fire intensity and putting pressure on indigenous species. However, management practices could play a critical role in optimizing the use of buffel grass as a forage and in restoring land in addition to reducing the negative impacts caused by its utilization.

V. RECOMMENDATIONS

Integration into Sustainable Land Management (SLM) Strategies: County governments and national land use agencies should include buffel grass in SLM measures where vulnerability to degradation is most likely to occur. The relevant authorities should develop guidelines and best practices that will enhance its benefits while minimizing its negative impacts on the environment.

Capacity Building and Education: Local communities and farmers as well as landowners should be educated on the advantages and disadvantages of growing Buffel grass. Another recommendation is to strengthen the participation of communities in the restoration of land, thus supporting more of their views and local knowledge on land management.

Balancing Conservation and Utilization: County and national governments should develop strategies to balance the use of Buffel grass with the protection of native biodiversity. Additionally, the planting of buffel grass together with other native plants should be promoted to improve the stability and variety of the ecosystem.

Policy and Regulatory Frameworks: Policies and legal instruments should be established concerning the use of buffel grass, especially for land restoration. Additionally, collaboration with relevant government departments, NGOs, and local people to achieve sustainable land management efforts is recommended.

Climate adaptation and mitigation: Identify areas that include buffel grass in other climate action approaches, such as climate change adaptation and mitigation, since the plant is capable of enhancing carbon sequestration. Authorities should explore opportunities for carbon credits and other incentives to promote the use of buffel grass in land restoration efforts.

Therefore, even though buffel grass is very effective for land restoration and as a forage in arid and semiarid landscapes, it must be used cautiously, with a special focus on ecological consequences. Hence, through the use of research and partnerships, Buffel grass can help in reclaiming degraded landscapes and providing resilience against the effects of global climate change.

STATEMENTS AND DECLARATIONS

The authors declare that there are no conflicts of interest. The authors alone are responsible for the accuracy and integrity of the paper content.

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