SHRUBS AND TREE FODDERS OR FARM ANIMALS

PROCEEDINGS OF A WORKSHOP IN DENPASAR, INDONESIA, 24 – 29 JULY 1989
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Shrubs and tree fodders for farm animals

Proceedings of a workshop in Denpasar, Indonesia, 24–29 July 1989

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Abstract

This publication presents the results of an international meeting held in Denpasar, Bali, Indonesia, 24–29 July 1989, that focused on the use of shrubs and tree fodders by farm animals. Through 26 papers, the workshop addressed feed-resource availability, use by ruminants and nonruminants, processing methodology, economics, and development issues. These aspects and the current knowledge on shrubs and tree fodders were further highlighted by country case studies detailing prevailing situations and policy matters. A special session was held to discuss the successful development and results achieved in the three-strata forage system in Indonesia. The workshop concluded with important working group discussions on the priorities for further research and development, and on the potential for the wider use of shrubs and tree fodders in the developing world.

Résumé

Cette publication présente les résultats d’une rencontre internationale tenue à Denpasar, Bali, Indonésie, du 24 au 29 juillet 1989 et qui a porté sur l’utilisation des arbustes et fourrages végétaux par les animaux d’élevage. Les 26 communications qui y ont été présentées traitaient de la disponibilité des ressources alimentaires pour les animaux, de leur utilisation par les ruminants et les non-ruminants, des méthodes de transformation, des aspects économiques et des questions du développement. Ces sujets et les connaissances actuelles sur les arbustes et les fourrages végétaux ont ensuite été étudiés plus à fond dans le cadre d’études de cas de divers pays exposant les circonstances particulières de chacun et les questions liées aux politiques. Une séance spéciale a porté sur la mise en place et les résultats des systèmes de production de fourrages végétaux en trois strates en Indonésie. L’atelier s’est terminé par d’importantes discussions des groupes de travail sur les priorités de recherche et de développement pour l’avenir et sur les possibilités d’utilisation élargie des arbustes et des fourrages végétaux dans les pays en développement.

Resumen

Esta publicación presenta los resultados de una reunión internacional celebrada en Denpasar, Bali, Indonesia, del 24 al 29 de julio de 1989, la cual centró su atención en la utilización de forrajes elaborados a partir de arbustos y árboles para alimentar a animales de granjas. En 26 trabajos presentados al seminario, los participantes abordaron temas tales como la disponibilidad de recursos alimentarios y la utilización de los mismos por rumiantes y no rumiantes, metodologías de procesamiento y cuestiones de economía y desarrollo. Estos aspectos y el conocimiento que se tiene actualmente sobre los forrajes de arbustos y árboles se vieron subrayados aún más por estudios de casos por países en los que se detallaron situaciones existentes y cuestiones de políticas. Se celebró una sesión especial para discutir el desarrollo y resultados exitosos alcanzados en Indonesia con el sistema de forraje de tres niveles. El taller concluyó con importantes discussiones de los grupos de trabajo sobre las prioridades existentes en el campo de la investigación y el desarrollo y sobre el potencial que encierra la amplia utilización de arbustos y árboles en el mundo en desarrollo.
## Contents

**Foreword** ................................................................. vii

**Acknowledgments** ................................................... ix

**Introduction** ........................................................... xi

### Session I: The Resources

The diversity and potential value of shrubs and tree fodders  
G.J. Blair ................................................................. 2

Shrubs and tree fodders in farming systems in Asia  
A. Topark-Ngarm ....................................................... 12

Major characteristics, agronomic features, and nutritional value of shrubs and tree fodders  
D.A. Ivory ................................................................. 22

Discussion ................................................................. 39

### Session II: Use by Farm Animals

The use of shrubs and tree fodders by ruminants  
C. Devendra ............................................................... 42

The use of shrubs and tree fodders by nonruminants  
P.D. Limcangco-Lopez ................................................. 61

Toxic factors and problems: methods of alleviating them in animals  
J.B. Lowry ................................................................. 76

Discussion ................................................................. 89

### Session III: The Three-Strata Forage System

The concept and development of the three-strata forage system  
I.M. Nitis, K. Lana, W. Sukanten, M. Suarna, and S. Putra ............... 92

Research protocols appropriate to the development of methodology for the three-strata forage system  
K. Lana, I.M. Nitis, M. Suarna, S. Putra, and W. Sukanten ................. 103

Socioeconomic aspects of the three-strata forage system in Bali  
I.W. Arga ........................................................................ 118

Communication aspects and research extension linkages of the three-strata forage system in Bali  
N.K. Nuraini .................................................................... 130

Discussion ................................................................. 136
Session IV: Country Case Studies

Availability and use of fodder shrubs and trees in tropical Africa
A.N. Atta-Krah .................................................. 140

Potential of legume tree fodders as animal feed in Central America
D. Pezo, M. Kass, J. Benavides, F. Romero, and C. Chaves ........ 163

Availability and use of shrubs and tree fodders in Pakistan
M. Akram, S.H. Hanjra, M.A. Qazi, and J.A. Bhatti ............... 176

Agrosilvipasture systems in India
P. Singh .............................................................. 183

Availability and use of shrubs and tree fodders in India
G.V. Raghavan ...................................................... 196

Availability and use of shrubs and tree fodders in Nepal
N.P. Joshi and S.B. Singh ......................................... 211

Availability and use of shrubs and tree fodders in Bangladesh
M. Saadullah ......................................................... 221

Availability and use of shrubs and tree fodders in Sri Lanka
A.S.B. Rajaguru .................................................... 237

Availability and use of shrubs and tree fodders in Thailand
M. Wanapat .......................................................... 244

Availability and use of shrubs and tree fodders in Malaysia
Wong C.C. ............................................................ 255

Availability and use of shrubs and tree fodders in Indonesia
M. Rangkuti, M.E. Siregar, and A. Roesyat .......................... 266

Availability and use of shrubs and tree fodders in the Philippines
L.T. Trung ............................................................. 279

Availability and use of shrubs and tree fodders in China
Xu Zaichun ........................................................... 295

Discussion ............................................................ 303

Session V: Processing, Methodology, and Economics

Opportunities for processing and using shrubs and tree fodders
M.R. Reddy .......................................................... 308

Development and evaluation of agroforestry systems for fodder production
A.N. Abd. Ghani and K. Awang ..................................... 319

Economic aspects of using shrubs and tree fodders to feed farm animals
P. Amir ................................................................. 331

Discussion ............................................................. 340

Conclusions and Recommendations .................................. 341

Participants .......................................................... 347
Availability and use of fodder shrubs and trees in tropical Africa

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International Institute of Tropical Agriculture, PMB 5320, Ibadan, Nigeria

Abstract — Generally, trees occupy a significant niche in the farming systems and overall way of life in tropical Africa. Fodder shrubs and trees (browse) in this region play a significant role both in farming systems, where they are protected as fallow species, and in livestock production. Livestock in this zone depend largely on browse for their dietary protein. Compared with tropical grass, browse is generally richer in protein and minerals. The importance of browse increases with increasing aridity and is generally most essential in the dry seasons, when most other feed resources depreciate in quality and quantity. Browse intake increases total dry matter intake, increases crude protein intake, and improves the digestibility of low-quality forages. The effect of browse feeding on livestock is shown in increased survivability (i.e., lower mortalities, especially over the dry season) and increased productivity.

Traditionally, throughout tropical Africa, processing and conservation of tree fodder is uncommon, and cultivation is minimal and insignificant. This paper advocates the need for increased cultivation and integration of fodder trees (especially leguminous ones) into local farming systems through agroforestry. It also stresses the need for increased research support for the efficient cultivation, management, and use of fodder shrubs and trees for improved livestock production.

Résumé — En général les arbres occupent un créneau important dans le mode de vie de tout paysan de l'Afrique tropicale. Les arbustes et arbres fourragers, dans cette région, jouent un grand rôle tant dans les systèmes d'exploitation agricole, où ils sont protégés comme espèces de jachère, que dans la production animale. Le bétail en tire une bonne partie de ses protéines alimentaires. Comparativement aux graminées tropicales, ces fourrages sont généralement plus riches en protéines et en minéraux. Ces fourrages deviennent plus importants quand l'aridité augmente et, en saison sèche, lorsque presque tous les autres fourrages se font rares et de qualité médiocre, ils deviennent essentiels. La consommation de ces fourrages augmente l'absorption totale de matières sèches et de protéines brutes et rend les fourrages de qualité inférieure plus digestibles. Il est prouvé que ces fourrages augmentent la survie (soit moins de mortalités surtout en saison sèche) et la productivité du bétail. Jusqu'à maintenant en Afrique tropicale la transformation et la conservation des arbres fourragers ont été chose rare et leur culture minime et négligeable. L'auteur affirme qu'il faut accroître la culture et l'intégration des arbres fourragers (particulièrement les arbres légumineux) dans les systèmes d'exploitation agricole locaux par l'entremise de l'agroforesterie. Il souligne aussi le besoin de financer plus de recherches sur la culture, la gestion et l'utilisation efficaces des arbustes et des arbres fourragers afin d'améliorer la production du bétail.

Resumen — En general, el papel que desempeñan los árboles en los
Introduction

Trees are important for two major purposes. The first, environmental protection (including soil fertility maintenance), is conservation-oriented. Watersheds, windbreaks, erosion barriers, forest reserves, and planted fallows are all strategies of conservation. The second purpose is produce-oriented and demands that trees be exploited. This, therefore, includes the harvest of trees as timber, poles, fuelwood, and fodder. Unfortunately, the balance between conservation and produce-use objectives has favoured the latter at the expense of the former.

In tropical Africa, trees occupy a significant niche in the life of the people. The dominant farming system, shifting cultivation or bush fallow rotation, is based strongly on the conservation and regenerative properties of trees (Nye and Greenland 1960; Ruthenberg 1980). This system is now under pressure from the increasing human population, resulting in a shortening of fallow periods and rendering the system inefficient for the regeneration of soil fertility. There is, as a result, an ever-increasing demand for fresh forest land for clearing and cultivation; this has made shifting cultivation a major factor in deforestation.

Use as fodder has also contributed to tree depletion. The importance of browse is universal throughout the tropics, where it serves as a major feed resource, especially in the drier regions and during dry seasons. During these periods, grasses, which are the major feed resource for livestock, dry up and deteriorate both in quality and productivity. De Leeuw and Brinckman (1974), for example, reported that the crude protein content of principal grasses in the Sahel is about 6% from May to mid-July and as low as 2% for most of the dry season. Dry mature grasses have been reported to have little or no digestible protein, practically no carotene, and a low level of phosphorus (Table 1). Ruminants cannot meet their maintenance needs on dry grass alone. Compared with tropical grasses, browse is generally richer in protein and minerals, especially in the dry season.
Table 1. Comparison of feed value of dry grass and browse during the dry season.

<table>
<thead>
<tr>
<th></th>
<th>Net energy (MJ/kg DM)</th>
<th>Digestible protein (g/kg DM)</th>
<th>P (g/kg DM)</th>
<th>Ca (g/kg DM)</th>
<th>Carotene (mg/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry grass straw</td>
<td>2.5–3.4</td>
<td>≤1</td>
<td>≤1</td>
<td>1.5–3.0</td>
<td>≤1</td>
</tr>
<tr>
<td>Browse</td>
<td>1.7–2.9</td>
<td>50–300</td>
<td>1.5–2.5</td>
<td>2.5–20.0</td>
<td>50–800</td>
</tr>
<tr>
<td>Maintenance needs</td>
<td>2.9</td>
<td>50</td>
<td>1.3</td>
<td>2.5</td>
<td>1.5</td>
</tr>
</tbody>
</table>


* DM, dry matter.

(Mohamed-Saleem et al. 1979; Adegbola 1985) and contains twice the amount of energy in dry grass (Le Houérou 1980).

Data assembled by Le Houérou (1980) on the nutritive value of browse from West and Central Africa suggest that, potentially, most browse species are able to supply the energy requirements for maintenance and growth of ruminants. The validity of this suggestion for different ruminant livestock species, however, depends on their preference for, and voluntary intake of, browse. The significance and extent of their contribution, however, varies across ecological zones, becoming greater in more arid regions (Le Houérou 1978; Adegbola 1982), where they play a more significant carry-over role in ensuring survival and sustainability of livestock during the dry season.

This paper analyzes the role of shrubs and trees as a feed resource for livestock in tropical Africa. Discussion focuses on the major agroecological zones in sub-Saharan Africa. Specific reference is made to Nigeria because of the familiarity with conditions in that country. Only ruminant animals (cattle, sheep, and goats) are considered.

Agroecological zones

Excluding deserts, there are five major agroecological zones (AEZs) in tropical Africa: humid, subhumid, semi-arid, arid, and montane (highlands) (Fig. 1). The humid zone covers $4.1 \times 10^6$ km$^2$ and receives over 1 500 mm rainfall, with a growing season of more than 270 days (ILCA 1987). The subhumid zone occupies 21% of tropical Africa, some $4.8 \times 10^6$ km$^2$, and has an average annual rainfall of 900–1 500 mm and a growing period of 180–270 days (ILCA 1983). In the arid and semi-arid zones, annual rainfall varies from 100 mm to 1 000 mm and plant-growing time is less than 180 days. The semi-arid zone falls between the 600 and 1 000 mm annual rainfall isohyets; the arid zone includes all land receiving less than 600 mm annual rainfall (Ahmed 1986).

The vegetation across these various ecozones is closely related to the climate (especially rainfall) and soil. It ranges from moist evergreen forests in the humid zone, Guinea savannah and Sudan savannah in the subhumid and semi-arid zones,
Importance and availability of shrubs and fodder trees

In the various AEZs, the importance and availability of fodder shrubs and trees are influenced by many factors. The most important are

- the natural distribution of trees with the zones,
- the distribution, type, and importance of livestock, and their integration and role within the farming system, and
- the availability of alternative sources of fodder (other than from trees) for livestock in the zone.

In the humid zone, trees are the dominant natural vegetation and they constitute the major component of the forests. This region, therefore, has the highest density of trees, which decreases toward the arid regions. The importance and significance of browse across agroecological zones, however, does not follow this pattern; other...
<table>
<thead>
<tr>
<th>Ecological zone</th>
<th>Cattle (1000 head)</th>
<th>Sheep (1000 head)</th>
<th>Goats (1000 head)</th>
<th>Ruminants* (1000 TLU)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arid</td>
<td>31462</td>
<td>37063</td>
<td>48287</td>
<td>41697</td>
</tr>
<tr>
<td></td>
<td>(21.3)b</td>
<td>(35.7)</td>
<td>(38.6)</td>
<td>(30.4)</td>
</tr>
<tr>
<td>Semi-arid</td>
<td>45454</td>
<td>23071</td>
<td>33215</td>
<td>37446</td>
</tr>
<tr>
<td></td>
<td>(22.2)</td>
<td>(13.6)</td>
<td>(16.2)</td>
<td>(19.2)</td>
</tr>
<tr>
<td>Subhumid</td>
<td>32758</td>
<td>14153</td>
<td>20266</td>
<td>26370</td>
</tr>
<tr>
<td></td>
<td>(22.2)</td>
<td>(7.9)</td>
<td>(9.2)</td>
<td>(5.9)</td>
</tr>
<tr>
<td>Humid</td>
<td>8814</td>
<td>8177</td>
<td>11586</td>
<td>8148</td>
</tr>
<tr>
<td></td>
<td>(6.0)</td>
<td>(7.9)</td>
<td>(9.2)</td>
<td>(5.9)</td>
</tr>
<tr>
<td>Highlands</td>
<td>29022</td>
<td>21401</td>
<td>11933</td>
<td>23646</td>
</tr>
<tr>
<td></td>
<td>(19.7)</td>
<td>(20.6)</td>
<td>(9.5)</td>
<td>(17.2)</td>
</tr>
<tr>
<td>Total</td>
<td>147510</td>
<td>103865</td>
<td>125287</td>
<td>137308</td>
</tr>
</tbody>
</table>

Source: Jahnke (1982).

a Including camels; TLU, tropical livestock unit.
b Values in parentheses represent population as a percent of the total.

considerations, such as animal populations and their importance within farming systems are involved. Table 2 gives the distribution of ruminants by ecological zones. The trend is opposite to that observed for tree dominance and density. The density and importance of livestock is highest in the arid and semi-arid regions and decreases toward the humid zone. Thus, the demand for browse and other feeds is higher in the drier areas than it is in the humid regions.

The length of the dry season across the various zones also influences the degree of dependence on browse. The longer and more intense the dry season, the longer the period of grass scarcity during the year, and the more valuable the browse. In the Sahel region of West Africa, for example, the dry season may last as long as 8 months and grass is available for only 3 or 4 months in a year (Adegbola 1982). Browse is, therefore, a critical feed element and plays an essential role in animal production systems.

The availability and use of crop residue is another factor that influences the degree and dependence on browse. Crop-residue availability is influenced by the type of crops grown, the length and reliability of the cropping season, and the crop–livestock system. In the humid zone, little use is made of crop residues for livestock, and, where supplementary feeding is required, shrubs and fodder trees are used. In the subhumid and semi-arid regions, crop residues play a major role in the feeding of livestock during the early dry season (van Raay and de Leeuw 1974). Animals are allowed on cropping lands to graze the residue, enriching the soil in the process through manure droppings. Toward the end of the dry season, when crop residues are used up and grass is at its worst, in quantity and quality, browse receives the most attention from sheep, goats, and cattle.

Major fodder shrub and tree species

Several authors have described tree species used to supply animal feeds to different categories of livestock in the AEZs of Africa. Detailed chemical analyses of these fodders have also been done (Dougall et al. 1964; Roose-Innes and Mabey
Fig. 2. Goats browsing on Acacia trees in semi-arid Africa, where grass and herb vegetation is almost totally absent.

1964; Le Houérou 1978). Within Nigeria, this subject has been studied by Mohamed-Saleem et al. (1979), Carew et al. (1980), Mecha and Adegbola (1980), Adegbola (1982), Agishi (1985), and others. The information on major browse shrubs and trees across the various AEZs of Africa refers mainly to West Africa.

Agishi (1985) classified fodder trees and shrubs in Nigerian rangelands into two groups: nonleguminous and leguminous. About 40 families of nonleguminous shrubs and trees were said to be forage species. Legume trees also constitute a major presence in the Nigerian rangelands; about 143 legume genera are represented (Agishi 1984). The subfamily Mimosaceae is the most important source of browse, accounting for 55% compared with 27.5 and 17.5% for Papilionaceae and Caesalpinaceae, respectively. The acacias are the most important browse species in the Sudan zone (Pellew 1980; Toutain 1980), both by number and by density, but they are poorly represented in the less arid regions south of this zone. Many important legume browse species have a wide distribution across zones. Afzelia africana, Daniella oliveri, and Pierocarpus erinaceus, for example, are found in all AEZs but the montane (Agishi 1985).

According to Mohamed-Saleem et al. (1979), the heavily browsed fodder shrubs and trees in the Sudan savannah include Acacia siberiana, Afzelia africana, Grawie mollis, Khaya senegalensis, Pierocarpus erinaceus, and Strychnos spinosa (Fig. 2). Most of them are also available in the Guinea savannah. Audru (1980) listed some of the palatable species of this zone as Cussonia barterii, Daniella oliveri, Ficus thonningii, Bridelia spp., and Albizzia lebbeck. De Leeuw (1979) included Dichrostachys cinerea, Piliostigma thonningii, and Parkia clappertoniana as browse species relished by livestock in the savannah.

Some of the most commonly selected browse for sheep and goats in the humid forest and derived savannah zones are Ficus exasperata, Newbouldia laevis, Aspilia africana, Spondias mombin, and Cyclicodiscus gabunensis (Carew et al. 1980).
Mecha and Adegbola (1980) included *Albizia ferrunginea*, *Ficus elastycoides*, *Baphia nitida*, *Cajanus cajan*, and *Leucaena leucocephala*. *Gliricidia sepium*, although widespread, is known more as a fencing and shade tree than as a fodder tree.

In the acid soil (ultisol) and high rainfall areas of the humid zone, introduced legume tree species such as *Leucaena* and *Gliricidia* have shown poor growth and poor productivity. The most widely used indigenous species in the acid soil region of southeast Nigeria include *Acioa barterii*, *Dialium guinensis*, *Anthonata* spp., *Baphia nitida*, *Harungana madagascariensis*, and *Alchornea cordifolia* (ILCA 1987; Wahua and Oji 1987).

**Use patterns of shrubs and tree fodders**

The degree and pattern of use of shrubs and tree fodders is influenced by the dominant livestock species and farming systems. In the humid zone, small ruminants are the dominant ruminant livestock species and their production is generally extensive with little or no management inputs. The major farming activity is tree crop (cocoa, oil palm, and kola) cultivation. Farming systems are based on shifting cultivation (Ruthenberg 1980) and land is either under cropping or in fallow.

Small ruminants in the humid zone are managed extensively or in smallholder confinement systems. The former occurs in southwest Nigeria and sheep and goats obtain their major feed requirements by scavenging around households, and by grazing and browsing along roadsides and in fallow lands (Atta-Krah and Reynolds 1989). In areas with high population densities (e.g., southeast Nigeria), cultivation is intensive and compound farming is practiced. In such areas, livestock is usually confined (at least during the cropping season). Cut and carry of fodder is therefore practiced. Browse from fallow lands constitutes the major component of feed offered and these trees are well valued and protected even on cropping land. However, over-exploitation and lack of management are threatening the continued availability of this highly valued feed resource.

In the subhumid zone, livestock are more important and better integrated into the farming system than in the humid zone. According to Mohamed-Saleem et al. (1986), crop–livestock production systems in the subhumid zone range from intensive cropping with no livestock kept (though residue is grazed by pastoralists’ cattle) through settled agropastoralism to settled pastoralism, with little or no cropping. In all these systems, crop residue is used as livestock feed during the dry season. Cattle are herded on natural pasture and communal grazing lands throughout the year, but especially in the cropping season and in the late dry season. Small ruminants are restricted during the cropping season and some cut-and-carry feeding is practiced, with browse such as *Afzelia africana*, *Daniella oliveri*, and *Ficus thonningii* frequently used. Browse is also frequently lopped by herders to provide either fruit or leaves for grazing cattle and sheep (Mohamed-Saleem et al. 1979; Milligan and Sule 1982). In recent decades, the human population has increased in the subhumid zone and cropping has encroached on grazing land. This has resulted in declining availability of trees, grasses, and other herbs used for animals.
In the arid and semi-arid regions, pastoralism is the dominant system, with livestock (especially cattle and, to a lesser extent, sheep) being moved from place to place in search of green pasture. Thus, in the dry seasons, the general movement is toward the less arid south. Such migration could go as far south as the Guinea and derived savannah zones, where trees, shrubs, and grass vegetation, as well as crop residues, are in relative abundance. Goats and sheep are not usually part of this transhumance. They are left, sometimes with herders, to roam the rangeland and grazing reserves and survive on whatever is available in the range. It is during this period that the greatest damage is done to browse, as grazing is unmanaged and excessive. All three classes of ruminant animals are represented in this region, but the high population of goats (see Table 2) is especially significant because of their preference for browse.

Most farmers are conscious of the value of browse trees and the need to conserve them. In most situations, these fodder shrubs and trees constitute the last trace of vegetation before the land is completely depleted. Vast areas of land in this critical state exist in all the arid and semi-arid countries. It is in these zones that one actually sees the process of deforestation leading directly to desertification and the role therein played by livestock and fuelwood gathering and harvesting (Atta-Krah and Okah 1986).

**Cultivating and processing shrubs and tree fodders**

There is little or no direct forage cultivation in traditional farming systems in tropical Africa. This is due to many factors, including the following:

- the subsistence nature of livestock production in some zones (e.g., small ruminants in the humid zone), which generally precludes activities that involve cost in terms of labour, land, or other resources;
- the extensive system of livestock management in the major livestock areas, which is based on pastoralism; and
- the land factor (in several parts of the tropics land tenure and ownership patterns do not favour individual pasture production; in many instances, the owners of animals do not own land that could be used for forage production).

Processing and preservation of tree fodders on an organized scale is largely unknown and is not practiced to any appreciable extent in any AEZ in tropical Africa. This is a reflection of the lack of management in the use of tree fodders and may reflect the labour constraints for such activities. One exception is the case in Malawi, where *Leucaena* is produced in smallholdings in villages and the foliage is sun dried and either fed as a winter supplement or sold as a cash crop. The dry *Leucaena* leaves are sold to local millers for incorporation in layers diets as a source of carotenoid for yolk pigmentation (Savory et al. 1980). Tree fodder is commonly browsed directly from the tree or is produced by lopping. Tree fodders are also offered fresh in cut-and-carry feeding systems. Some tree fodders, like *Gliricidia*, may be wilted to increase intake.

Proper management of fodder trees can result in increased feed availability for livestock, especially in the dry seasons. Research carried out at the International Livestock Centre for Africa (ILCA) on *Leucaena* and *Gliricidia* in alley farming
hedgerows showed significant differences in overall productivity of forage in response to different pruning and management schedules. Foliage harvested before the dry season was conserved by sun drying and storage in sacks for use in the dry season, in addition to foliage retained on the trees (Fig. 3). Simple processing techniques such as sun drying could be used to preserve tree fodders for critical periods such as the dry season (Savory et al. 1980). Some research is required on the major shrub species to determine the effect on feed quality and assess the economics of such systems.

**Fodder trees in agroforestry**

Most fodder shrubs and trees have many functions. They provide fodder, firewood, poles for building and fencing, live fence, fibre, fruits, spices, fats, medicines, dyes, and tannins (McKell 1980; Wickens 1980; Adegbola 1985). Most of these uses are exploitative and compete, either in the short or long term, with the supply of fodders by the trees. For example, Wilson (1980) reports that 90% of all the wood burned in the Niono area in the Sahel region of Mali is from *Pterocarpus lucens*, which Le Houérou (1979) described as one of the most palatable and nutritious browse species in the region. Some other uses, such as for live fencing,
are complementary, as they encourage cultivation of the species and increase the availability of feeds.

Of the various other uses to which fodder trees are put, perhaps the most significant is that dealing with soil fertility maintenance, as it raises the chances of cultivation of fodder trees in production systems. Leguminous fodder trees such as *Gliricidia sepium*, *Parkia clapertoniana*, *Leucaena leucocephala*, and *Acacia albida* have an even better potential in this respect. Traditional farmers have been known to protect and encourage the growth of useful trees on their farmland during both cropping years and fallows. Obi and Tuley (1973) reported several browse tree species as dominating 5- to 10-year fallows in southeast Nigeria. These included *Alchornea cordifolia*, *Acioa barterii*, *Anthonata macrophylla*, *Harungana madagascariensis*, and *Cnestis feruginea*. Such multipurpose trees are commonly protected during cropping years to ensure their regeneration in the next fallow period. During the cropping period, they are managed and put to a variety of uses including fodder and human food.

The traditional tree intercropping (agroforestry) system with *Parkia* spp. and the shea butter tree (*Butyrospermum paradoxum*) in the Guinea and Sudan savannahs, and *Acacia albida* in the drier parts of the African tropics (Sahel region), is an indication of this awareness (Boudet and Toutain 1980; Wickens 1980). Of these examples, only *Acacia albida* is clearly agropastoral in character; both *Parkia* and *Butyrospermum* are probably kept more for their human food use than as fodder. All three examples, however, show the integration of fodder trees into cropping systems, for soil fertility improvement and other products. Crop yields under *A. albida* have been reported to be 56% higher than yields in areas without the tree (Poschen 1986). Felker (1978) also reported that in the infertile sandy soils of the Senegalese groundnut basin, crop yields of groundnut and millet increased from 500 to 900 kg/ha when grown under *A. albida*. Similar results have been reported from India with *Prosopis cineraria* (Mann and Sharmkarnaarayan 1980; Mann and Saxena 1981). Both trees are highly preferred fodder species and their attraction to livestock is complementary to their role in maintaining soil fertility, as browsing animals help enrich the soil through their droppings.

Leguminous fodder trees in rangelands have also been observed to influence the productivity of grass growing under them. This is the case in the Sahel of West Africa, where productivity of *Pennisetum pedicellatum* is about twice under the trees than it is in the open (Bille 1978). Also, the grass under the trees dries out 3–6 weeks later and photosynthetic efficiency was 1.4% under shade and 0.3% in the open. Le Houérou (1978) made similar observations in Botswana on *Panicum maximum*. Potential evapotranspiration was reduced by 50–70% under shade and the grass remained green 6 weeks longer into the dry season. A number of agroforestry technologies have been proposed for the development of fodder shrub and tree cultivation within smallholder farming systems (Atta-Krah and Reynolds 1989). These include alley farming, alley grazing, and intensive feed (fodder) gardens.

**Alley farming**

Alley farming involves the planting of leguminous or other soil-improving fodder trees in rows within arable crop farms. The trees are managed to provide
Table 3. Leaf biomass, nitrogen, and crude protein yield of alley farming tree species.

<table>
<thead>
<tr>
<th>Species</th>
<th>Total annual leaf biomass yield$^a$ (t DM/ha)</th>
<th>Annual nitrogen yield$^a$ (kg/ha)</th>
<th>Crude protein$^b$ (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acioa barterii</td>
<td>3.0</td>
<td>40.5</td>
<td>8.2</td>
</tr>
<tr>
<td>Alchornea cordifolia</td>
<td>4.0</td>
<td>84.8</td>
<td>12.0</td>
</tr>
<tr>
<td>Gliricidia sepium</td>
<td>5.5</td>
<td>169.1</td>
<td>20.0</td>
</tr>
<tr>
<td>Leucaena leucocephala</td>
<td>7.4</td>
<td>246.5</td>
<td>21.25</td>
</tr>
</tbody>
</table>


$^b$ Crude protein (CP) content estimated as N × 6.25.

Mulch on a continuous basis to maintain soil fertility and to provide fodder at critical periods for livestock. The concept is based on the alley cropping system (Kang et al. 1981) developed at the International Institute of Tropical Agriculture (IITA) in which legume trees are integrated into cropping fields to maintain soil fertility and promote continuous cropping. Food crops are planted in the 4-m alleys between established tree rows. Tree pruning management during the cropping period should prevent excessive shading of arable crops growing within alleys. The nitrogen-rich prunings (foliage and twigs) are used as green manure or as mulch to improve soil fertility and enhance crop production. When fodder tree species are used in alley farming, some of the prunings (foliage) could also be fed to livestock. Leguminous, nitrogen-fixing fodder trees, therefore, have a special advantage in these systems, although nonlegumes can also be used. Information on the establishment and management of alley farms can be found in Kang et al. (1984) and Reynolds et al. (1988).

The foliage productivity and foliar N content of alley farming tree species may be seen as significant elements both in soil fertility maintenance and in feed production. Annual foliage productivity of Leucaena and Gliricidia under alley farming management is 5–8 t dry matter (DM)/ha, with four to six cuttings per year (Kang et al. 1981; Atta-Krah et al. 1986). Table 3 shows foliage DM, nitrogen yield, and crude protein contents of four tree species (two legumes and two nonlegumes) used in alley farming. Both biomass productivity and N content of the legume trees were observed to be higher than for the nonlegumes.

Alley grazing

Alley grazing is simply the grazing of alley farms by livestock during periods when no crop is carried on the land. This system allows direct integration of livestock within alley farming. The grazing period could be during the dry season, at which time the animals may graze on crop residues, natural weed growth, and tree regrowth. It could also be through integration of specific grazed fallow periods in rotation with cropping, within the alley farming system (Atta-Krah et al. 1986).

Even though effects on soil, crops, and trees are all positive following a grazed fallow, animal management within the system poses a number of practical problems, raising doubts as to its practicality and suitability for smallholder farmers (L. Reynolds, personal communication). Some of the problem issues are the
Fig. 4. Effect of 2-year fallow with and without livestock on first-season maize yields under conventional cropping and alley farming with gliricidia: A, continuous cropping; B, cropping after 2 years of ordinary fallow; C, cropping after 2 years of grazed fallow.

requirement for fencing, theft of animals left grazing in fields, and over-grazing and debarking of trees by animals. Debarking is more serious with goats than with sheep and can result in loss of trees and lower productivity of prunings when these fallow plots revert to cropping. This could reduce the expected gain in crop yield in postfallow cropping, compared with yield from an alley farm that has benefited from an ordinary fallow without livestock. Such observations have been made in a trial with *Gliricidia sepium* with integration of a 2-year grazed and ordinary (ungrazed) fallow (Fig. 4).

Intensive feed gardens

The intensive feed garden (IFG) is a system in which fodder trees are cultivated either in sole stands or in combinations with grasses. They are especially suitable for farmers who show some intensification in their livestock production and are prepared to invest in pasture production, even if only on a very small scale.

With tree–grass systems, tree hedgerows may be established 4 m apart, with four rows of grasses sown in between. Tree hedgerows may also be established 2.5 m apart with two rows of grasses. This latter arrangement has a high density of trees, and therefore, a higher protein yield; however, it requires more management attention. Using leucaena and gliricidia mixed with *Panicum maximum* in such gardens, a productivity of over 20 t DM/ha of mixed tree–grass fodder is available from both designs under humid zone conditions (Atta-Krah and Reynolds 1989).
With tree-only plots, productivity is dependent on the interrow spacing of the hedgerow and the cutting frequency. Research at ILCA has shown that, of the two factors, cutting frequency has a greater effect on tree productivity. Increasing the regrowth cycle (period between cuttings) from 6 to 12 weeks leads to fewer harvests per year, but gives a greater total yield of fodder. Also, increasing interrow spacing from 0.5 through to 2.0 m results in decreasing yields per unit area. For 3 consecutive years, the highest yield of fodder has been obtained from the combination of 0.5-m interrow spacing with a regrowth cycle of 12 weeks (ILCA 1987, 1988). An annual fodder yield of over 30 t DM/ha has been obtained from this combination in the 3 years of cultivation.

**Effect of browse intake on livestock**

The fact that browse is available during periods of stress and scarcity is important. Some livestock species have a preferred taste for browse, and this adds to their importance. Species such as cattle are primarily grazers; others such as goats and camels are mainly browsers; sheep are in-between. A. Blanchemain (unpublished; FAO, Rome, 1964) showed, for instance, that high-performance goats producing 1 000 kg of milk in 300 days can still consume up to 30% of their diet in browse.

Survivability on browse has been clearly and satisfactorily explained by Sarson and Salmon (1978), who worked out the relationship between maintenance needs of cattle, sheep, and goats and possibilities of ingestion with respect to quality per 100 kg live weight. This analysis showed that browse (nutritional value of which varies from 0.25 to 0.40 feed units (FU)/kg DM) alone cannot ensure the maintenance requirements of cattle (0.65 FU/kg DM). It can, however, ensure maintenance of sheep (0.35 FU/kg DM), but does not allow production. With goats, maintenance and production may be provided on a pure browse diet (0.19 FU/kg DM). This explains why only goats, camels, and some wild herbivores can survive on depleted rangelands, where browse constitutes most of the feed. It also explains why goats and camels are less affected by catastrophic droughts in the Sahel of Africa, compared with sheep and cattle (Le Houérou 1978).

Another reason for the importance of browse is its effect on intake. Often, when the quality of feed drops, livestock respond by taking in less. For example, consumption of *Andropogon gayanus* by heifers decreased from 76 to 47 g/kg metabolic body weight when CP of the hay decreased from 5.35 to 2.35% (Zemmelink et al. 1972). Research conducted at the Humid Zone Programme of ILCA with sheep and goats receiving ad libitum grass (*Panicum maximum*) and different rates of mixed leucaena-gliricidia supplements, showed that increasing levels of browse legume supplementation led to a decrease in intake of *Panicum*, an increased intake of the legume browse fodder, reflecting amounts offered, and an overall increase in total DM intake (Fig. 5). This situation was observed both for adult animals and for freshly weaned lambs (Reynolds and Adediran 1988). Similar results have been reported by other workers (Ademosun et al. 1985; Ademosun et al. 1988).

Because of the generally high protein content of browse, its intake affects the digestibility of overall feed intake by livestock. Based on established relationships, it has been estimated that digestibility of CP tends to approach zero below 3.7%
Fig. 5. Dry matter (DM) intake of adult sheep offered different levels of supplementary browse (g/day): A, 550; B, 1100; C, 2200; D, 3300 (source: Reynolds and Adediran 1988).

(Milford and Minson 1966). Generally, if the level of crude protein in the diet drops below 6%, as happens with grass during the dry season, rumen microbes are unable to make enough protein to maintain their rate of reproduction and growth. This leads to a drop in the number of microbes in the rumen, slowing the rate of digestion of food and reducing fresh intake (Reynolds and Adediran 1988).

Ademosun et al. (1988) showed that supplementation of grass diets with leucaena and gliricidia not only results in increased DM intake but also improves digestibility and hence the total intake of digestible dry matter (DDM) (Table 4). Another study by the same workers, in which gliricidia and leucaena were fed at 100%, 75:25%, and 50:50%, revealed that inclusion of leucaena into a sole gliricidia diet clearly improved DDM intake (42 vs 37 g/kg\(^{0.75}\) per day).

The ultimate effect of supplementation with tree fodder is increased survivability and productivity of livestock. For example, Reynolds and Adediran (1988) showed that supplementation of a grass and cassava peel basal diet with a mixed leucaena–gliricidia feed resulted in significant increases in both growth rate of lambs and their survival to 24 weeks (Table 5). Survival rates of offspring and their growth rates increased with the level of supplementation. In Malawi, dried leucaena leaf meal, as a dietary supplement to maize bran and maize stover, allowed stall fed steers to gain 1.2 kg/head per day (Thomas and Addy 1977). Supplementing a basal diet of *Panicum* grass with leucaena–gliricidia was also reported to reduce the interval between parturitions (Reynolds and Adeoye 1989).

Productivity index from varying levels of mixed leucaena–gliricidia browse offered to adult females during the final 8 weeks of pregnancy through to weaning at 12 weeks postpartum showed a positive effect to supplementation (Reynolds and
Table 4. Some results of feeding trials carried out by the University of Ife Goat Research Project.

<table>
<thead>
<tr>
<th>Feed</th>
<th>Daily offer (g/kg&lt;sup&gt;0.75&lt;/sup&gt;)</th>
<th>Daily Intake (g/kg&lt;sup&gt;0.75&lt;/sup&gt;)</th>
<th>Digestibility (%)</th>
<th>Daily DDMI&lt;sup&gt;a&lt;/sup&gt; (g/kg&lt;sup&gt;°.75&lt;/sup&gt;)</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>P. maximum</em> (well fertilized, 6 weeks)</td>
<td>75.0</td>
<td>54.9±2.2</td>
<td>75.8±2.6</td>
<td>40.6±2.5</td>
</tr>
<tr>
<td><em>P. maximum</em> (hay)</td>
<td>77.1</td>
<td>43.1±6.4</td>
<td>45.0±6.1</td>
<td>19.5±4.1</td>
</tr>
<tr>
<td><em>C. rlemfluensis</em> (hay)</td>
<td>74.9</td>
<td>37.2±2.5</td>
<td>55.1±2.9</td>
<td>37.9±3.1</td>
</tr>
<tr>
<td><em>G. sepium</em></td>
<td>73.4</td>
<td>36.8±5.1</td>
<td>47.7±3.1</td>
<td>32.6±2.3</td>
</tr>
<tr>
<td><em>L. leucocephala</em></td>
<td>131.5</td>
<td>39.9</td>
<td>46.6</td>
<td>18.5</td>
</tr>
<tr>
<td><em>C. nlemfluensis</em> (hay)</td>
<td>87.5</td>
<td>40.6</td>
<td>43.2</td>
<td></td>
</tr>
<tr>
<td><em>G. sepium</em></td>
<td>31.9</td>
<td>31.9±0.2</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td><em>L. leucocephala</em></td>
<td>31.6</td>
<td>31.6±1.2</td>
<td>—</td>
<td></td>
</tr>
</tbody>
</table>

Source: Ademosun et al. (1988).

<sup>a</sup> DDMI, digestible dry matter intake.

Table 5. The effects of supplementary leucaena and gliricidia browse on the growth and survival rates of small ruminants, Ibadan, Nigerian humid zone, 1986/87.

<table>
<thead>
<tr>
<th>Species</th>
<th>Browse Intake (g DM/day)</th>
<th>Growth rate (g/day) to:</th>
<th>Survival to 24 weeks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dam&lt;sup&gt;b&lt;/sup&gt;</td>
<td>Offspring&lt;sup&gt;b&lt;/sup&gt;</td>
<td>weaning&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>Goats</td>
<td>143</td>
<td>39</td>
<td>17.4</td>
</tr>
<tr>
<td></td>
<td>254</td>
<td>83</td>
<td>28.7</td>
</tr>
<tr>
<td></td>
<td>554</td>
<td>160</td>
<td>25.9</td>
</tr>
<tr>
<td></td>
<td>719</td>
<td>246</td>
<td>31.9</td>
</tr>
<tr>
<td>Sheep</td>
<td>0</td>
<td>0</td>
<td>39.0</td>
</tr>
<tr>
<td></td>
<td>120</td>
<td>34</td>
<td>46.7</td>
</tr>
<tr>
<td></td>
<td>239</td>
<td>77</td>
<td>57.2</td>
</tr>
<tr>
<td></td>
<td>441</td>
<td>136</td>
<td>66.3</td>
</tr>
<tr>
<td></td>
<td>741</td>
<td>250</td>
<td>84.0</td>
</tr>
</tbody>
</table>


<sup>b</sup> During the final 2 months of pregnancy up to weaning.
<sup>c</sup> From weaning to 24 weeks.
<sup>e</sup> Weaning at 12 weeks for lambs and 16 weeks for kids.

Adediran (1988). Productivity index, measured as kilograms of lamb weaned per ewe per year, depended on parturition interval, litter size, survival rate to weaning, and weaning weight. All of these factors, with the exception of litter size, were reported to improve as supplementation levels increased. From the regression line (Fig. 6), it was deduced that supplementation to dams with 100 g DM daily for the last 2 months of pregnancy and 3 months of lactation using a total of 14 kg browse DM raised the productivity index by 1.4 kg.

The fruits of some browse trees are also good sources of feed and protein. For example, livestock farmers in Africa are aware of the value of fruits of *Acacia* trees. In the Masai system in semi-arid Kenya, flocks are taken to *Acacia tortilis* woodland during dry periods to feed on ripe pods shaken from the trees by herdsmen. The pods make up about 50% of total daily intake during this period, and the animals gain weight. Conception rate were 80% for sheep and 54% for goats compared with 20 and 47% for control animals, respectively (de Leeuw et al. 1954).
Fig. 6. Effect of browse intake on productivity of sheep (source: Reynolds et al. 1988).

Table 6. Growth rate, intake, true nitrogen digestibility and appearance of whole seeds in the feces of sheep fed noug cakes and fruits from four acacias, Addis Ababa, 1987.

<table>
<thead>
<tr>
<th></th>
<th>Noug cake</th>
<th>Acacia tortilis</th>
<th>Acacia albida</th>
<th>Acacia nilotica</th>
<th>Acacia sieberiana</th>
</tr>
</thead>
<tbody>
<tr>
<td>Growth rate (g/day)</td>
<td>32.6a</td>
<td>32.3a</td>
<td>21.6ab</td>
<td>16.1b</td>
<td>0.4c</td>
</tr>
<tr>
<td>Maize stover intake (g/day)</td>
<td>483a</td>
<td>430b</td>
<td>401b</td>
<td>347c</td>
<td>320c</td>
</tr>
<tr>
<td>Fruit intake (g/day)</td>
<td>80</td>
<td>206</td>
<td>194</td>
<td>204</td>
<td>211</td>
</tr>
<tr>
<td>True N digestibility (%)</td>
<td>86a</td>
<td>81b</td>
<td>80b</td>
<td>80b</td>
<td>70c</td>
</tr>
</tbody>
</table>

Note: Means in the same row followed by the same letter(s) do not differ significantly (P < 0.05).

1986). An experiment conducted at ILCA to determine the nutritive value of fruits of four Acacia species (A. albida, A. nilotica, A. sieberiana, and A. tortilis), compared with noug cake (Guizotia abyssinica), showed that growth rate was highest in animals fed A. tortilis fruits and noug cake and lowest in those fed A. sieberiana (Table 6).

Limitations in the use of shrubs and tree fodders

Some browse plants contain biochemically active materials, such as cyanogenic glycosides, tannins, and goitrogenic and allergenic substances, that affect metabolism. For example, the seed pods of A. nilotica, relished by cattle, may be harmful if consumed in large amounts (Pratt and Gwynne 1977). Fruits of many Acacia species contain polyphenolic compounds that alter carbohydrate and protein use, decreasing urinary loss and increasing fecal N loss (ILCA 1987). The best
known toxic principle in browse plants is probably that of leucaena, which contains mimosine, an amino acid derivative that in ruminants is normally degraded to the toxic 2,4-dihydroxy pyridine (DHP). This can be harmful to livestock if leucaena is consumed in large quantities (Jones and Hegarty 1984).

Goats in Hawaii are able to thrive on diets composed mainly of leucaena for extended periods without signs of DHP toxicity (Jones 1981). Research has shown that this is due to the presence of a bacteria in the rumen that can metabolize the DHP into harmless products (Jones and Megarrity 1983). It has also been shown that, when kept under certain conditions, this bacteria can be transferred to other animals (see Kang et al. 1990). Such a transfer has been attempted in a joint project by ILCA and the West African Dwarf Goat Project in Nigeria with, as yet, inconclusive results (Ademosun et al. 1988).

When livestock are on free range, as in extensive production systems, they are hardly affected by the toxicity of browse. This is because of the variety of forage materials that are available.

**Government policy on browse use**

In the humid and subhumid zones, browse is freely lopped or grazed from fallow lands and natural pasture. The major problem with grazing in these zones is the encroachment on crop farms, leading to conflicts between livestock owners and crop farmers; there are bylaws in certain areas forbidding unherded or free-roaming animals during cropping seasons. There appears to be no government policy against lopping of browse or browsing in fallow land or rangelands. Land tenure rules in these zones may influence an individual’s rights to harvest and use trees growing on particular types of land and to plant trees on such lands (Francis 1987). In some areas, just establishing trees on a piece of land may confer ownership rights on that land to the one who planted the trees. There is, therefore, some conflict between landowners and tenants with regard to planting of trees on rented or borrowed land.

In semi-arid and arid regions, the threat of desertification and the increasing role of livestock and fuelwood harvesting in it has resulted in widespread, far-reaching regulations against tree harvests. Legislation ranges from draconian rules, such as those prohibiting the carrying of a hatchet in some areas, to laws of little practical value, such as those listing protected species (Piot 1980). For example, according to Boudet and Toutain (1980) and Miche (1986), government policy forbids lopping throughout the Sahel. This measure was taken up by most Sahelian countries, and Article 39 of the Malian Forestry Code, passed on 17 February 1968, states that in the Sahel zone “the cutting, mutilating or felling of trees and shrubs for the purpose of feeding animals are strictly forbidden.” Boudet and Toutain (1980) explain that in the context of this article, all pastoral land is legally subject to forestry regulations, and the “hand of man” is prevented from intervening to make browse available to livestock. Although justified by the ecological conditions and the increasing desertification, such regulations are difficult to enforce, and virtually inapplicable in these low-populated, extremely vast areas. Thus, the protection of trees, particularly browse trees, remains an unsolved problem, especially in the arid areas.
Conclusion

Shrubs and tree fodders play a significant role in livestock production in all agroecological zones of tropical Africa. Because of its generally high protein content, browse intake improves digestibility of low-quality feeds and leads to an overall increase in intake of digestible dry matter. Intake of browse, especially over critical periods such as the dry season, also results in increased survival and productivity of livestock.

There is a need for more research on the efficient cultivation, management, and use of fodder trees and shrubs for livestock production. Tree fodder production should be concentrated in high-potential areas such as the humid and subhumid zones, and fodder should be preserved and transported to the major livestock zones in the semi-arid and arid areas. Some more research is needed to improve the management and use of browse fodder to increase their effects on livestock productivity. The use of browse fodder in livestock diets should also be studied. Simple conservation and preservation techniques are required for the operation of such a system and to ensure that quality of forage is maintained.

The protection of trees, particularly browse trees, remains a major problem, especially in the dry areas. Governments should educate the local people on the dangers, both to livestock and to the environment, of over-exploitation, and initiate the organization of community-based efforts to improve and properly manage grazing reserves and rangelands. This can be done both through preservationist measures, as advocated by Boudet and Toutain (1980), and through enrichment planting of such reserves with preferred fodder trees. If well organized and managed, such reserves could be the basis of individual attempts at fodder preservation and range improvement, given favorable land tenure regulations, adequate education, and support by the government livestock and forestry sectors.

Acknowledgement

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