Understanding the causes of bush encroachment in Africa: The key to effective management of savanna grasslands

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Abstract. The increase in biomass and abundance of woody plant species, often thorny or unpalatable, coupled with the suppression of herbaceous plant cover is a widely recognized form of rangeland degradation. Bush encroachment therefore has the potential to compromise rural livelihoods in Africa, as many depend on the natural resource base. The cause of bush encroachment phenomenon is not without debate, but fire, herbivory, nutrient availability and rainfall patterns have been shown to be the key determinants of savanna vegetation structure and composition. In this paper, these determinants are deliberated upon, with particular reference to arid and semi-arid environments of Africa. To improve our current understanding of causes of bush encroachment, an integrated approach, involving ecological and indigenous knowledge systems, is proposed. Only through our knowledge of causes of bush encroachment, both direct and indirect, can better livelihood adjustments be made, or control measures and restoration of savanna ecosystem functioning be realized.

Keywords: Bush encroachment, fire, indigenous ecological knowledge, livestock grazing, rainfall variability.

Introduction

Savanna ecosystems are characterized by continuous layer of herbaceous plants (*e.g.* grass) and sparsely populated patches of trees and shrubs. The proliferation of woody plants in savanna ecosystems is known as bush encroachment (Van Auken 2009) and an increase of 10 % woody cover will lead to 7 % decline in grazing resources in east Africa (Oba *et al.* 2000). Subsequently bush encroachment lead to reduced livestock carrying capacity of that particular ecosystem (Ward 2005). This has a serious implication on food security as large areas of arid lands occupied by millions of people are encroached by woody plants, leading to decline in agricultural productivity. For example, it has been indicated that agricultural productivity of 10-20 million ha in South Africa (Ward 2005) and 37 000 km² in Botswana in 1994 (Moleele *et al.* 2002) has been affected by bush encroachment, thereby threatening the sustainability of livestock production systems and human wellbeing particularly in rural areas of Africa.

Bush encroachment has also been shown to have a positive impact on the savanna ecosystem, which is not widely acknowledged. Pastoralists in Africa have indicated that woody plants contribute significantly towards livestock feed especially during drought periods (Moleele 1998; Kgosikoma *et al.* 2012a), thereby reducing the cost of supplementary feed. Yet, most grazing policies in Africa do not consider browse plants when determining grazing capacity of a particular land. In addition, leguminous woody vegetation improves soil quality through nitrogen fixation and could also contribute significantly towards carbon sequestration. That notwithstanding, there is a consensus between pastoralists and ecologists that the uncontrolled shift from grass dominated savanna to bush savanna ecosystem has a negative impact on sustainability of savanna ecosystem as a whole.

Despite bush encroachment being observed in many grasslands and savannas in Africa and elsewhere, the mechanisms that promote it are not clearly understood (Ward 2005). Several factors such as overgrazing, fire frequency, soil moisture, nutrients and global warming have been associated with bush encroachment (Van Auken 2009) but it is still controversial how each factor contributes to increased woody plant cover. Probably it will be difficult to attribute a single factor as sole cause of bush encroachment (Van Auken 2009) especially that most environmental factors are spatially correlated (Hernandez-Stefanoni *et al.* 2011). In this paper, commonly cited causes of bush encroachment are briefly reviewed and an integrated approach proposed for understanding causes of bush encroachment and sustainable management of savanna ecosystems.

Causes of bush encroachment

Suppression of fire

Regular burning suppresses woody plant growth by destroying the shrubs and juvenile trees and thus prevents their development into mature woody plants that will be resistant to fire and be out of reach for browsers (Mphinyane *et al.* 2011). However, policy makers in Africa fail to recognize the importance of fire as a management tool in savanna ecosystems and thus prohibit burning of rangelands (Dalle *et al.* 2006). Subsequently, pastoralists and ecologists argue that lack of regular burning have

allowed proliferation of woody vegetation (Kgosikoma *et al*. 2012a). Therefore, fire should be an integral part of management on savanna ecosystems.

In addition, savanna ecosystems are also overgrazed such that there is limited fuel load to allow frequent burning at high intensity. Given the important role of fire, it is necessary to establish sustainable burning intervals (Fatunbi *et al*. 2008) and institutions that will govern regular burning of savanna ecosystems. Otherwise, uncontrolled burning could increase pastoralist's vulnerability to impact of drought and increase release of carbon into the atmosphere. Sustainable use of fire as a management tool therefore requires knowledge on future climate conditions and ability to minimize its negative impact (*e.g*. air pollution and carbon loss).

Rainfall variability

Savanna ecosystems are generally water limited and subsequently bush encroachment is associated with inter-annual rainfall variability (Angassa and Oba 2007). In arid and semi-arid environments, the woody cover and density tend to increase with increasing mean annual precipitation (Sankaran *et al*. 2005). At the local scale, unusually high annual rainfall in multi-years promote an increase in woody vegetation cover and encroacher plants like *Acacia mellifera* require at least 3 years of successive good rainfall to recruit successfully (Jourbert *et al*. 2008). Increased soil moisture availability, particularly when there is limited competition from grass, allows woody plant seedlings to survive and grow into bush thickets. Meanwhile drought, through restricted plant growth, seed germination and increased competition for limited water at high shrub densities leads to death of some plants (Rogues *et al*. 2001) and thus reduces bush encroachment. As a result, bush encroachment is a cyclic natural phenomenon influenced by recruitment and death of encroacher plants in response to rainfall patterns (Wiegand *et al*. 2006).

Soil properties

Sankaran *et al*. (2005) demonstrated that woody cover is negatively correlated with soil clay content. Thus, bush encroachment is likely to occur in sandy soil with low clay content as observed in the Kalahari sands of Botswana as illustrated in Figure 1 (Kgosikoma *et al*. 2012b). A broad scale analysis of woody cover in African savannas also revealed that woody cover was negatively associated with soil nitrogen and therefore, increased nitrogen deposition may reduce bush encroachment (Sankaran *et al*. 2008). In a similar study, it was observed that woody cover had a complex and non-linear relationship with total soil phosphorus (Sankaran *et al*. 2008). On the contrary, other authors have indicated that soil types had no significant impact on shrub dynamics in African savannas (Roques *et al*. 2001).

Overgrazing

In Africa, most rangeland degradation including bush encroachment is associated with high cattle density around the boreholes and kraals (Moleele and Perkins 1998; van Vegten 1981). This thinking is supported by the declining density of encroacher plant species with increasing distance

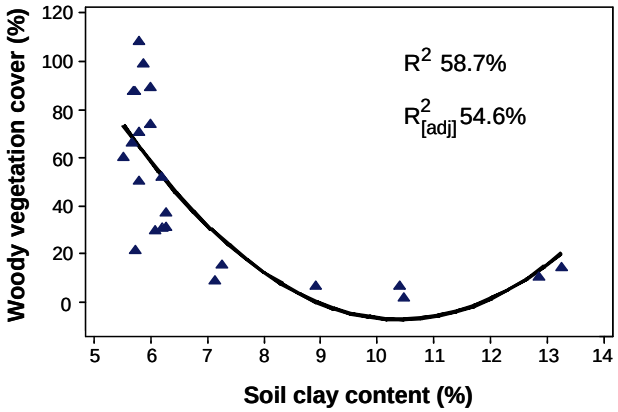

Figure 1. Relationship between woody cover and soil clay content across savanna ecosystems of Botswana (Kgosikoma *et al.* 2012b).

from water sources along grazing piospheres. In communal grazing lands of Botswana, bush encroachment zone has been observed between 0 and 300 m from foci (boreholes) where there is high concentration of grazers (Moleele *et al*. 2002). The possible explanation is that overgrazing suppress the dominance of grass species and favour the growth and multiplication of woody species because they then have increased access to available soil moisture (Skarpe 1990). Grazing also indirectly contribute towards bush encroachment through dispersal of encroacher plant's seeds. Plants like *Dichrostachys cineria* and *Grewia flava* are highly palatable and are therefore largely consumed by livestock and their seeds are deposited with animal fecal material around boreholes and subsequently recruited in high numbers in these areas. In contrast, other studies have shown that grazing pressure is not significantly related to bush cover (Oba *et al*. 2000).

Integrated approach is needed to understand causes of bush encroachment

Savanna ecosystems are complex and simple models that focus on one variable are not likely to help us understand causes of bush encroachment partly because there will be confounding effects of other factors not accounted for in such studies. It is highly likely that the causes of bush encroachment discussed above interact to facilitate the establishment and dominance of bushy vegetation as suggested by Van Auken (2009). Therefore, understanding causes of bush encroachment requires an integrated approach that will ensure that both ecological and indigenous ecological knowledge are applied (Sop and Oldeland 2011) as shown in Figure 2. This approach also ensures that strategies adopted to address the problem are economically, culturally and environmentally suitable for the local conditions.

In the African context, there is limited long-term ecological data and the indigenous ecological knowledge on vegetation and other environmental changes accumulated through long-term observation and land use (Allsopp *et al*.2007) could complement the scientific knowledge by providing the long-term perspective on vegetation change and underlying causes (Bart 2006). Most rangeland development projects have failed because they focused on addressing the technological aspect, without addressing the

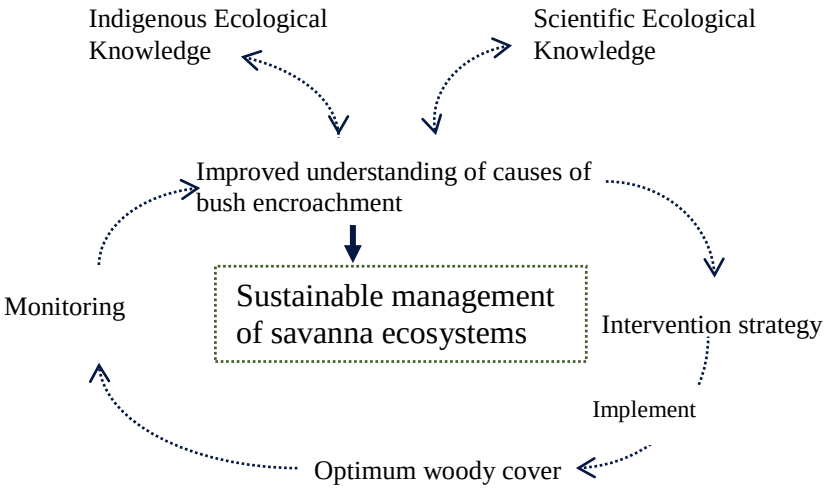

Figure 2. Schematic outline to understanding bush encroachment dynamics.

socio-economic factors (Squires *et al*. 1992). Therefore, the use of both scientific and indigenous ecological knowledge ensures that a common goal is set and strategies (policy) adopted to curb bush encroachment also take into consideration the livelihood of that particular community. New grazing policies need to promote transparent decision making that is flexible to changing circumstances, and embraces a diversity of knowledge and values. Given that factors such as rainfall and soil properties are not manipulative, management of bush encroachment needs to focus on regulating grazing pressure and optimum burning intervals.

Conclusion

Bush encroachment is one of the most widespread forms of land degradation in African rangelands and elsewhere. Sadly, its exact causes are still one of the least understood. Rural livelihoods, the majority of whom are dependent on range resources will have to be assisted to reverse bush encroachment or to adapt accordingly to the new environment. Success to controlling bush encroachment requires improved understanding of underlying causes and integrated approach provides an opportunity to widen our knowledge on dynamics of bush encroachment. There are few comprehensive studies (*e.g.* Sankaran *et al*. 2008) that investigate dynamics of woody vegetation across broad environmental conditions and therefore future research on bush encroachment should include multi-variables.

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