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Perspectives on the assumed causes of land degradation in the rangelands of Sub-Saharan Africa

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Abstract

Soil erosion and land degradation are serious problems in tropical Africa, especially Sub-Saharan Africa, where they are widely recognized as more serious problems than in non-tropical areas. Sub-Saharan Africa experiences deleterious levels of soil erosion, largely due to the interaction between harsh climates of high erosivity, fragile soils of high erodibility, steep slopes, and poor natural resource management. The fundamental challenge is to separate purely background-level soil erosion due to biophysical, geomorphic, topographic, and climatic conditions from what is caused by humans. This review shows that the human-induced causes of soil erosion and land degradation in Sub-Saharan Africa are not fully understood and some of the commonly listed causes may not always stand the test of critical scrutiny. The popular views of human-induced soil erosion and land degradation not only fail to take into consideration the fact that land degradation is primarily a physical process, but also they do injustice to adaptive ecosystem management by the local inhabitants. The review specifically questions the stereotypes of overpopulation, overgrazing, deforestation, overstocking, and general rangeland degradation due to human resource use in Sub-Saharan Africa. Empirical evidence suggests that biophysical factors including soil properties, climatic characteristics, topography, and vegetation can sometimes interact among themselves to yield high soil erosion and degradation rates independent of anthropogenic impacts.

Keywords
land degradation, overgrazing, rangelands, soil erosion, Sub-Saharan Africa

I Introduction

Humans have interacted with their environments on the African continent perhaps longer than any other ecosystems in the world, thereby yielding a long and complex history that has stimulated investigations (Asfaw et al., 2002; Bonnefille, 2010; Reynolds et al., 2011; Woldegabriel et al., 1994). One of the unfortunate outcomes of the human-environment interactions is land degradation through soil erosion: the detachment, transport, and deposition of soil (usually topsoil). Energy for the erosional process is supplied from physical sources including the action of wind and water, chemical reactions, perturbation from animals, and anthropogenic activities (Lal, 2001). Although soil erosion is an important land forming process

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(Dunne and Leopold, 1978; Toy et al., 2002), it is also associated with severe economic and environmental impacts throughout the world (Crosson, 1995; den Biggelaar et al., 2001; Lal, 1998; Pimentel and Kounang, 1998; Pimentel et al., 1995; Telles et al., 2011). Irreversible damage can occur when erosion rates exceed soil formation rates (Wiebe, 2003). Soil erosion usually exacerbates the land degradation process, i.e. long-term decline in soil quality and productivity, and a general reduction in attributes of the land that perform functions of value to humans and life in general (Doran and Jones, 1996; Johnson et al. 1997; Karlen et al., 1997; Lal, 1997, 2001). Usually soil erosion and land degradation operate in tandem, with each exacerbating the other.

In the tropical region of Africa, especially Sub-Saharan Africa, soil erosion is widely recognized as a more serious problem than in non-tropical areas (Lal, 1990, 2000, 2001; Sanchez, 2002; Sanchez and Swaminathan, 2005). Soil erosion and land degradation contribute significantly to the problem of food insecurity that plagues the region (Lobell et al., 2008; St Clair and Lynch, 2010). Estimates show that losses in productivity of land in Sub-Saharan Africa are close to 1% annually, which suggests productivity loss of at least 20% over the last 40 years (World Meteorological Organization, 2005). Research shows that the situation is bound to worsen as demand for food is expected to increase up to fivefold by 2030, while per capita arable land area dedicated to crop production continues to shrink because of population growth and soil degradation (Daily et al., 1998; Lal, 2009; Lobell et al., 2008).

A number of reasons have been proposed to explain why the tropics experience such deleterious levels of soil erosion. They include harsh climates of high erosivity, the prevalence of fragile soils of high erodibility, steep slopes, poor land management, and predominantly resource-poor farmers who cannot afford to adopt conservation-effective measures (Lal, 2009; Lobell et al., 2008; Podwojewski et al., 2011). Understanding the interactions of climate, human socio-economic activities, and soil degradation in Sub-Saharan African landscapes presents a serious methodological issue. The fundamental challenge is to separate purely background-level soil erosion due to biophysical, geomorphic, topographic, and climatic conditions from what is caused by humans. The initial paradigm that gained prominence among policy-makers and development agencies working in Africa in the 1980s and 1990s was that soil erosion and land degradation is essentially a function of poor land management practices of the inhabitants due to ignorance and lack of education (Kimaru and Juma, 2005). That initial paradigm was drawn from the paternalist ideology that was established in Sub-Saharan Africa during colonial times but which was embarrassingly reinforced by independent states (Stocking, 1995). The tenets of the paternalist model included using selective measurements to identify an environmental problem and determining technical solutions that are then forced upon the 'ignorant' indigenous people. This model is despite the fact that Sub-Saharan Africa had a long history of indigenous soil conservation practices that included ridging, mulching, construction of earth bunds and terraces, multiple cropping systems, fallowing and planting of trees (Igbokwe, 1996; Junge et al., 2008; Scoones et al., 1996). However, increasing scientific evidence is fueling the potential for a paradigm shift to biophysical factors and rainfall fluctuations associated with climate variability as the primary cause of soil erosion and degradation (Eklundh and Olsson, 2003; Hellden, 1991; St Clair and Lynch, 2010; Tucker and Nicholson, 1999).

The soil erosion and land degradation processes can endanger the livelihoods of millions of Sub-Saharan Africans, especially those who live in the rangelands including the Sahel, and if allowed to persist it might become even more widespread. Rangelands cover by far the greatest

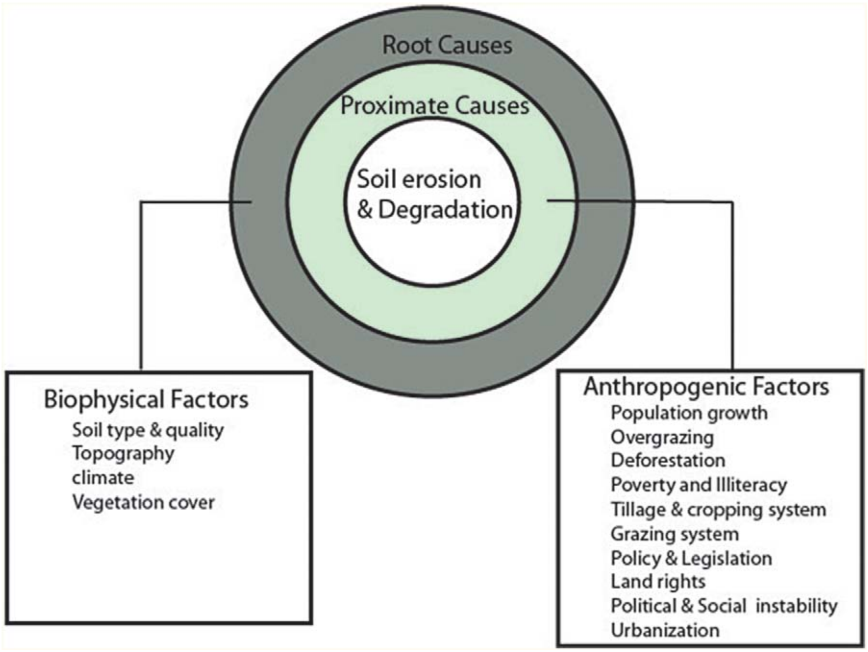

Figure 1. A schematic showing some of the proximate and ultimate causes of soil erosion and land degradation.

part of the Sahel (Warren, 2005). To date the efforts geared towards combating soil erosion and degradation in the African rangelands have only achieved mixed results (Carr and Mpande, 1996; Niamir-Fuller, 1998, 1999; Reynolds et al., 2007; Warren, 1995). That is despite substantial physical and monetary investments in mitigation schemes, and increasing global awareness of the problems of soil and land degradation. One of the reasons for the mixed results has to do with how policy-makers conceptualize the problem, especially the root causes. This paper reviews some of the assumed basic anthropogenic causes of soil erosion and degradation in the African rangelands and problematizes the significant issues involved in the current understanding of the assumed causes.

What will emerge in this review is that the human-induced causes of soil erosion and degradation in Sub-Saharan Africa are not fully understood. Whereas some researchers appear to focus on the immediate (proximate) causes, others see more sense in studying the root (ultimate) causes (Figure 1); hence the changes in viewpoint and possible paradigm shifts. In most cases it takes interaction between human activities and the biophysical environment for soil erosion and land degradation to occur (cf. Kiage, 2010; Lal, 2001) (Figure 2). However, most literature and reports have tended to exaggerate anthropogenic impacts relative to the biophysical predisposition of the land. Biophysical factors including soils, climate, topography, and vegetation cover have important roles in the soil erosion process. For instance, the inherent properties of soils (e.g. texture, structure, organic matter content, clay mineralogy, and water retention properties) determine the erodibility of the soils. Topographic conditions, such as the steepness, length, and shape of the slope, control the rates of erosion, while rainfall characteristics, including intensity, amount, and

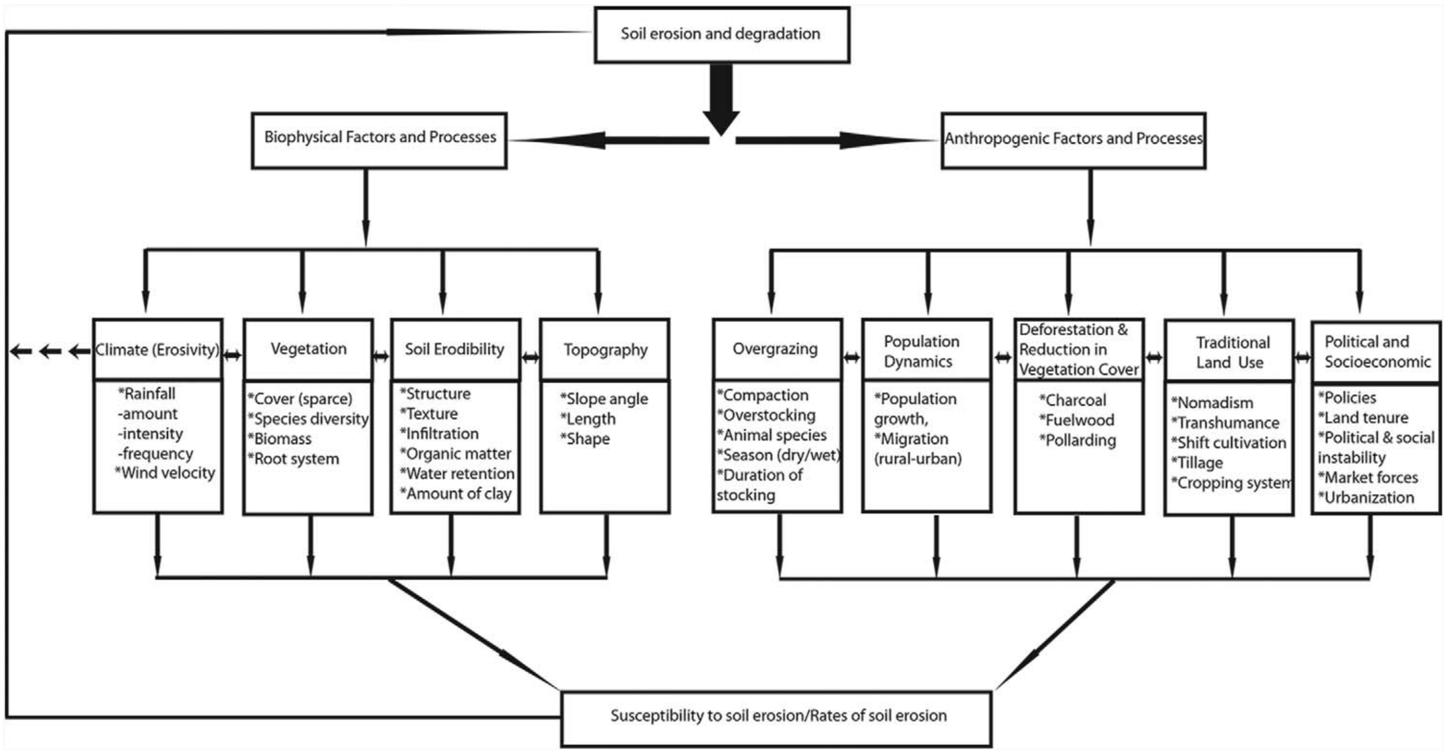

Figure 2. The interaction of biophysical and anthropogenic factors during the soil erosion and degradation processes. Although both anthropogenic and biophysical factors affect the susceptibility and rates of soil erosion, the interaction among biophysical factors could also cause soil erosion.

frequency, influence erosivity (Lal, 2001). These biophysical factors often require the influence of human activities to cause soil erosion but can, in fact, interact among themselves to cause soil erosion. By highlighting the predisposing role of biophysical factors in the soil erosion and land degradation process, this review should not be construed as geared towards diminishing the influence of inappropriate human activities in the soil erosion and land degradation process. In most cases, however, humans alter the vegetation cover in areas of high erosion susceptibility, thereby triggering the operation of biophysical contributors, which are the predisposing factors that contribute most to soil erosion. To challenge the stereotypes of overpopulation, overgrazing, deforestation, overstocking, and general rangeland degradation due to human resource use in Sub-Saharan Africa is not an easy task, and I recognize that some readers may disagree with some of my conclusions. That should not come as a surprise since this review does not address every form of land degradation – a subject of investigation for which scholars can bring their own unique insights and experiences into the debate.

II Background

On the global scale, rangelands (including grasslands, scrublands, and tundra) cover approximately 50% of Earth's terrestrial surface. They cover well over 30% of the total land area in the vast continent of Africa (Tappan et al., 1992). The African rangelands, mostly the savanna, are ecosystems whose vegetation is dominated by large expanses of grassland, interrupted by trees and shrubs, and where the main human preoccupation is agropastoralism (Hein, 2006; Pratt et al., 1966). Most of the rangeland ecosystems are situated in arid and/or semi-arid environments. Such ecosystems are often in constant flux, turning from almost desert conditions to green grassland and back by occasional events such as drought. The majority of the inhabitants of the rangelands are predominantly engaged in pastoralism although some arable agriculture is practiced by smallholders (Hoffman and Vogel, 2008; Kuiper and Meadows, 2002; Little, 1996; Mortimore, 1998). The African rangelands are largely characterized by relatively low human populations that tend to be mobile and distant from centers of decision-making, and therefore are often marginalized. Considering that rangelands often border the unproductive systems of the desert, its inhabitants have developed adaptive systems unique to these areas, which over centuries have enabled them to thrive in this fragile environment.

The challenges posed by land degradation in African rangelands came into the international limelight in the 1970s following fears of desertification that culminated in the United Nations Conference on Desertification in Nairobi in 1977 (UNCOD, 1978). In recent decades, there has been mounting concern that soil erosion and degradation is likely to accelerate as we enter an era of unprecedented climate change driven by anthropogenic impacts. In the 1980s, it was estimated that as much as 742 million hectares of Africa (about 26% of the total land area and 85% of rangeland area) had been affected, or was undergoing, moderate or severe soil degradation (Darkoh, 1993; Timberlake, 1988). The general picture emerging from literature on soil degradation in Africa does not inspire hope, especially when reputed institutions such as the Food and Agriculture Organization (FAO) described Africa's soils as being 'under attack' (FAO, 1990). Others such as the Worldwatch Institute painted an even bleaker picture, claiming that Africa's future is being written off (Brown and Wolf, 1986) while the map on the status of human-induced soil degradation also supports a picture of a generally serious condition (Oldeman et al., 1990) (Figure 3). Table 1 clarifies the classification used in Figure 3.

Perhaps the most dramatic assessment is the one offered in a report by the World Bank which

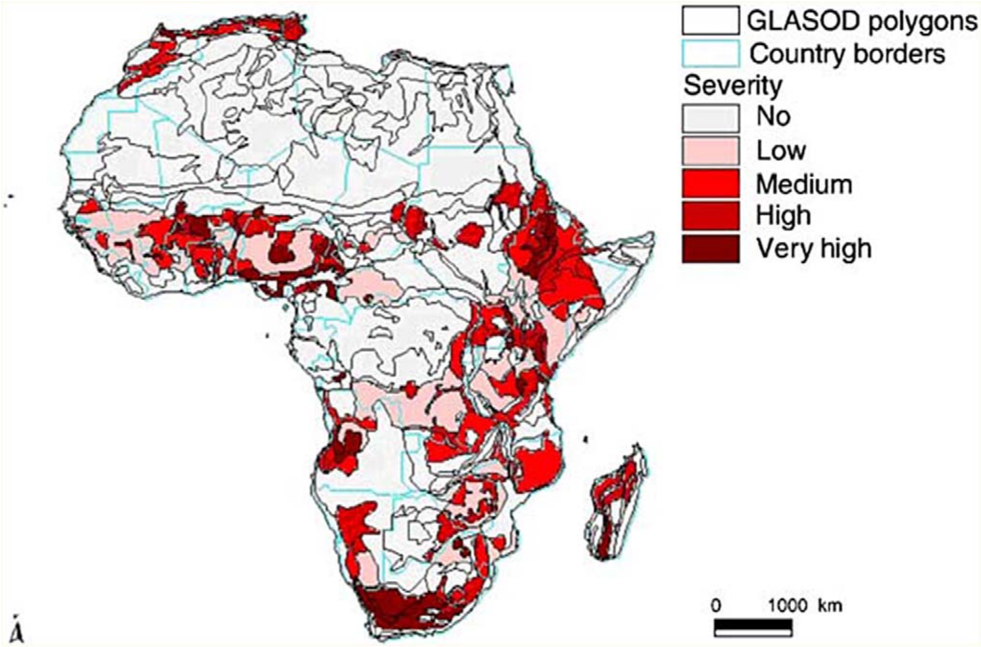

Figure 3. The Global Assessment of Soil Degradation (GLASOD; Oldeman et al., 1990) map of water erosion severity in Africa. Although the map is somewhat dated, and some changes may have occurred since its production, what is evident is that most of the areas with serious soil erosion are in Sub-Saharan Africa.

Table 1. Erosion classes according to the amount of topsoil lost per year (Symeonakis and Drake, 2010).

Soil erosion rate range (t ha^{-1} year^{-1})	Soil erosion class
0–5	Low
5–10	Medium
10–20	High
>20	Very high

states that 'estimates of land damaged through soil degradation range from moderate to apocalyptic' (Blackwell et al., 1991). However, these assessments of soil erosion and degradation need to be interpreted with a healthy dose of caution, because some of the reports and literature regarding the severity of erosion in Africa lack objectivity while others lack strong databases and are basically qualitative observations derived from reconnaissance surveys (Lal, 1990; Symeonakis and Drake, 2010). The extent and trends are hard to establish given that many agencies and individuals often use terms such as 'serious', 'significant', or even 'apocalyptic' without defining what they mean. Interestingly, as early as the 1920s soil degradation in Sub-Saharan Africa was already considered a scourge (Hailey, 1938). This poses the question: if the soil degradation is driven by humans and the situation has been 'catastrophic' for that long, why have the economies and the livelihoods of the inhabitants of Sub-Saharan Africa not collapsed (cf. Mortimore, 1998)? The fact that Sub-Saharan African economies and livelihoods have not collapsed raises the possibility of potential fundamental flaws in the statistics and their predictions. Some of the statistics on soil erosion and land degradation in Sub-Saharan Africa are wrong in the sense that they involve extrapolation of measurements taken at one scale to provide estimates based on an entirely different scale. In some cases, the policies adopted by some governments in the region were not

Table 2. Global extent of human-induced soil degradation (Lal, 2001).

World regions	Total land area (110^6 ha)	Human-induced soil degradation (10^6 ha)	Soil erosion (110^6 ha)	
			Water	Wind
Africa	2966	494	227	186
Asia	4256	748	441	222
South America	1768	243	123	42
Central America	306	63	46	5
North America	1885	95	60	35
Europe	950	219	114	42
Oceania	882	103	83	16
World total	**13,013**	**1965**	**1094**	**548**

necessarily drawn from experience but out of fear to avert soil erosion and land degradation. Most of the quotations predicting doom and hopelessness may be wrong because they are wrongly founded. The fundamental problem lies in the conceptualization of the perceived causes, especially the human-induced causes of soil erosion and land degradation in the region.

III Human-induced causes of soil erosion

Studies show that globally about 12×10^6 ha of arable land (slightly less than the size of the state of Mississippi) are destroyed and/or abandoned annually because of unsustainable use (den Biggelaar et al., 2001; Pimentel and Kounang, 1998; Pimentel et al., 1995; Valentin et al., 2005). Human-induced soil degradation is estimated at 2 billion hectares, of which soil erosion by water and wind account for 1100 and 550 M ha, respectively (Table 2). Sub-Saharan Africa is one of the hotspots of soil erosion (Lal, 2001). Although both biophysical and anthropogenic processes contribute to soil erosion (Figure 2) it is important to note that it is the latter that has been adversely cited in literature on soil degradation in Sub-Saharan Africa. The occurrence of widespread soil degradation in Sub-Saharan Africa is attributed to the mismanagement of marginal lands (semi-arid, steep slopes, shallow soils) in harsh and highly variable climates (Lal, 2000). The cultivation of marginal lands is an inevitable outcome of rapid population growth that leads to shortage of prime agricultural land. Whereas it is true that anthropogenic processes contribute a fair share to soil erosion and soil degradation processes, increasing empirical evidence (e.g. Kiage and Liu, 2009; Vlek et al., 2010) suggests that the assertion that 'soil degradation and desertification is caused almost entirely by the human misuse of the environment' (Cloudsley-Thompson, 1984) may be exaggerated because the process of soil erosion and degradation takes place within a biophysical environment whose role is often downplayed or ignored altogether. In some cases soil erosion and land degradation occur due to biophysical processes and events over which land users have little or no control (Nkonya et al., 2011; Vlek et al., 2010). A closer look at some of the assumed anthropogenic causes of soil erosion and degradation in Africa yields a different perspective, as demonstrated below through the examination of issues around: (1) population growth; (2) overgrazing; (3) traditional grazing systems; (4) deforestation and firewood collection; (5) political, socio-economic, and historical factors.

1 Population growth

Perhaps the most important human-related cause of soil degradation is the increasing pressure of human and bovine population. Sub-Saharan Africa has experienced phenomenal population growth since the beginning of the 20th century. Its population increased from 100 million in 1900 to 906 million in 2005 and, with an annual rate of growth of 2.2%, the region is expected to have approximately 2 billion inhabitants by 2050 (UNFPA, 2011). Such a rapid growth in population can lead to intensified stresses on natural resources, namely water, land, forest, and pasture, especially in rangeland ecosystems (Balasubramanian et al., 2007; de Rouw and Rajot, 2004; Jamu et al., 2011; St Clair and Lynch, 2010). The stresses on rangeland resources often translate to overexploitation through overgrazing, deforestation, overcultivation, and, to some extent, poor irrigation practices. The consequences of the stresses on the rangeland ecosystems are soil erosion and degradation that perpetuate food insecurity and poverty in Africa.

There is a general agreement among researchers that population pressure disrupted traditional farming systems of shifting cultivation and transitory resource use especially in the semi-arid environments (Droz and Sottas, 1997; Franke and Chasin, 1980; Kossoumna et al., 2010). Shifting cultivation, also known as bush and fallow rotation farming, involved clearing a bush or forested area, farming it for a period of years, and thereafter abandoning it, permitting natural regeneration. Typically, the abandoned land would be left fallow for up to a decade. Population increases have disrupted the fallow arrangement for natural recovery (de Rouw and Rajot, 2004). The inevitable outcome has been soil erosion and degradation. In some countries, the response to rising populations has been to attempt to resettle people on ‘vacant lands’, often at great cost, and seldom with sustained success because the so-called vacant lands are often semi-pristine forestland. This occurred in Sub-Saharan African countries such as Kenya in the 1970s and 1980s (Campbell, 1986). These programs were a significant cause of deforestation, and in some cases settlers were unable to adapt to their new environment, causing soil erosion and degradation (Darkoh, 1998; Kiage, 1998). This problem is also evident in the marginal semi-arid environments of rangelands where population spillover has had disastrous outcomes, including soil erosion, reduced productivity, and crop failures (Darkoh, 1998).

However, although population growth is variously associated with soil erosion and land degradation in Sub-Saharan Africa, those linkages are neither clear-cut nor direct. For instance, Tiffen et al. (1993) examined the interactions between people and their environment in eastern Kenya over a period of 60 years using conventional data, oral history, and photographic records. They showed that population growth, rather than causing soil erosion and land degradation, resulted in awakening renewed interest in land management that led to a reduction in soil erosion and general environmental recovery. This case clearly shows the ambiguity surrounding the impact of population growth and density on soil erosion and degradation. Evidently there are cases in Sub-Saharan Africa where more people have enhanced the local vegetation (trees and woodlots) and ultimately lessened soil erosion (Darkoh, 1998; Mortimore, 1998; Tiffen et al., 1993). Even in cases where population growth may be considered one of the causes of soil degradation, it is seldom the primary cause, but one that acts in conjunction with other factors such as drought, desiccation, rural poverty, and poor national policies.

2 Overgrazing

Overgrazing has been identified as a prominent cause of catastrophic soil erosion and degradation in many different environments, including the African rangelands (Karyotis et al., 2011; Podwojewski et al., 2011; UNEP, 1992) (Table 3). The unfortunate effects of the Sub-Saharan

Table 3. Main causes of soil degradation in the susceptible drylands of Africa (UNEP, 1992).

Causes	Area affected (M ha)	Area affected (%)
Overgrazing	194.4	15.1
Overcultivation (agricultural and over exploitation)	115.9	9.0
Deforestation	22.0	1.7
Total	332.3	25.8

droughts of the 1970s and the 1980s appeared to confirm the prognosis that overgrazing damages sustainability (Warren, 1995). In Sub-Saharan Africa overgrazing is largely linked to increases in human and bovine population following improved veterinary care for animals and better health care for humans while the grazing resource has remained unchanged. The effects of overgrazing are numerous. They include reduction in vegetation cover and trampling (which, depending on the type of livestock involved, may cause compaction and reduced infiltration or loosening of soil surface; Aksakal et al., 2011; du Toit et al., 2009), leading to the impoverishment of species composition, reduction of vegetation cover, and exposure of soil to erosion (Papanastasis, 2009; Thornes, 2007). Donkor et al. (2002) showed that animal hooves exert pressures of up to 200 kPa, which is considerably greater than the pressure exerted on the soil surface by a tractor ($\sim$110kPa). Based on erosion plot data from Mediterranean ecosystems, Cerdan et al. (2010) show a clear correlation between soil erosion and alteration of the vegetal cover; especially where the soil cover is often patchy. The net effects of overgrazing may resemble a drought even when precipitation remains unchanged (Dahlberg, 2000). Besides, overgrazing may raise dust that could stabilize atmospheric conditions with subsiding air masses and thereby reduce precipitation (Prospero and Lamb, 2003). Some observations suggest that this could be happening in the Sahelian-Sudanic zone of African rangelands (Taylor et al., 2002). If that could be confirmed, it could be argued that overgrazing contributes to both climate change and soil degradation.

However, the extent to which overgrazing contributes to soil degradation remains uncertain. For instance, the UNEP (Middleton and Thomas, 1997; UNEP, 1992) reports that overgrazing is responsible for 58% of soil degradation in the rangelands of Sub-Saharan Africa and affects up to 61% of African rangelands, and has done so for several decades. These statistics are, however, challenged by reality on the ground considering that the livestock economy in the African rangelands is yet to collapse years after they were derived (cf. Mortimore, 1998). The statistics and those behind them ignored the fact that African rangelands, and grassland vegetation in general, respond sensitively to variations in rainfall (Hein, 2006; Mortimore, 1998). For this reason, it is difficult to estimate the impact of grazing independent from rainfall, more so where nomadic pastoralism is practiced as in the African rangelands. A number of scientists (e.g. Coppolillo, 2000; Fratkin and Mearns, 2003; Perevolotsky and Seligman, 1998; Warren, 1995) suggest that grassland communities are not normally damaged by grazing. Animal mortality usually causes a fall in numbers that coupled with migration cushions land from damage. The controlling factor is actually the amount of dry season vegetation. When the rains return, usually insufficient animals remain to threaten recovery of the rangelands (Hiernaux, 1994; Mortimore, 1998).

Despite the alarming statistics, there is little evidence for overgrazing in the Sub-Saharan African rangelands because the term 'overgrazing' implies excessive use of forage by herbivores, with the result that biotic and abiotic components of the ecosystem are so changed that the system cannot recover within ecological time (i.e. years or decades) (Perevolotsky and Seligman, 1998). A simplistic mechanical attribution of soil erosion to overgrazing is not appropriate because the problem is not just one of overstocking. The state of the rangeland ecosystem is a function of the interaction between herbivory and vegetation which depends on many factors, including the season, duration of stocking, animal species, vegetation characteristics, climatic conditions, and presence of non-domestic herbivores (Perevolotsky and Seligman, 1998; Wilson and Macleod, 1991). Hence, caution must be exercised when evaluating the impacts of livestock populations on overgrazing and soil erosion. Evidence from Sub-Saharan Africa shows that in isolated areas where overgrazing has occurred other factors such as encroachment of cultivators, who diminish grazing resources, are to blame rather than overstocking (Darkoh, 1998). Indeed, apart from being incapable of inflicting permanent damage, grazing has some positive effects, such as promoting tillers. Some kind of disturbance is necessary for diversity and adaptability of ecosystems including those of rangelands (Mortimore, 1998; Williams and Balling, 1995).

A number of rangeland experts (e.g. Behnke and Abel, 1996; Ellis and Swift, 1988; Sullivan, 1996; Sullivan and Rohde, 2002) argue that most of the African rangelands experience extreme and highly unpredictable variability in rainfall to the extent that they do not conform to the conventional equilibrium ecological model given that they are continually in disequilibrium. Therefore, the rangeland management models predicated on equilibrium concepts of carrying capacity are ill-suited for African rangeland ecology (Sullivan and Rohde, 2002). Extreme variability and unpredictability in rainfall imply that the use of grazing resources by pastoralists in the African rangelands, which is uncritically listed as one of the primary causes of land degradation and desertification through overstocking, might not cause irreversible ecological change. Semi-arid ecosystems in Sub-Saharan Africa seldom, if ever, reach equilibrium because they are often in a state of flux, buffeted by fire, drought, insect attack, and (least of all) management (Ellis and Swift, 1988; Walker, 1987). Therefore, the equilibrium model and the accompanying carrying capacity concepts are often sidestepped because seasonal and long-term droughts control the herd sizes. In these systems droughts take a significant toll on the pastoralists, culling up to 70% of their herds, on average once every decade, such that subsequent rebuilding of herds do not reach the point of damaging or overgrazing the pastures before another drought intervenes (Ellis and Swift, 1988; Warren, 1995). Productivity in non-equilibrium environments such as the African rangelands is controlled by climatic events, particularly rainfall, not herbivory.

3 Traditional grazing systems

Nomadic pastoralist communities, such as the Maasai and the Pokot of East Africa, and the Fulani in West Africa, among others, regard ownership of large herds as a sign of wealth and status while land tenure is communal (Kiage, 1998). It has been argued that the communal ownership of land contributes to soil erosion and degradation patterns after the somewhat overworked Hardin's (1968) tragedy of the commons thesis.

However, a close scrutiny of the traditional grazing regimes in Sub-Saharan Africa shows that applying Hardin's (1968) tragedy of the commons would be a mistake. In fact, the concept of communal mismanagement of grazing resources has been widely questioned in the sense that it fails to consider the fact that nomadic pastoralist societies have evolved effective systems of managing common resources in the long-term interest (e.g. Behnke and Abel, 1996; Darkoh, 1989; Ellis and Swift, 1988; Homewood and Rodgers, 1987; Sullivan, 1996; Sullivan and Rohde, 2002; Ward et al., 2000). Darkoh (1989) and Ward et al. (2000) argue that the term 'common property' is largely misunderstood and falsely interpreted by outsiders who look at the practice using modern lenses. Proponents of

Hardin's theory and the arguments associated with it paid scant attention to some crucial environmental and cultural features of African grazing systems (Warren, 1995). Common property regimes in Sub-Saharan Africa were not the free-for-all that they have been painted to be. They were closed systems of structured ownership arrangements in which land was the inalienable common property of the members of the group or community. Elaborate institutional arrangements, rules and regulations existed that governed land use and ensured sustainable utilization of resources by members. Soil erosion and degradation, while mistakenly attributed to common property systems, actually began with the dissolution of local-level institutional arrangements whose very purpose was to give rise to sustainable resource use patterns. Darkoh (1989) argues that when local institutional arrangements were undermined or destroyed the traditional common property regimes gradually converted into open access in which the rule of capture drove each to grab as much as possible before others did. The dissolution of traditional local arrangements by colonial governments, and later by their successors, has not been followed by the establishment of more effective institutions. The reality in Sub-Saharan Africa is the 'tragedy of open access' rather than 'tragedy of the commons' (Darkoh, 1989).

Whereas it is true that large herds can put more pressure on the grazing resource base, the manner of exploitation is important. The composition of traditional herds is diverse, constituting browsers and grazers. While grazers such as cattle specialize on grasses, the browsers (goats and sheep) specialize on twigs and leafy vegetation. This minimizes damage to land especially where mobility is high (Oba, 1994). Hoffman (2003), citing the South African rangeland experience, suggests that because goats prefer bush and tree vegetation they open up some savanna woodlands, increase the ground cover, and might actually reduce soil erosion in the long run. Usually it is herders who keep goats in a locality for too long who might cause soil degradation (Oba, 1994). However, since nomadic pastoralists are constantly on the move in search of pasture and water, it is highly unlikely that their grazing activities might cause soil erosion, and ultimately land degradation.

4 Deforestation and firewood collection

As early as 1935, deforestation was already identified as one of the leading causes of soil erosion and degradation (Stebbing, 1935). Cases of charcoal burning and firewood collection, both of which might contribute to the decimation of tree cover, are widespread in many parts of Sub-Saharan Africa (Braimoh, 2006). Whereas it is true that deforestation may trigger or enhance soil degradation, determining the critical limits is difficult, especially in rangelands. Changes in woody vegetation are hard to measure because exploitation in the vast Sub-Saharan rangelands often takes the form of the collection of dead wood or harvesting from woodlots established for firewood (Kiage, 1998; Mahiri, 2003; Mahiri and Howorth, 2001). Nonetheless, the World Bank (1985) reported that firewood collection and use is a crucial factor in the degradation of the Sahel. This is reinforced by UNEP (1992) which states that over the last several decades deforestation or domestic exploitation of wood fuel or other uses have accounted for over 17% of soil degradation in Sub-Saharan Africa, almost all of it in the Sahel. This statistic implies an acute scarcity of firewood and the imminent collapse of energy systems in the region. However, this has not been observed even in the most densely populated areas in of the Sahel (Mortimore, 1998).

Further, conventional wisdom (Delwaulle, 1977; Eckholm and Brown, 1977; Warren and Khogali, 1992) suggests that 'intense fuelwood cutting causes the severest forms of rangeland degradation near urban areas'. Barrow

(1994) supports this view by documenting that Khartoum and Nairobi are surrounded by zones depleted of wood and dung for as much as 300 km from urban limits. Although firewood is the primary source of energy in Sub-Saharan Africa and may indeed have contributed land degradation in some regions, these views must be evaluated with caution because in some cases they cannot stand the reality check. For instance, in the case of Nairobi, Kenya, three observations from the area challenge the assertions of Barrow (1994): (1) in Kenya dung is not an energy option yet (Kituyi et al., 2001; Mahiri, 2003; Mahiri and Howorth, 2001); (2) the western city limit of Nairobi is occupied by a national game park wherein firewood collection is not only prohibited but is practically impossible due to the dangerous wild animals, such as lions and leopards, inhabiting the park; and (3) the other precincts of the city are agricultural districts which are known to supply the city with food and not firewood. It is true that charcoal is extensively used as an energy source in Nairobi but it is not necessarily sourced from the immediate neighborhoods of the city (Kituyi et al., 2001). Tiffen et al. (1993) actually report an increase in total area covered by vegetation and a general decrease in land degradation in Machakos district, which is within the 300 km ring of the supposedly deforested area. Yet, even if Barrow's (1994) contention were true, observations from elsewhere in Sub-Saharan Africa suggest otherwise. For example, Mortimore (1998) notes that Kano, Nigeria, one of the largest cities within the African rangelands, is surrounded by dense farmed parkland full of trees that maintained or increased its woods even through major drought cycles in the 1970s and 1980s (cf. Cline-Cole et al., 1990). Another example from Mali shows that, rather than leading to deforestation and land degradation, fuelwood needs of greater Bamako can be supplied on a 20-year rotation from accessible dry forests (Mortimore and Turner, 2005).

5 Political, socio-economic, and historical factors

Political instability in many parts of Africa is a partner in the soil degradation process, particularly because it is responsible for the creation of large numbers of refugees. For example, over the past three decades political upheaval in Sudan, Ethiopia, and Somalia has led to an outpouring of refugees into Kenya. These refugees are usually confined to refugee camps, which are set close to the borders of the source countries. Most of these refugee camps are set in semi-arid environments, which may be ecologically incapable of handling large concentrations of humans within small areas. Therefore, concentric rings of increased degradation are evident around the refugee camps mainly due to unsustainable levels of exploitation of wood resources for energy, timber, and construction. The rings of degradation surrounding refugee camps are obvious in northern Kenya in camps run by the United Nations Human Center for Refugees such as Dadaab, Hagadera, Ifo, and Dagahaley among others (Beaudou et al., 1999).

The other causes of soil degradation may be grouped largely together as socio-economic and/or historical, and are related to colonialism. The effects of the European settlers in Africa which had major influences on soil erosion degradation in the continent may be viewed under three major groups: introduction of exotic crops and farming methods, accelerated resource extraction, and changes in the indigenous human population structure.

Through the introduction of exotic crops such as maize, wheat, beans, cassava, groundnuts, and even sweet potatoes, the European settlers transformed the traditional agricultural systems in the continent (Purseglove, 1976). Soon the local population were to abandon traditional crops attuned to the climatic conditions in the rangelands and embrace the new crops. This marked the beginning of crop failures, food insufficiency, and associated land degradation.

In East Africa, the 20th century saw massive timber extraction and mining in the interior following the introduction of railroads. About the same time, plantation agriculture hitherto restricted to the coastal regions was introduced in the highland regions of Kenya and the colonialists claimed stake in tribal lands. To the colonialists, these vast tribal lands appeared to be very sparsely populated, not knowing that these lands were mostly dry-season grazing areas for the pastoralists (Kiage, 1998). By displacing the pastoralists, the European settlers disrupted the indigenous knowledge of grazing resource management, and the status quo was maintained after independence. For instance, the Pokot of northwestern Kenya, like other nomadic pastoral communities, made every effort to serve the needs of their livestock. Their traditional location of settlements and movement were determined by considerations of the welfare of their livestock, whereupon forage regimes were determined by climatic conditions and grass quality (Kiage, 1998). Movement of herds and settlements was an adaptation to the erratic climate so as to make use of the scarce and variable grazing resource. Accordingly, animals would be grazed in the lowlands during the wet season. Later in the year, during the dry season, they would move their animals to the highland areas. This was the most rational decision, because during this period grass would be very scarce in the lowlands and water in the seasonal streams would have dried up. Apart from dry season and wet season grazing lands, the community had a practice of setting aside grazing land for periods of drought (Kiage, 1998). These were regions with termite resistant grass, which would be preserved for periods of even 10 years. Such arrangements born out of adaptation to the variable semi-arid conditions ensured that in the event of drought the damage was minimized. Following the collapse of traditional environmental management arrangements due to colonial interference, soil degradation became inevitable.

IV Biophysical factors and processes

Although soil erosion and degradation processes are often artifacts of resource management failures by humans, there are a number of natural biophysical factors that control these processes in different environments, especially in Sub-Saharan Africa. The four most important ones are: (1) soil properties; (2) climatic characteristics; (3) topography; and (4) vegetation. These physical factors of soil erosion usually work in conjunction with resource exploitation processes to result in soil erosion but also have the capability of interacting among themselves independent of anthropogenic impacts (Einsele and Hinderer, 1998). However, as noted earlier, determining or isolating purely physical from anthropogenic contribution to the problem of soil erosion is not straightforward. This is best exemplified by the Lake Baringo drainage area in northern Kenya.

The Lake Baringo area in the northern Kenyan Rift Valley has been described as a classic of areas in Sub-Saharan Africa where changes to traditional land-use practices are degrading range resources (Bryan, 1994; Thom and Martin, 1983). Extensive areas are severely eroded due to a combination of factors including lithology, climate, relief, and depravation of ground cover from anthropogenic processes (Figure 4). The semi-arid climate of Baringo, especially the rainfall pattern, only compounds the soil erosion and degradation problem. The amount of rainfall received in the area is low (less than 600 mm per annum) and erratic, falling in heavy downpours within a few days in April/May/June and October/November (Johansson and Svensson, 2002). Low rainfall can only supports sparse vegetation cover in a region that experiences high evapotranspiration rates (>2500 mm per year) while the sporadic nature of the rainstorms has high erosive power on bare grounds or low vegetation cover.

A study by Snelder and Bryan (1995) in the Baringo area recorded soil loss values of over

Figure 4. A picture showing a severely degraded area by soil erosion in the rangelands near Lake Baringo in East Africa. Biophysical factors including soil type, climate, topography, and vegetation cover can interact to enhance soil erosion with little or no anthropogenic input.

80 g m^{-2} for 30-minute storms and 30 g m^{-2} for 60-minute storms during single rainstorm events, thereby demonstrating that storm duration and intensity greatly influence soil erosion rates. The rainfall pattern in Baringo appears to encourage soil erosion even in the context of limited anthropogenic influence especially in an area dominated by steep slopes. The slope of the land and the soil properties often combine to enhance the erodibility (i.e. soil resistance to detachment and transport) of any given landscape (Lal, 2001; Morgan, 1995; Vrieling, 2006). In the Lake Baringo area soil erosion is compounded by the soil properties of clay, clay loams, and silty clay that prominently feature in the area (Hickley et al., 2004; Johansson and Svensson, 2002). Soils differ in their inherent properties (i.e. texture, structure, roughness, organic matter content, and soil moisture) which in turn affect their susceptibility to erosion agents or erodibility (Lal, 2001). Sub-Saharan soils, especially in the savannas of East and West Africa, are particularly prone to erosion as they are predominantly sands, sandy loams, or black cracking clays that have a weak structural stability (Mati and Veihe, 2001). Table 4 provides a summary of calculated erodibility values for some soils in various Sub-Saharan African countries. Clay soils have high erodibility because they seal soil pores, reduce infiltration, and encourage large surface runoff, thereby increasing the possibility of high rates of erosion (Lal, 2001; Morgan, 1995). That is probably why almost 90% of the catchment (6820 km^2) is considered degraded (Hickley et al., 2004; Johansson and Svensson, 2002; Onyando et al., 2005). It is, therefore, no wonder that Lake Baringo records high sedimentation rates (0.84–1 cm/yr) when compared to other lakes in the region (0.02–0.66 cm/yr) (cf. Beuning et al., 1997; Johnson et al., 2004; Lamb et al., 2003; Stager, 1988; Talbot and Livingstone, 1989).

A recent study that used multiple proxies to study climate change and land degradation in the Lake Baringo area by Kiage and Liu (2009)

Table 4. Measured erodibility of different soil types in select countries in Sub-Saharan Africa (Mati and Veihe, 2001).

Soil	Country	Erodibility	Reference
Lavisols	Kenya	0.24	Onstad et al. (1984)
Lixisols	Nigeria, Tanzania, and Kenya	0.19–0.47	Vanelslande et al. (1987); Kilewe (1987); Ngatunga et al. 1984
Vertisols	Nigeria and Bukina Faso	0.20–0.53	Vanelslande et al. (1987); Roose and Sarrailh (1990)
Plinthosols	Bukina Faso, Benin, And Ivory Coast	0.05–0.10	Roose and Sarrailh (1990)
Cambisol	Nigeria	0.25	Vanelslande et al. (1987)
Mixture of soils (Various)	0.03–0.35		Jaiyeoba and Ologe (1990); Mati (1999)

found that soil erosion and degradation in the Lake Baringo drainage basin commenced much earlier than previously documented (Anderson, 2002), and that the rates of pre-colonial soil erosion are similar to those evident in modern time. One argument advanced by Kiage and Liu (2009) to explain this finding is that humans may not be the main drivers of soil erosion in the area, and the high sedimentation rates at the lake. This hypothesis is reasonable considering that increased population and the accompanying increase in the use of vegetation resources in the Lake Baringo ecosystem over time has not significantly altered the sedimentation rates. Given the steep landscape, sparse vegetation cover, clay, and volcaniclastic material, and the climate within the Lake Baringo area, it is likely that these biophysical factors interact to yield the high sedimentation rates independent of anthropogenic impacts. Indeed the soil properties of clay, clay loams, and silty clay in the context of steep slopes, sparse vegetation, and heavy sporadic rainstorms may hold the key to understanding the high soil erosion rates in many parts of Sub-Saharan Africa.

It is possible to argue that the case of land degradation in the Lake Baringo area which presents empirical evidence from a paleoenvironmental perspective is an isolated case and that it may be located in a region of intense geologic erosion. Regrettably, that argument is reinforced by the paucity of paleoenvironmental data on land degradation in Sub-Saharan Africa which grossly undermines detailed reviews of similar temporal perspective throughout the region. Nonetheless, the Lake Baringo data highlight the unique role of the interaction of biophysical factors in the soil erosion process which has been overlooked in literature.

V Synthesis/conclusion

Soil erosion and degradation has been a widely known problem in Africa, especially the tropical rangelands, ever since the dawn of civilization. It is well understood that the problem can be exacerbated by an increase in human and bovine population that put pressure on marginal lands. However, the popular views of human-induced soil erosion and degradation not only fail to take into consideration the fact that soil erosion is primarily a physical process but they also do injustice to adaptive ecosystem management of the local inhabitants in Sub-Saharan Africa. This review has questioned the stereotypes of (1) overpopulation, (2) overgrazing, (3) deforestation, (4) overstocking, and (5) general rangeland degradation due to human resource use in Sub-Saharan Africa, and problematized the significant issues involved in the current understanding of the assumed causes of soil erosion and land degradation in the region. There is ambiguity surrounding the impact of population growth and density on soil erosion and degradation given that there are many cases in Sub-Saharan Africa where a higher density of people leads to more vegetation cover and less soil erosion. Some of the alarming statistics on overgrazing in Sub-Saharan African rangelands are often lacking in objectivity. Simplistic mechanical attribution of soil erosion to overgrazing is inappropriate because the problem is not just one of overstocking but many factors including season, duration of stocking, animal species, vegetation characteristics, climatic conditions, and presence of non-domestic herbivores. The claims of rangelands being on the precipice of desolation due to soil erosion and degradation are contradicted by the general long-term increase of livestock populations in the African region.

With regard to traditional grazing systems in Sub-Saharan Africa and soil erosion, it appears that it would be a mistake to apply Hardin's 'tragedy of the commons' hypothesis to local use of grazing resources because common property regimes in Sub-Saharan Africa were not the free-for-all that they have been painted to be by outsiders. They were systems of structured ownership arrangements where grazing resources were a common property of the members of a community. It is the dissolution of the traditional local arrangements by colonial governments and later by their successors that undermined their effectiveness. Nomadic pastoralists are constantly on the move in search of pasture and water and it is, therefore, highly unlikely that their grazing activities might cause catastrophic soil erosion. With regard to the role of deforestation and fuelwood collection in soil erosion and degradation, claims that firewood collection and use are a crucial factor in the degradation of the Sahel and that intense fuelwood cutting causes the severest forms of rangeland degradation near urban areas are exaggerations. Changes in woody vegetation are hard to measure because exploitation often takes the form of the collection of dead wood or pollarding. Evidence from a number of studies shows that rather than leading to deforestation and soil degradation, fuelwood needs of large urban areas in Sub-Saharan Africa have led to the emergence of dense farmed parkland full of trees around the cities.

The human-induced causes of soil erosion and degradation in Sub-Saharan Africa are not fully understood, to the extent that even those which are commonly listed may be questionable. Most of the outlandish statements on the causes and estimates of soil erosion and degradation are used in reports in embellished fashion to support questionable 'facts'. The concern over soil erosion and degradation in the rangelands has taken insufficient notice of physical factors such as climate change including rainfall variability. Empirical evidence suggests that biophysical factors including soil properties, climatic characteristics, topography, and vegetation can interact among themselves to yield high soil erosion and degradation rates independent of anthropogenic impacts. However, isolating purely physical from anthropogenic contribution regarding the problem of soil erosion in Sub-Saharan Africa is quite complex, especially in steep environments dominated by clayey soils. Intervention measures have failed to realize meaningful success because they have been premised on the wrong assumptions regarding the causes of soil erosion and degradation in the region. Wholesale adoption and implementation of mitigation strategies based on insights and models that may have been developed elsewhere rather than on unique local experiences cannot be guaranteed success in Sub-Saharan Africa. Any external development intervention and conservation measures targeting the African rangelands need to familiarize themselves with unique adaptation and coping strategies employed by local people and seek to support and strengthen these.

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