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Ecology and Conservation of *Acacia senegal* in the Rangelands of Luwero and Nakasongola Districts

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Abstract

Ecology and conservation status of *Acacia senegal* in the rangelands of Luwero and Nakasongola Districts were assessed between November 2002 and February 2003. Sixty plots measuring 50 x 50 m were laid at 50 m intervals along six 1,000 m transects, and the diameter at breast height (DBH), of *Acacia senegal* trees measured. Each tree was visually assessed for physical damages as health indicators. Maturity class, terrain types and other trees growing together with *Acacia senegal* were identified and recorded. A structured questionnaire and interviews were used to collect data on the constraints and opportunities of conserving and managing *Acacia Senegal*. Data on the population structure, maturity class and stock density of *Acacia senegal* were analysed using MINITAB and DECORANA. The population structure of *Acacia senegal* trees was unbalanced, with only 24% young trees (DBH < 8 cm). Sixty five percent of trees were old (DBH > 8 cm) and 84% physically damaged. Hills had significantly ($P < 0.05$) higher tree density than plains and streams. Thirty-two tree species were recorded growing together with *Acacia senegal* in the rangelands and the most common were *Acacia mellifera, Acacia hockii, Acacia seyal, Combretum collinum and Combretum molle.* Grazing livestock, bush fires, land tenure, tree tenure, pests and diseases were the major challenges to conservation of *Acacia senegal* in the rangelands. Collaborative conservation and management plan should be developed to conserve the species. Impacts of livestock grazing, settlement and farming on regeneration of *Acacia senegal* should be assessed before developing strategies for management and conservation.

Key words: ***Acacia senegal, rangeland, stocking, conservation***

Introduction

Conservation of forests and woodlands is important because of human destruction and over exploitation (Adams *et al.*, 1992; Opio-Odongo, 1998). Loss of populations and individuals within species due to human-induced forces (FAO, 1996,) often result in loss of genetic diversity upon which productivity, ecosystem stability, long-term survival and evolution depend (Bunyan, 1981; Namkoong, 1986). *Acacia senegal*, a promising agroforestry multi-purpose tree species in Uganda, is faced with these problems. Smith and Goodman (1986), Belsky *et al.* (1989) and Milton and Dean (1995) have reported that *acacia* trees play a major role in structuring associated plant communities by modifying solar radiation, soil moisture and nutrient concentrations available to understorey plants. *Acacia* trees also affect the distribution and abundance of animal species by providing resources and services including shade, shelter, nesting sites, observation posts and specialized food or prey items (Shalmon, 1981; Dean and Milton, 1988; Greenberg *et al.*, 1997; Kruger and McGavin, 1998; Dean *et al.*, 1999).

The trees function as 'keystone species' in the arid and semi-arid regions of Africa and the Middle East. Changes in the abundance of *Acacia* population in these regions may alter the ecosystem functioning and biodiversity (Milton and Dean, 1995; Ward and Rohner, 1997, Dean *et al.*, 1999). The species whose population structure is little known extends over a wide ecological range that differs in rainfall, soil and altitude (Cossalter, 1991). Studies carried out on *Acacia senegal* have been limited to provenaces and morphological characteristics (Cossalter, 1991). There is a need to establish the population structure and health status and develop conservation measures and maintain optimum breeding populations (Haines, 1994). The objectives of this study were (1) determine the population structure of *A. senegal* in the rangelands (2) determine the health status of *A. senegal* trees (3) assess the stocking density of *A. senegal* in relation to topographic gradient and (4) identify the challenges of conserving *A. senegal* in the rangelands.

Study area

The study area, formerly Luwero district before Nakasongola gained a district status, borders with the districts of Masindi in the northeast, Kiboga in the west, Mukono in east and Mpigi to the south (NEMA, 1997). To the north are Apac and Lira districts. The area covers 9,204.0 km^2 representing 3.81 % of the country's total and surface. Of these, about 240.2 km^2 is open water, which is equivalent of 2.61% of the district's land area (NEMA, 1997). The largest part of the districts is underlain by metamorphic rocks of the pre-cambrian origin (Omoding, 1994). The soils are not uniform and consists mainly of Buruli catena to the north and Lwampanga catena in the low-lying areas and valleys (Omoding, 1994, Parker *et al.*, 1967). Hilly uplands dominate the southern part and ancient granitic rocks rise up in the north. Wide interlocking valleys break up the low hills in the central region.

The climate of the area is considerably modified by relief. The mean diurnal maximum temperatures range from 18 °C to 35 °C while the minimum diurnal range is from 8 °C and 25 °C (Omoding, 1994, Parker *et al.*, 1967). Much of the area receives 1,000-1,250 mm of rain per annum. The southern part, especially Bamunanika and Katikamu counties, receives more than 1,250 mm and has two rain seasons: April-May and October-November. The vegetation types are forest/savanna mosaic (excess of 1,250 mm of rainfall per year), moist combretum woodland (1,125 - 1,250 mm rainfall per year), dry combretum (less than 1,125 mm of rainfall per year), grass savanna (1,000 mm of rainfall), seasonally flooded grass swamps (2009.3 km^2 of the two districts), permanently flooded swamps (412.2 km^2 of the districts) and post-cultivation vegetation (Forest Department, 1995; NEMA, 1997).

The Baganda, Baruli, Banyarwanda, Banyankole, Bahima and the Bakiga are the dominant tribes. Crop production, animal husbandry and charcoal production for sale in Kampala are the major economic activities in the districts with devastating effects on the savanna woodlands. Bee keeping and honey production are also common (NEMA, 1997).

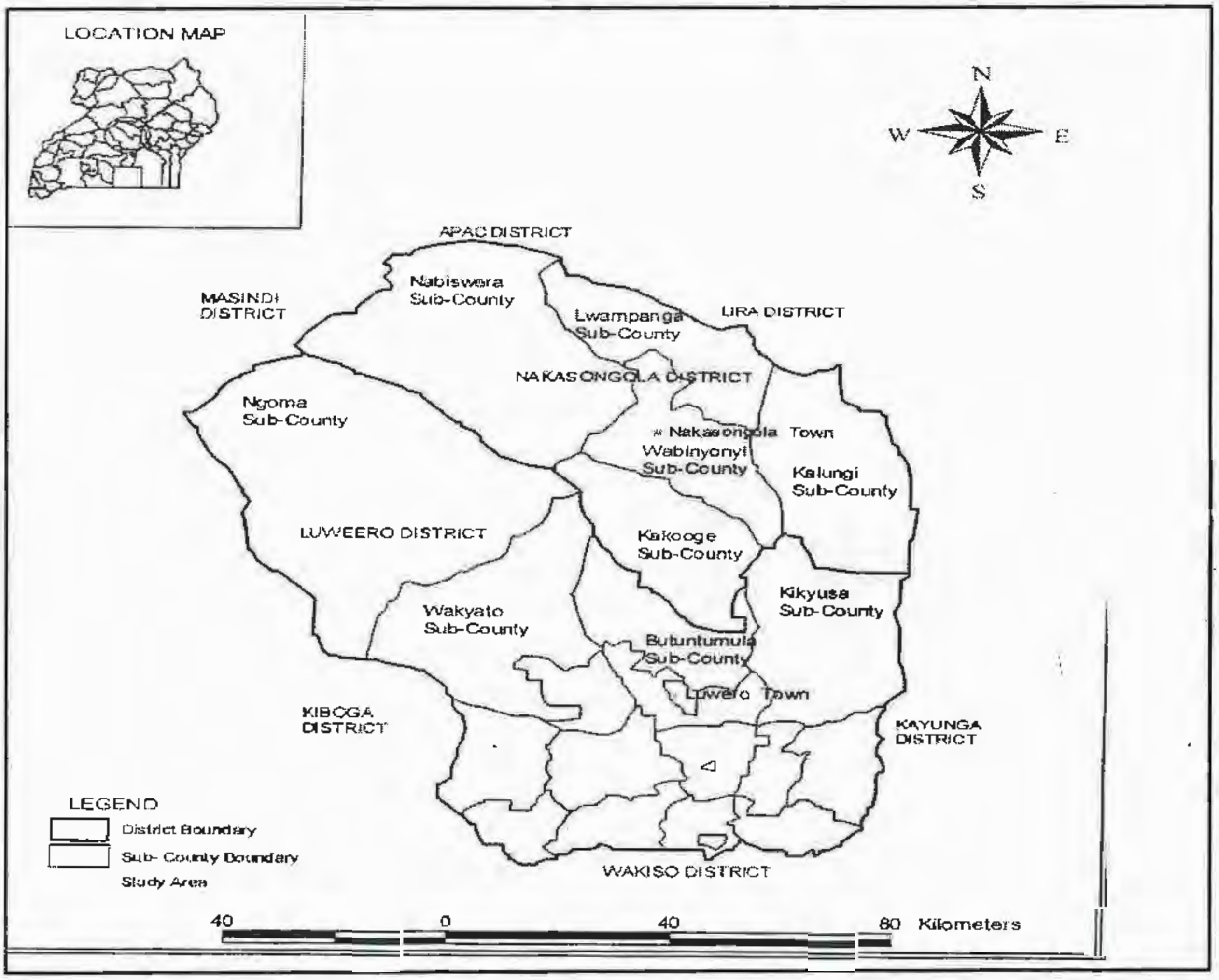
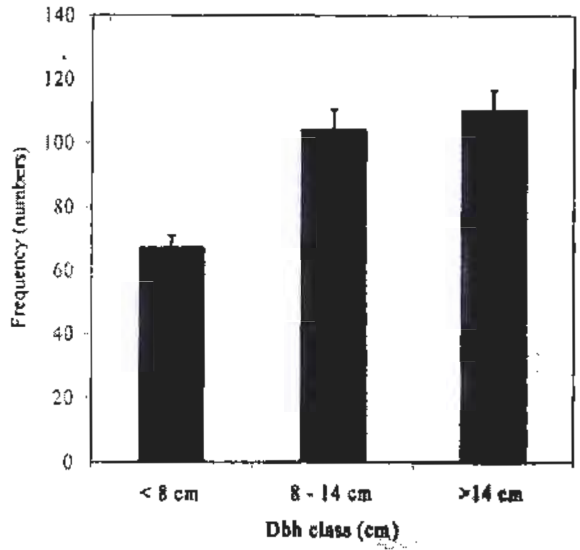


Figure 1. Map of the study area.

Diameter distribution

Figure 2 shows the distribution of *Acacia senegal* in the rangelands based on 377 trees recorded as alive. There was an inverse DBH distribution of *Acacia senegal*. The population comprised mainly of trees in bigger diameter class (DBH = 8 cm) while smaller diameter trees (DBH < 8 cm) were few.

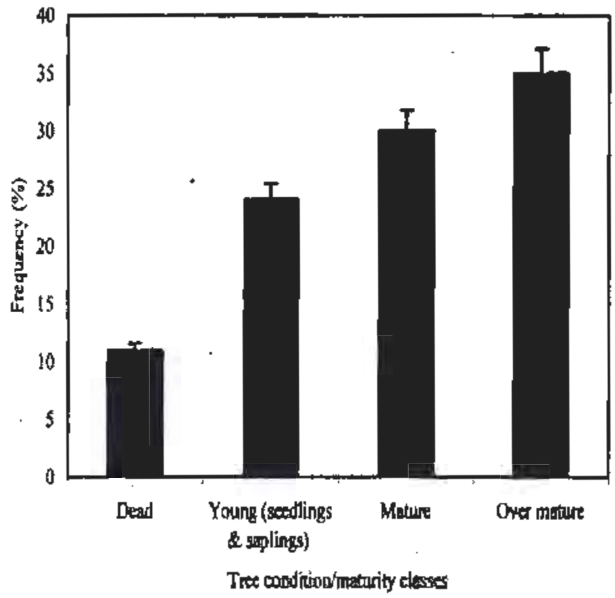
Figure 2. Distribution of* Acacia senegal *in the rangelands of Luwero and Nakasongola districts.



Maturity size class

Figure 3 shows the maturity size class of *Acacia senegal* trees. A total of 412 trees were recorded as live standing trees, freshly cut or dead. These included seedlings and saplings whose heights were below 1.3 m. Thirty five percent of the trees were over-mature (DBH >14 cm), 30% were mature (8 cm = DBH = 14 cm), 24% were young (DBH < 8 cm) and 11% were dead trees. Most of the trees (65%) were old and few (24%) were young (trees with DBH < 8 cm, seedlings and saplings).

Figure 3. Maturity size class/tree condition of *Acacia senegal.*



Physical damage to trees

A total of 377 *Acacia senegal* trees were alive. Eighty four percent of these were physically damaged and considered unhealthy. *Acacia senegal* trees that had dead branches and stems, cracked bark, cavities or signs of decay are presented in Table 1.

Table 1. Physical aberrations indicating tree health

Tree physical aberrations	Mean %
Dead branches and stems	61
Cracks in bark	24
Cavities	10
Sign of decay	05

Stocking density of *Acacia senegal*

Table 2 shows the stocking density of *Acacia senegal* in the rangelands. Plains had the lowest stocking density (6 stems ha^{-1}) while hills had the highest stocking density (11 stems ha^{-1}).

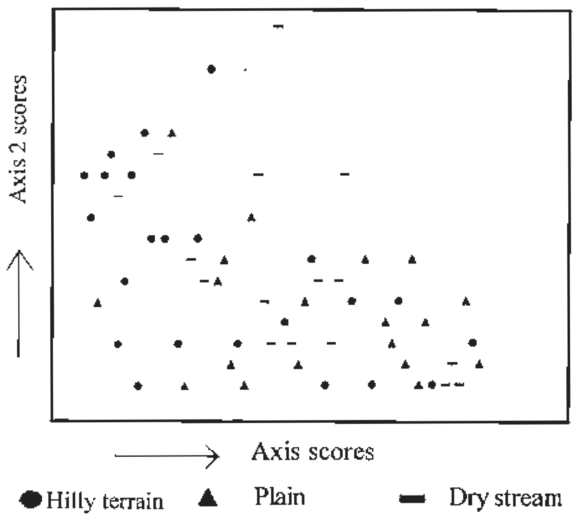
Table 2. Stocking density of *Acacia senegal* in the rangelands

Terrain types	Stocking density (stems ha^{-1})
Hills	11
Plains	06
Dry streams	08

Mean stocking density = 8 stems ha^{-1}

DECORANA ordination of stocking density of *Acacia senegal* and terrain types in the rangelands (Eigenvalues: Axis 1 = 0.772; Axis 2 = 0.510) shows that 77.2 % of the variation in stocking densities in relation terrain types is explained by axis 1, where the hilly terrains contributed a value of 0.38 (Figure 4). The high eigenvalues indicate wide variations in the stocking density of *Acacia senegal* in the different terrain types. Analysis of variance showed significant differences ($F = 1.639$, $P = 0.043$) in the stocking density between the three terrain types (Table 3). *Acacia senegal* trees on plains and the dry streams were scattered.

Figure 4. DECORANA ordination of stocking density of *Acacia senegal* and terrain types in the rangelands of Luwero and Nakasongola Districts based on 60 samples.



Eigen values: Axis 1 = 0.772; Axis 2 = 0.510

Table 3. Analysis of variance of the stocking density of *Acacia senegal*

Source	SS	Df	MS	F	P-value
Terrain types	47.21	2	23.605	1.639	0.043
Error	2548.18	177	14.396		
Total	2595.39	179			

Tree species occurring together with *Acacia senegal* in the rangelands

Thirty-two species were recorded growing together with *Acacia senegal* trees in the rangelands (Table 4). *Acacia mellifera, Acacia hockii, Acacia seyal, Combretum collinum and Combretum molle* were the most common species recorded. *Anona senegalensis, Balanites orbicularies, Borassus aethiopum, Carissa edulis, Ficus exasperata, Kigelia africana, Milicia excelsa, Schinus molle* and *Vitex doniana* were, less common.

Table 4. Tree species growing together with *Acacia senegal* in the sample plots.

Species	Frequency
Acacia gerradii	11
Acacia hockii	30
Acacia mellifera	54
Acacia senegal	63
Acacia seyal	26
Acacia sieberiana	11
Acacia tortilis	4
Albizia coriaria	2
Albizia glaberrima	1
Anona senegalensis	1
Balanites orbicularies	1
Borassus aethiopum	1
Carissa edulis	1
Combretum collinum	26
Combretum fragans	6
Combretum molle	30
Commiphora africana	14
Erythrina abyssinica	2
Euphorbia candelabrum	2
Euphorbia candelabrum	6
Ficus exasperata	1
Ficus natalensis	2
Ficus sycomorus	2
Grewia mollis	3
Kigelia afrcana	1
Mangifera indica	2
Milicia excelsa	1
Phoenix rectinata	2
Schinus molle	1
Tamarindus indica	13
Vitex doniana	1
Ziziphus abyssinica	8

Challenges of conserving *Acacia senegal*

The challenges of managing *Acacia senegal* both in the rangelands and on individual land are given in Table 5. About 35% of the respondents said that grazing is one of the major challenges in the management of the tree species both in the rangelands and on farms. Other challenges were pests and diseases (33%), bush fires 27%, land and tree tenure (31%) and harsh climatic conditions (10%).

Table 5. Challenges of conserving *Acacia senegal* in the rangelands (N=184)

Challenges	(%)
.Grazing animals	35
.Pest and diseases	33
.Land and tree tenure	31
.Bush fires	27
.Others (harsh climate, lack of planting materials)	10

Discussion

Population structure of *Acacia senegal*

The population of *Acacia senegal* in the rangelands comprised mainly trees with large diameters and less representation of poles, saplings and seedlings. This is characteristic of a heavily browsed tree population structure (Caughley, 1976). A population, whose regeneration has been temporarily interrupted through excessive harvesting of fruits or seeds, trampling of seedlings, or lack of pollinators or dispersal agents tend to be dominated by larger diameter trees (Peters, 1996).

In Luwero and Nakasongola rangelands, respondents said that *Acacia senegal* trees including poles, saplings and seedlings are heavily browsed, trampled and damaged by bush fires. The population of the livestock (cattle, goats and sheep) in Uganda is estimated to have increased from 10440 to 17983 from 1990 to 2000; and this number is expected to double by 2010 (MAAIF, 2000). Over 80% of the livestock are reared on the rangelands (Kisamba-Mugerwa, 2001). Young *Acacia senegal* trees are good fodder. Studies carried out elsewhere (Obeid and Seif El Din, 1970) have shown that regeneration of *Acacia senegal* can be adversely affected by browsing. The results of this study compare closely with findings by Dewitt (1994), who reported that livestock affect the health and productivity of woodlands by damaging seedlings and saplings. Slender young trees, which are the next generation of the woodlands, are usually at the right size and height (» 1.3 m) to be eaten and destroyed by livestock. Cattle and goats often strip foliage and bark from the trees and trample and break the stems.

Weyerhaeuser (1985) reported that elephants and other browsers kill smaller (< 20 cm DBH) *Adansonia digitata* trees and the degree of elephant damage decreases linearly with increasing stem diameter. Wilson (1988) disputed the importance of browsers in causing the absence of young stems in tree populations. Absence of young stems are attributed to long-term effect of drought and farming. The population structure of *Acacia senegal* that has fewer representations of smaller diameter, negatively affects long-term conservation of species.

Physical damage to *Acacia* trees

Tree health is a useful parameter attracting attention to management problems and finding socially desired solutions. A healthy tree population is generally sustainable; capable of meeting the ecological, economic, and socially- determined needs and aspirations of the present without compromising the ability to meet future needs. Many factors affect tree health in rangelands, including natural and human-caused disturbances and variations in climate. Trees weakened by moisture stress are susceptible to insects, diseases and wildfires (Sabiiti, 1988). All these risks can be reduced through proper management. Otherwise, all ecological, economic, and social values associated with trees and forests are at high risk.

Information on health of many rangeland and woodland trees including *Acacia senegal* is however, scanty. It was observed that many *Acacia senegal* trees were physically damaged, indicating that the population of *Acacia senegal* trees in the rangelands could be at risk of extinction. Of the physical aberrations observed, dead branches and stems seemed very common. Though the causes of the tree health conditions are complex (Agee, 1994), bush fires experienced during the dry seasons and the grazing livestock are assumed to be the major causes of the physical tree damage (decay, cracks, cavities and dead branches and stems). Young trees are especially vulnerable to fire (Hall, 1976). They are killed, wounded or stressed thereby increasing their susceptibility to attack by insects and diseases. Livestock and other herbivores physically destroy vegetation (Heitschmidt, 1990). The direct impacts are related to the destruction of tissue as a result of trampling and browsing (Klemmendson, 1977). The large proportion of *Acacia senegal* trees with broken branches and stems observed in this study were mainly as a result of browsing by livestock.

Stocking density of *Acacia senegal* and its relationship to topography

Generally, the stocking of *Acacia senegal* in the rangelands was low due to over grazing, frequent fires, drought and cutting for fuelwood by the local communities. The farmers practice communal grazing, depend on natural pasture and keep many animals beyond the carrying capacity of the area (Kisamba-Mugerwa, 2001). They do not practice proper pasture management, which results in overgrazing. Extensive degradation of the rangelands occurs along livestock routes, watering points and settled areas. These sites experience high concentrations of livestock during most parts of the year resulting in overgrazing and trampling of vegetation rendering the surfaces of these areas bare. Roques *et al.* (2001) attributed low shrub densities to the effects of frequent fires, drought and high grazing/browsing pressures, which are consistent with the findings of this study.

From results of ordination and analysis of variance, the stocking of *Acacia senegal* in the rangeland is influenced by terrain type. Hilly terrain received high loading on axis 2 meaning higher stocking density. The preference for hilly terrain may relate to topographic and soil factors. Lind and Morrison (1974) indicated that while large plant formations are influenced by climate, differences in plant communities are attributable mainly to topographic and soil conditions. Hills generally support soils that are coarse in texture and well drained and thus suitable for the growth of the species and are rarely grazed by livestock except in the dry seasons. Such areas would therefore have minimum disturbance of the vegetation due to browsing and grazing. Plains and dry streams, however, represent areas where human settlement and farming are rather intense and have on average low stocking density. Earlier studies have shown that in settled areas, trees and shrubs are cut for making homesteads, livestock enclosures and fuelwood (Egadu, 2002; and Lusigi *et al.*, 1986).

Chikamai *et al.* (1995) found a similar pattern of distribution of *Acacia senegal* with respect to the topography. They observed higher densities on the hills than along the luggas and plains. FAO (1971) in the classification of vegetation based on geomorphological features also found that *Acacia senegal* was an indicator species for basement hills and ridges in Isiolo District, Kenya.

Trees species associated with *Acacia senegal*

Many tree species were found growing together with *Acacia senegal*. Some of them like *Acacia mellifera* form a big component of dryland agroforestry systems. It is valued for fuelwood, mulch, bee forage, nitrogen fixation, soil conservation and fodder (Katende, 1995). Tree species generally depend on one another for survival. The seedlings of different species in the tree community tend to grow in particular soil conditions created by the presence of other species (Otike, 1998). Some species form a 'club' that excludes other species and increase the reproductive success of all its members (Belsky *et al.*, 1989; Otike, 1998). If one species in the community produces a chemical that other plants need, then another may produce a noxious chemical that keeps insect herbivores away from all of them.

The occurrence of many tree species with *Acacia senegal* in the rangelands of Luwero and Nakasongola appears to indicate ecological links. *Acacia senegal* could have co-evolved with these other tree species over time and benefited from each other. Many birds whose nests were observed on *Acacia senegal* trees could act as pollinators and seed dispersers of other trees. Any conservation effort aimed at protecting *Acacia senegal* would therefore, benefit other tree species and biodiversity in general.

Conclusions and recommendations

The survival of *Acacia senegal* trees in the rangelands of Luwero and Nakasongola districts is a case for concern. The population structure is unbalanced, with 24% young trees. A number of trees are physically damaged although the threat of such damages to overall health is not known. The stocking density varies with topography (terrain types), with higher densities found on the hills than the plains and dry streams. *Acacia senegal* grows in association with many other tree species and the most common are *A. mellifera, A. hockii, A. seyal, Combretum collinum and Combretum molle.* Grazing, pests and diseases, bush fires, fuelwood collection and charcoal, are the major conservation threats of *A. senegal* in the rangelands.

Community-based conservation and management should be encouraged if the species is to be protected. Livestock grazing, settlement and changes in the farming system that affect the regeneration of *Acacia senegal* should be assessed before developing strategies for management and conservation. Research should also be conducted to determine the extent to which physical damages affect the health and survival of *A. senegal.*

References

Adams W.T, Strauss S.H, Copes D.L and Griffin A.R. 1992. Population genetics of forest trees. Kluwer academic publishers.

Agee, J.K. 1994. Fire and weather disturbances in terrestrial ecosystems of the eastern Cascades. General technical report PNW-320. U.S. Forest Service, Pacific Northwest Research Station, Portland, Oregon

Belsky, A. J., Amundson, R.G., Duxbery, J.M., Riha, S. J., Ali, A.R., Mwonga, S.M., 1989. The effects of trees on their physical, chemical and bilogical environments in a semi-arid savanna in Kenya. Journal of Applied Ecology 26: 1005-1024.

Bunyan, G.V. 1981. "Tree Management - The Alternative to a tree-less Future," *Arboriculture Journal*, 5: 15-21.

Caughley, G. 1976. Plant-herbivore systems. Chapter 6 in R.M. May (ed.) *Theoretical Ecology: Principles and Applications*. p. 94–113. Blackwell, London.

Chikamai, B.N., Hall, J.B. and Banks, W.B. 1995. Survey of *Acacia senegal* resources for gum arabic in northern Kenya. *Commonwealth - Forestry Review* 74: 3, 246-252

Cossalter, C. 1991. *Acacia senegal*, gum tree with promise for agroforestry. NFT Highlights, NFTA 91-02. Nitrogen Fixing Tree Association, Hawaii.

Dean, W.R.J and Milton, S.J. 1988. Dispersal of seeds by raptors. African Journal of Ecology 26: 173-176.

Dean, W.R.J., Milton, S.J and Jeltsch, F. 1999. Large trees, fertile islands, and birds in arid savanna. Journal of Arid Environments 41: 61-78.

Dewitt, B. 1994. Forest grazing hurts. *Missouri Conservationist.* New Franklin. http://www.conservation.state.mo.us forest/health/ForestGrazingHurts/

Egadu, S. P. 2002. Survey of Acacia tree resources for Gum Arabic production in Kotido and Moroto districts. MSc Thesis Makerere University, Kampala Uganda.

FAO. 1996. Domestication and commercialisation of Non-timber forest products in agroforestry systems. Non-Wood Forest Products 9.

FAO. 1971. Range development in Marsabit district, Kenya, AGP: SF/Ken, 11. Working paper 9, 134pp.

Forestry Commission. 1984. Census of woodlands & trees 1979-82: County of Merseyside, UK.

Greenberg, R., Bichier, P., Sterling, j. 1997. Acacia, cattle and migratory birds in southeastern Mexico. Biological Conservation 80: 235-247.

Haines, R. J. 1994. Biotechnology in forest trees improvement: research directions and priorities. *Unasylva* 45 (2): 177.

Hall, F.C. 1976. Fire and vegetation in the Blue Mountains-implications for land managers. Proceedings of Tall Timber Fire Ecology Conference 15: 155-170.

Heitschmidt, R.K. 1990. The role of livestock and other herbivores in improving rangeland vegetatioo. Rangelands 12 (2). 26-29

Katende AB, Birnie A and Tengäs B. 1995. Useful trees and shrubs for Uganda. Identification, Propagation and Management for Agricultural and Pastoral Communities. RSCU, Nairobi, Kenya.

Kisamba-Mugerwa, W. 2001. Rangelands management policy in Uganda. A paper presented at International Conference on Policy and Institutional Options for the Management of Rangelands in dry Areas. Hammamet, Tunisia. May 7 - 11, 2001

Klemmedson, J.O. 1977. Physical effects of herbivores on arid and semiarid rangeland ecosystems, p. 187-120. In: Proc. 2nd US/Australia Rangeland Panel, Adelaide, 1972. Australian Range Soc., Perth, W. Australia.

Kruger, O and McGavin, G.C. 1998. Insect diversity of acacia canopies in Mkomazi game reserv , north-east Tanzania. Ecography 21: 261-268.

Lind, E. M and Morrison, M. E. S. 1974. East Aftrican Vegetation. Longman, London.

Lusigi, W. J., Nkurunziza, E.R., Gyegye, K. A., Masheti, S. 1989. Range resource assessment and management strategies for South Western Marsabit, Northern Kenya. IPAL technical report no. D-5, UNESCO, Nairobi. 230pp.

Malloch, A.J.C. 1988. Vespan II. Institute of Environmental and Biological Sciences, Lancaster, U.K.

MAAIF 2000. Background to the national cattle breeding policy. Government of Uganda, Kampala.

Milton, S.J and Dean, W.R.J., 1995. How useful is the keystone species concept, and can it be applied to Acacia erioloba in the Kalahari Desert? Oceologic and Naturschutz 4: 147-156.

Namkoong G. 1986. Genetics and forests of the future. Unasylva 38(2): 152.

Forestry Department, 1995. Land Use/Cover Stratification of Uganda Districts. Ministry of Natural Resources, Kampala.

NEMA, 1997. The State of Environment Report for Luwero District. Ministry of Natural Resources.

Obeid, M and Seif El Din, A. 1970. Ecological studies of the vegetation of Sudan: I. *Acacia senegal* (L) Wild. and its natural regeneration. Journal of Applied Ecology 7 (3): 507-518.

Opio-Odongo, J.M.A., Godber WT and Kakuru, W. 1998. Biodiversity in Uganda In: Mugabe J and Clark N (1998). Managing Biodiversity. National systems of conservation and innovation in Africa. African Centre for technology Studies (ACTS), Nairobi, Kenya.

Omoding, J. 1994. Grasses of Luwero. Msc. Thesis Makerere University, Kampala.

Otike, P. 1998. Population structure and natural regeneration of *Acacia tortilis* in the lake shore savanah woodlands in Nambieso sub-county Apac District. FFNC, Makerere University.

Parker D., Downer E.R. and Cole G.E.D. 1967. Atlas of Uganda. Dept. of Lands and Survey. Govt. Printer Entebbe.

Peters, C.M. 1996. Sustainable Harvest of non-timber plant resources in tropical moist forest: An Ecological Premier. Biodiversity Support Program, Washington DC, pp. 45.

Roques, K.G., O'Connor, T.G. and Watkinson, A.R. 2001. Dynamics of shrub encroachment in an African savanna: relative influences of fire, herbivory, rainfall and density dependence. Journal of Applied Ecology, Volume 38 Issue 2 Page 268.

Sabiiti, E. N. 1988. "Fire effects on Acacia regeneration" Ph.D. Thesis, University of New Brunswick, Canada.

Shalmon, B. 1981. A hidden to tropical world amongst the acacia tree. Teva Va-Aretz 23, 198-205.

Smith, T.M., & Goodman, P.S. 1986. The effect of competition on the structure and dynamics of *Acacia* savannas in Southern Africa. *Journal of Ecology* 74:1013-1044.

Ward, D. & Rohner, C. 1997. Anthropogenic causes of high mortality and low recruitment in three Acacia tree taxa in the Negev desert, Israel. *Biodiversity and Conservation* 6: 877-893.

Weyerhauser, F.J. 1985. Survey of elephant damage to baobabs in Tanzania's Lake Manyara National Park. Afr. J. Ecol. 23: 235-243.

Wilson, R.T. 1988. Vital statistics of the baobab (Adansonia digitata). Afr.J.Ecol.26: 197-206.

Wood R., Turner M and Brack W. 1999. Code of Forest Mensuration Practice: A guide to good tree measurement practice in Australia and New Zealand. URL: http://www.anu.edu.au/Forestry/mensuration/rwg2/code.