Terrestrial Ecology Baseline Studies

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This report includes and combines information from *JESS Reports No. 9* – "Interim Report on Vegetation Survey of the Jubba Valley," Christopher F. Hemming, October 1986; *No. 17* – "JESS Interim Report: Riverine Forest of the Jubba Valley, Issues and Recommendations for Conservation," Ian Deshmukh, November 1987; and *No. 23* – "JESS Interim Report: Vegetation Survey of Baardheere Reservoir Zone," Christopher F. Hemming, August 1987. Associates in Rural Development, Burlington, Vermont. Unless otherwise noted, all photographs in this report are by the author.

Preface

This report presents findings of the Terrestrial Ecology Baseline Studies (TEBS) of Jubba Environmental and Socioeconomic Studies (JESS). Long-term studies by the JESS ecologist are incorporated with information from aerial surveys conducted by Resource Management and Research (RMR), a JESS subcontractor, and several JESS short-term consultants. Most analysis is directed at determining the implications of development, particularly construction of Baardheere Dam, on biological resources in the Jubba Valley.

Acknowledgements

A project the scope and length of JESS inevitably depends upon, and is supported by, a large number of people.

USAID project managers for JESS in Somalia were Sally Patton (1985-1987) and Weston Fisher (1987-1989). Both were exemplary in their support and enthusiasm for the project and ARD project staff.

At Ministry of Jubba Valley Development/Ministry of National Planning and Jubba Valley Development (MJVD/MNPJVD), the project was overseen by Minister Habib and a succession of project managers including Cali Warsame Aden, Aweys Xaji Yusuf, Cabdi Cali Macalin, Yasiin Cusman Nur, and Cabdiraxman Islow Maxdalle. Also at the Ministry, JESS collaborated with the master planning team whose technical assistance was provided by Agrar-und Hydrotechnik, GMbH (AHT).

The core TEBS fieldwork team comprised Cabdulqaadir Xaji Ibrahim ("Saab"), Axmed Shariif Ibrahim, Cabdikriin Xasan Nur, and Yusuf Cabdullahi Madhiinba ("Makalangow"). We were usually fed by Cusman Macalin and driven by Maxamed Hared or Cabdulle Gurey. These people, and all JESS staff, performed well beyond the call of duty.

The following provided professional advice and encouragement. Among short-term JESS consultants, Christopher Hemming provided crucial collaboration in initiating TEBS ground surveys, in identifying plants in the field, and liaising with the Kew and Nairobi herbaria. At those herbaria, Mr. J. Gillett and Miss Christine Kabuye, respectively, provided rapid identifications. ARD consultants, Timothy Synnott and David Pearson, worked closely with TEBS. Professor Warfa and Tom Thurow (National University); Denis Herlocker and Peter Kuchar (Central Rangelands Development Project); Maxamed Cabdiraxman and Giles Leigh-Brown (National Tsetse and Trypanosomiasis Control Project); Neil Bird, Rod Bowen, and Gus Carty (British Forestry Project, Somalia); and Michael Madany (World Concern) all provided helpful technical discussion. TEBS is grateful to the Somalia Research Project for making various drafts and reports available. Murray Watson (RMR) collaborated closely on his aerial surveys and provided numerous insights into Somali ecology.

The long-term JESS team: Kathryn Craven, Jim and Nancy Merryman, and Gus and Marie Tillman, were a joy to work with. We were also blessed with a fine group of short-term consultants and excellent support from ARD home-office staff.

People of the Jubba Valley were always hospitable and generous with their time. This report is dedicated to them and the TEBS field crew.

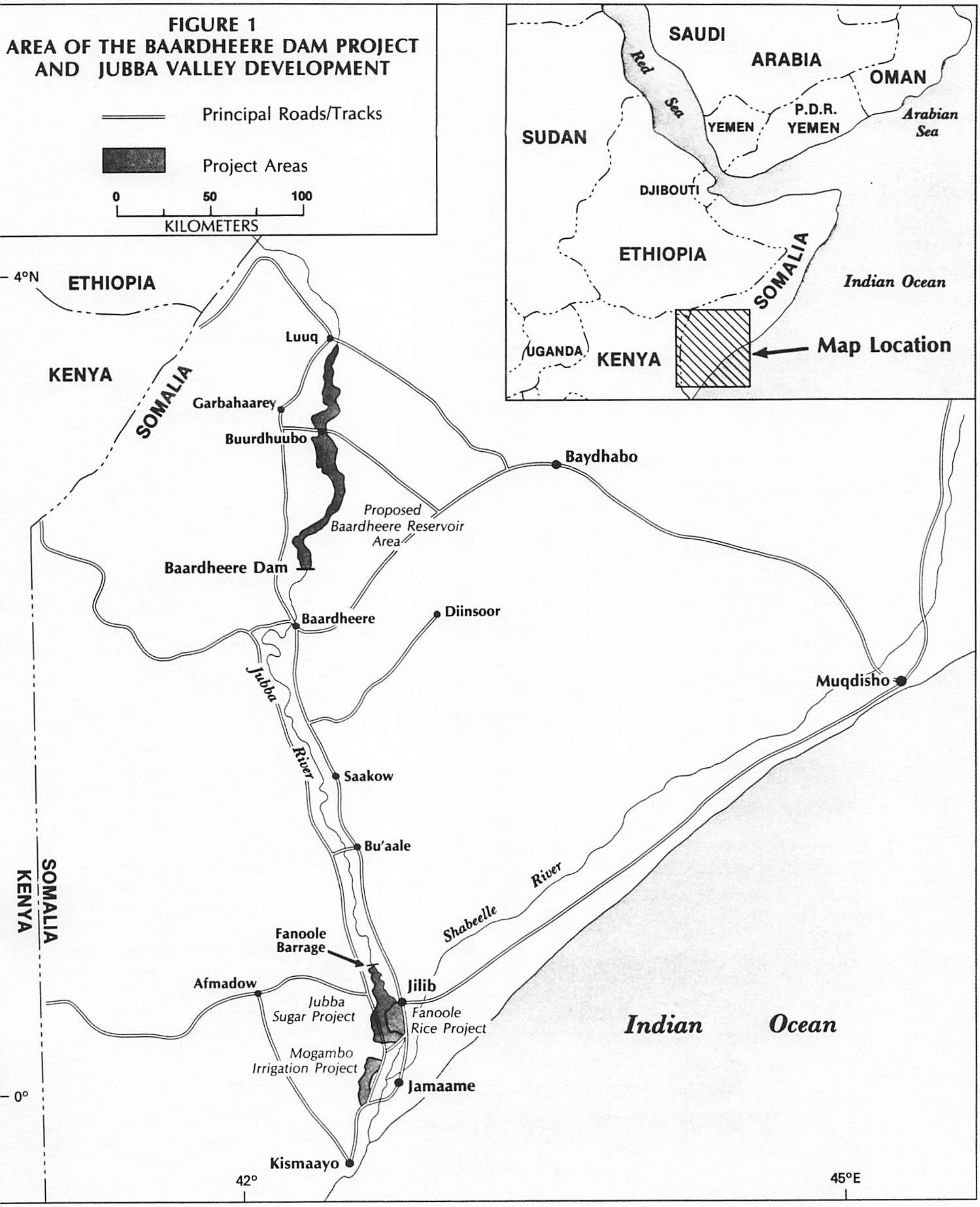


FIGURE 1
AREA OF THE BAARDHEERE DAM PROJECT AND JUBBA VALLEY DEVELOPMENT

I. EXECUTIVE SUMMARY

The Jubba Environmental and Socioeconomic Studies (JESS) investigated conditions in the Jubba Valley of southern Somalia (see Figure 1 at the front of this volume). Projections from that baseline information were intended to elucidate changes likely to occur as a result of construction of a high dam near Baardheere and related developments. In particular, JESS was required to suggest ways of mitigating adverse impacts, enhancing potentially good impacts, and to draw up a program for future environmental and socioeconomic monitoring.

This report contains an analysis of the Terrestrial Ecology Baseline Studies (TEBS) section of the JESS project. Human use of biological resources is examined from the perspectives of land use, forestry, rangelands, and biological conservation. TEBS activities are used as the basis for a future monitoring program of terrestrial ecology.

A multi-level approach to data collection was adopted using aerial photography at various scales, low-level aerial censuses, and ground monitoring sites. In this report, these different methods are integrated to present an overview of the Jubba Valley environment. However, basic data from the different methods can be found in JESS data repositories in Somalia, Kenya, and the United States.

The JESS study area covered the three administrative regions of Gedo, Middle Jubba, and Lower Jubba. However, TEBS concentrated on three "impact zones" which will be most affected by construction of the dam and related developments:

- the inundation area behind the dam;
- the Jubba floodplain downstream of the dam; and
- a "river-dependent zone" extending 30 km east and west of the floodplain.

It was assumed that biological resources outside this 35,000 km^2 area would be minimally changed by expected developments in the Jubba Valley.

Particular emphasis was placed on describing and explaining ecological differences between the floodplain and river-dependent zone. Environments similar to the river-dependent zone are widespread in southern Somalia, but floodplain ecology is unique since the Jubba is Somalia's only perennial river.

The floodplain will be altered immediately when Baardheere Dam is closed. Upper reaches will be permanently inundated, while downstream areas will no longer flood extensively and, as a result, will be less naturally fertile. Production systems, particularly floodplain agriculture and livestock forage production, will be negatively impacted by these changes. Although terrestrial productivity in the reservoir area will undoubtedly decrease, at least in the first instance, it seems likely that parts of the drawdown area may have potential for both agriculture and forage production. To make optimum use of hydrological resources during the transition to more sophisticated agricultural systems, the following recommendations are made:

- *Feasibility of controlled floods to maintain floodplain production systems should be assessed.*
- *Potential of the reservoir drawdown zone as a productive resource should be assessed and incorporated into land-use planning and dam operating schedules.*

These recommendations do not require that the dam be delayed since investigations can be carried out during construction. Proposed dam designs do not preclude release of a controlled flood.

Recent Land-use Changes

Comparison of aerial photography of riverside land from 1960, 1983-1984, and 1987 shows two major trends: denser vegetation types (particularly riverine forest) have declined markedly, and many floodplain farms previously dependent on flooding and rainfall have been converted to pumped irrigation. Changes in land use between 1960 and 1983-1984 were relatively slow, but the accelerated rate over the last few years suggests that all riverside land will be farmed by the end of this century. This trend indicates that Jubba Valley planners must take action before the dam is completed if they want to influence the development of land-use patterns.

Vegetation

Vegetation of the Jubba Valley comprises mainly deciduous bushlands of various densities. In the river-dependent zone, this pattern results from the interaction over centuries among climate, soils, and grazing and browsing patterns of wild and domestic large mammals. Until relatively recently, much of the floodplain was covered by evergreen riverine forest. More than 50 percent of the floodplain has now been cleared for agriculture. Most remaining native vegetation has been degraded by human influences such as fires, felling, livestock grazing, and abandonment of fields. Only 900 ha of forest remained in 1987—most of it in small patches threatened by agricultural expansion.

Closure of the dam will lead to sudden loss of terrestrial vegetation in the inundation area and gradual degradation of floodplain vegetation downstream as flooding is either eliminated, or substantially reduced in frequency and extent. Downstream vegetation will also be influenced by development activities increasing the area under irrigation.

Forestry

Review of human use of wood from native vegetation indicates that most is used for fuel. Conservative estimates of wood biomass in TEBS study area exceed 30 million tonnes, while annual production exceeds 400,000 tonnes. However, detailed inventory is needed for accurate estimation. If people were evenly spread throughout the area, sustainable wood production would be adequate for their current needs. However, most of the population is close to the river and most wood in the river-dependent zone is beyond a reasonable collecting distance on foot. TEBS analyses suggest that, taking population distribution into account, demand for wood is matched by sustainable supply in Baardheere and Saakow Districts, but falls short in Jilib, Jamaame, and Kismaayo Districts. In riverine areas of Garbahaarey and Luuq Districts, severe shortages of fuelwood occur due to high population density refugee camps. Only in Bu'aale District does wood production exceed demand.

In the future, demand for wood will increase due to natural population growth, resettlement, and immigration. Resettled populations will include long-term inhabitants of the inundation area and, possibly, some refugees. People entering the area will include dam construction workers and their associates and new settlers attracted by opportunities in the Jubba Valley. However, supply of wood will decrease due to inundation and conversion of floodplain land from native vegetation to agriculture.

Planners should address this predicted shortfall of wood supplies. Options include more widespread collection from and effective management of the river-dependent zone, planting of trees, and increasing the efficiency of wood use so that per capita consumption decreases. Current and planned projects within the forestry department of the National Range Agency (NRA) address tree-planting and increased efficiency, but are weak in optimizing use of native vegetation. TEBS recommendations for the forestry sector include the following:

- *NRA forestry activities in the study area should be strengthened to increase tree planting and more effectively regulate use of vegetation for fuelwood.*
- *Better information on forest inventory and tree and shrub growth rates is urgently needed if optimal use of vegetation is to be practiced.*
- *The area to be inundated by Baardheere Dam should be cleared of woody vegetation and the wood used to supply fuel needs of construction workers and their associates.*
- *Where reservoir area people are resettled, land clearance procedures should include using as much as possible of the cleared wood for construction and clearance.*
- *To meet continuing fuel and construction needs, people should be resettled at low population density, in areas where their forestry needs can be met locally.*

Rangelands

The pastoral sector is economically vital to Somalia, including the Jubba Valley. Sustainable use of range resources is, therefore, an essential component of planning.

The Jubba River and its floodplain attract large numbers of livestock, particularly during the jiilaal dry season between December and April. TEBS analyses of range resources and consumption by livestock show that overall there is an approximate balance between supply and demand for forage in years of average and above-average rainfall. There is, however, local degradation of range resources in some areas, particularly in Lower Jubba. In drought years there is probably a shortage of forage which is acute in the inundation area and to the north. Since some good grazing areas will be lost by inundation, a redistribution of livestock is likely when the dam is closed. Adequate forage resources to support increased livestock exist at present in some parts of Middle Jubba. However, these areas have high infestation with tsetse flies.

It is clear that access to the river for drinking and floodplain forage are essential to support Jubba Valley livestock during jiilaal. Besides range vegetation, livestock also rely on crop residues produced in the floodplain and river-dependent zone. Clearance of floodplain land for agriculture will decrease range resources and increase the need for crop residues. To deal with these developments, TEBS recommendations for the range sector include the following:

- *Agricultural development should take place in such a way that suitable crop residues are available to livestock.*
- *Maintenance of livestock watering points along the Jubba River should be an integral part of floodplain development.*

Conservation and Wildlife

Biological conservation prospects in the study area are limited. Wildlife densities are low, except for some pest species. Opportunities for self-financing conservation areas through tourism are minimal. Conservation activities should, therefore, focus on maintenance of biological diversity and national heritage. Financial and technical support from donors is essential.

Any worthwhile and feasible conservation projects related to Jubba Valley development should concentrate on wetlands, which are rare in Somalia. In particular, swamps of the lower Shabeelle and remnants of Jubba riverine forests should be given the highest priority for establishment of protected areas. Conservation recommendations from TEBS include the following:

- *External funding and technical assistance should be sought to support a coherent conservation program in Somalia.*
- *Shoonto and Barako Madow forest reserves should be given increased protection immediately. Future management options depend on external funding, but should take account of a proposed management plan and the additional measures suggested in this report.*
- *Appropriate areas in the lower Shabeelle Swamps should be conserved for their wildlife populations, because of the scarcity of such wetlands in Somalia, and because of their importance in downstream flood control.*

Other issues of importance to conservation policy in the study area presented in the body of the report include previous proposals for conservation areas, control of pests (including cropping of crocodiles), tsetse eradication proposals and their effect on wildlife, and biological diversity of floodplain vegetation.

Monitoring

Most TEBS monitoring proposals are designed as continuations of TEBS studies, but at reduced intensity. The recommendations assume that the MNPJVD or similar body will establish a monitoring unit to coordinate both environmental and socioeconomic monitoring activities (Tillman 1989). This unit would undertake some field work, but would also commission and collect information from contractors and other agencies.

Specific monitoring activities proposed by TEBS include:

- *Improved collection of rainfall data*—Current rainfall records are inadequate as a basis for planning agricultural and range management activities, and estimating likely effects of drought.
- *Periodic updating of the status of vegetation monitoring sites*—Aerial photographs will show changes in vegetation structure and land use, and ground sites will indicate changes in species composition and biological diversity.
- *Vegetation and soil monitoring of the reservoir drawdown zone*—Developments in this area may include opportunities for seasonal agriculture and livestock forage production.
- *Periodic low level aerial censuses*—These can be used to highlight changes in farming patterns, livestock and wildlife populations, land clearance and enclosure, rural structures, and water sources.

Effective use of JESS-based monitoring data will require a trained and motivated group of scientists and technicians who can communicate with planners and policymakers. Collecting monitoring data is not worthwhile unless it is analyzed and interpreted in a useful way.

II. INTRODUCTION

Wise use of biological resources is an essential component of development planning. Since a basic requirement of JESS was to provide baseline information useful to planners, ecological surveys were essential. This report describes terrestrial biological resources and their current use by the human population of the Jubba Valley. The consequences of proposed developments on terrestrial ecosystems, most importantly the construction of a high dam on the Jubba River north of Baardheere, are assessed. Impacts on aquatic ecology are discussed in other JESS reports contained in this volume: Biological Limnology of the Jubba River (Njuguna and Muthuri 1988); Fisheries in the Jubba River (Meredith 1988); Water Balance and Sediment Transport in the Jubba River Watershed (Alford 1987); and Water Quality and Public Health Aspects of Proposed Dam and Development in Jubba Valley (Jobin 1988).

Experience with large dam projects elsewhere in Africa shows that major changes are inevitable. Obviously some land upstream of a dam is inundated and lost as a terrestrial ecosystem. More subtle environmental changes occur downstream of a dam as a result of reduced flooding irrespective of other human interventions. Since one purpose of Baardheere Dam is to increase land under irrigation, major land-use changes will occur, further impacting floodplain ecology. Such changes are clearly of scientific interest. From a development perspective, it is the interaction between people and ecosystems that is crucial. This report is primarily concerned, therefore, with how people and their use of biological resources will be influenced by changes in terrestrial ecology.

Numerous recent reviews which consider impacts of dams and related developments on terrestrial ecology point to issues concerning vegetation change, redistribution of range and forest resources and loss of biological conservation value (*e.g.*, Adams and Hughes 1986; Roggeri 1985; Scudder 1988; Goldsmith and Hildyard 1986).

The most immediate vegetation change is loss of terrestrial plants from the inundation area. For example, the proposed Kogoufoulbe Dam in Senegal would flood 3,600 ha of riverine forest (University of Michigan 1985). Downstream effects also indicate an impoverishment of riverine forests on, for example, the Tana River in Kenya (Hughes 1985). Such forest loss has obvious consequences for human supplies of forest products, including fuelwood. These forests are often of great significance for biological conservation. Throughout Africa, river valleys are usually settled and farmed leaving only remnants of native forest. Besides endemic plant species, these forest remnants may also contain endemic wildlife. Thus loss of these ecosystems can result in loss of genetic diversity. For example, the Tana River forests house two threatened endemic primate subspecies (Adams and Hughes 1986). Loss of remaining forests on the Tana would undoubtedly cause extinction of these animals in the wild.

Increase in irrigation potential following dam construction leads to clearance of additional forest land for cultivation. Similar losses may occur in rangeland production, either through flooding upstream of a dam or changed hydrology downstream. The Kafue Flats in Zambia, for example, have been adversely affected by both these processes (Scudder 1988). Eastern sections have been permanently inundated by Kariba Dam while upstream portions are less productive because of reduced floods caused by Itezhitezhi Dam.

However, all impacts on human use of biological resources are not negative (Scudder 1988 gives many examples). Wood harvested from inundation areas may be used for construction or fuel. New grazing or agricultural lands may be created in the drawdown zone of the impoundment. Prevention of unpredictable flooding can save millions of dollars (U.S.) in damage to crops, houses, and rural infrastructure. Controlled releases from a dam can make management of downstream lands more predictable than in a pre-dam situation. More intensive agriculture resulting from irrigation can potentially decrease pressure on areas of prime conservation value.

JESS, including TEBS, attempts to give a balanced view of likely losses and potential gains following construction of Baardheere Dam. In particular, recommendations are directed at mitigating adverse effects and enhancing potential gains.

Terrestrial ecology in southern Somalia was little studied until the 1980s. Two important ecological surveys were carried out in the first half of the decade for the Ministry of Livestock, Forestry, and Range. The Southern Rangeland Survey (SRS) (Watson and Nimmo 1985) was the last in a series of three surveys covering the whole country. A combination of satellite imagery, low level aerial reconnaissance, sample aerial census, and ground monitoring sites was used to establish land-system units. These units were described in detail in terms of vegetation, larger wildlife species, livestock, and human resources. Aerial census and vegetation data from SRS, in conjunction with newly commissioned aerial photography and ground surveys, were used by the National Tsetse and Trypanosomiasis Control Project (NTTCP) in preparation of a land-use survey of southern Somalia from the northernmost part of the Shabeelle River to the border with Kenya (LRDC 1985). This survey provides some detail about lower reaches of the Jubba, but places more emphasis on the Shabeelle.

These recent surveys did not focus on the Jubba Valley specifically, or the consequences of construction of a dam on the Jubba River and related developments. However, they provide an up-to-date account of terrestrial ecology over the extensive rangelands surrounding the Jubba floodplain. The existence of these surveys enabled TEBS to concentrate on the Jubba floodplain and adjacent drylands. It is these areas that will change most after closure of the dam. As soon became apparent to JESS, ecological and sociological changes are rapid close to the river, but much slower elsewhere.

TEBS collected and integrated information from a variety of sources. Aerial photography, sample aerial censuses, and ground studies were combined to assess the resource base, how it is used, how it is changing now, and how it is likely to change when the dam is completed. This report was prepared by the TEBS ecologist, but it incorporates work by several JESS consultants. Aerial photography and aerial census were conducted by RMR (Watson and Nimmo 1988). Vegetation surveys were a collaborative effort with Christopher Hemming (1986; 1987—presented in this report as Appendix I); some of the aerial photointerpretation was carried out by Eric Trump (1987). Timothy Synnott (1988) served as a forestry consultant. JESS also collaborated with, and partially supported, the Somalia Research Project (SRP) of University College, London. This three-month expedition conducted ecological and land-use surveys in riverine forests of Middle Jubba. SRP also focused on issues of biological conservation in these forests, producing a management plan for two forest reserves as part of its final report (Madgwick 1988).

TEBS surveys were designed to complement existing and ongoing work in such a way that likely impacts of Baardheere Dam and related developments in the Jubba Valley could be assessed. As emphasized in the ARD project proposal (1985), precise predictions of change are usually not possible. Nevertheless, it was expected that "best estimates" of probable changes could be made and presented in a way useful to planners.

Long-term TEBS field research comprised aerial surveys (photography and censuses) conducted by RMR and ground studies of vegetation and land-use monitoring sites. Both low-level aerial censuses and ground visits were conducted in different seasons to give an idea of annual cycles of land-use, vegetation quantity and quality, and livestock and wildlife occupancy. Spatially, the study area was divided into three distinct impact zones: the inundation area behind the proposed dam, the floodplain downstream of the dam, and the river-dependent zone east and west of (but close to) the floodplain.

For this report results of aerial and ground surveys are combined to give assessments of land use, vegetation, forestry, range resources, and biological conservation. This sectoral approach is appropriate for most development planning activities. Others may wish to see raw data so that different combinations and interpretations can be made. For these people, uninterpreted data sets from aerial and ground studies can be found in the data repositories described at the end of this section and in JESS Final Report, Volume IV, Bibliography.

Basic descriptive material in this report is contained in Sections III to VI. Section III is a broad view of the Jubba Valley including a brief account of socioeconomic conditions. Section IV defines the TEBS study area and its subdivisions. The overall approach to the studies is also described.

Section V concerns land-use changes between 1960 and 1987 which were derived from interpretation of aerial photographs with emphasis on riverside land. Seasonal changes were analyzed from sample aerial censuses conducted in 1987. Section VI describes vegetation in TEBS study area. Vegetation structure, species composition and diversity, and vegetation dynamics are considered. Contrasts between floodplain and river-dependent zone vegetation are emphasized. Sections V and VI present basic information and conclusions relating to future change, but without recommendations relating to planning. Recommendations pertaining to information presented in these sections concern use of biological resources and monitoring which are covered in subsequent sections.

Sections VII to IX are more development-oriented since they deal with human interactions with biological resources. Human use of vegetation as forest products and rangelands is detailed in Section VII. Quantitative assessments are made of forestry and range resources and related to estimates of production and consumption of fuelwood and livestock forage. Section VIII concerns biological conservation. Wildlife populations, plant communities, and protected areas are discussed in the context of conservation prospects in Somalia. Related issues such as tourism, hunting, harvesting, crop protection, beekeeping, and plans to eradicate tsetse fly are considered.

While Sections III to VIII deal with biological resources from a sectoral viewpoint, Sections IX and X combine conclusions from these sectoral analyses. In Section IX an attempt is made to give an overview of how floodplain environments will change after construction of Baardheere Dam. Section X presents proposals for environmental monitoring drawn from conclusions in other sections. Most TEBS studies were designed as potential bases for future monitoring. Priority monitoring activities and approaches are given in this last section.

Conclusions relating to development activities, notably the Baardheere Dam, are given in appropriate sections along with recommendations to mitigate adverse impacts or enhance development opportunities. Most recommendations are at the level of advice to planners as required of JESS, rather than comprising project proposals.

Basic research data such as tables, computer diskettes, descriptions of monitoring sites, aerial photographs, and manuscript maps are housed in five data repositories: MNPJVD, USAID/Somalia, USAID/REDSO East Africa (Nairobi), USAID/Washington, and ARD. At each of these locations a *TEBS Data Guide* describes how to use the contents relevant to this volume.

III. JESS STUDY AREA

A. Physical Geography

1. Landform, Geology, and Soils

The JESS study area is defined as the three administrative regions of Gedo, Middle Jubba, and Lower Jubba (see Map 1; further elaboration is given in Section IV.A). Geological maps are presented in Watson and Nimmo (1985) and LRDC (1985). Much of Gedo Region comprises limestone hills, terraces and plateaus dating from Jurassic and Cretaceous periods (65 to 190 million years ago). Local variations include gypsums, basalts, sandstones, and shales. From north of Saakow to Bu'aale, a zone of Pre-Cambrian (570 million years ago) basement granitic gneisses and schists crosses the area east-west. Most of the study area is flatter than that underlaid by limestone, but this formation also contains granite inselbergs characteristic of part of Bay Region. South of Bu'aale are extensive alluvial plains of clays and marls deposited under oceanic condition in recent times (two million years ago). The coastal strip comprises mobile sand dunes to the seaward side and stabilized dunes inland. Around Kismaayo and southward is a region of recent coralline limestones.

Differences in elevation in most of the study area are minor. Following the river southward, the disputed Somalia/Ethiopia border is at 200 m, Luuq at 150 m, the dam site at 100 m, Bu'aale at 40 m, Jilib at 20 m, and Jamaame at 10 m above mean sea level (masl). Local relief can be substantially greater in northern limestone areas, but only exceeds 500 m in a region north of Baardheere and 50 km west of the Jubba river. South of Baardheere, 200 m is not exceeded and most land is virtually flat except for occasional inselbergs north of Saakow.

Soils vary in a sequence related to geological formations (USBR 1987). North of Baardheere soils are often rocky or stony. Finer deposits are sometimes associated with togga (seasonal streams) and depressions containing gypseous soils (Appendix I). In flatter areas of southern sections of the limestone hills and plateaus, vertisols are the predominant soil type as they are in the marine plain. The intermediate zone of basement gneisses and schists has patches of somewhat lighter soils than other non-riverine areas. The surface consists of sand-loams to sand-clays. Gravel layers sometimes occur leading to better drained soils than the surrounding vertisols. All these soils are neutral to alkaline and have low levels of organic matter, nitrogen, and available phosphate (LRDC 1985).

The Jubba River presents a major departure from this overall pattern. A complex mixture of recent alluvial deposits creates a floodplain ranging from less than 100 m to almost 15 km in width. The physiography and gross soil features of floodplain environments are described in Section IV.A.

2. Climate and Hydrology

Rainfall is the most important climatic variable affecting biological resources in low-lying tropical dry to semi-arid areas, such as the Jubba Valley. Unfortunately, rainfall records are poor. Too few stations and too many gaps in data mean that only a coarse picture can be drawn of relationships between biological and climatic phenomena. Watson and Nimmo (1985) present the most extensive and critical rainfall data set for the study area. Within TEBS study area (see below), only three stations (Luuq, Baardheere, and Kismaayo) have more than 30 years of data. Figure 2 shows rainfall for eight stations with the longest records. Other stations have operated for brief or sporadic periods at Diinsoor, Doolow, Yontooy, Saakow, and Bu'aale.

Most of the study area demonstrates the bimodal pattern of rainfall typical of equatorial East Africa. The main rainy season (gu') is from April to June followed by a moderate dry season (xagaa) from July to October. A minor and erratic rainy season (deyr) occurs in November and December followed by an intense dry season (jiilaal) from January to early April. This pattern is modified near the coast where xagaa showers follow gu' until October, but deyr rain is slight. Xagaa rains are usually said to penetrate approximately 50 km inland, but heavy showers occurred as far north as Baardheere in August 1987 and 1988. In 1987 Saakow and Bu'aale received significant xagaa rainfall of 51 mm and 103 mm, respectively, in August and September.

Between Doolow and Jilib mean annual rainfall increases in a southerly direction from around 200 mm to more than 700 mm at Mareerey (Figure 2). South of Jilib rainfall declines to 450 mm at Jamaame and 350 mm at Kismaayo. Mean annual

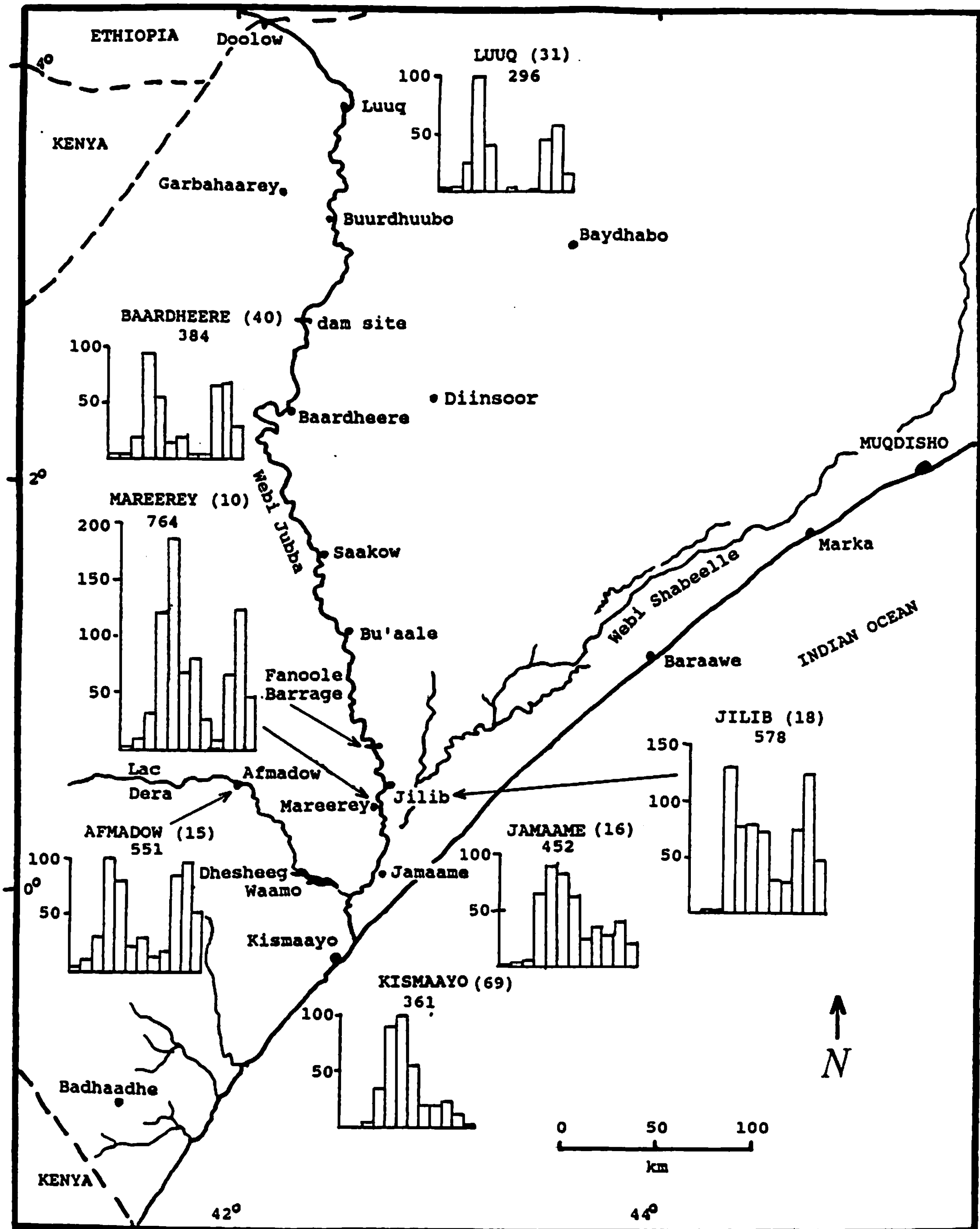


Figure 2. Rainfall map of southern Somalia. Rainfall charts have annual total beneath station name and number of years of records in parentheses. (Data from Watson & Nimmo 1985 and Food Early Warning System, Ministy of Agriculture.)

rainfall for each river section of TEBS study area (see Section IV.A; Map 1) has been approximated by examination of all available rainfall records and isohyet maps in Watson and Nimmo (1985), LRDC (1985), and AHT (1988).

River Section	Mean Annual Rainfall (mm)
I	300
II	350
III	400
IV	450
V	550
VI	650
VII/VIII	450

Information given above implies predictable rainfall patterns. As in other semi-arid areas, mean monthly or annual rainfall for the Jubba Valley are statistical abstractions rather than predictions of what happens in a given month or year. The extent of temporal variation can be examined by comparing annual monthly means with those experienced during the study period or by plotting long-term records of mean annual rainfall as presented by Watson and Nimmo (1985).

Mean monthly rainfall (where records exist) is close to 1986 and 1987 data in only 16 out of 50 comparable records (Figure 3). Monthly patterns in 1986 and 1987 are erratic with xagaa rains tending to be well above average and substantial as far north as Saakow. Gu' rains in 1987 were very late at most stations. Deyr rains varied greatly spatially and from year to year during the study period as expected with the short rainy season in equatorial East Africa. Even seasonality is not very distinct in particular years with the exception of jiilaal being dry. Comparisons of seasonal rainfall at two stations (Baardheere and Jilib; Table 1) show substantial geographical variations, also. In 1987 gu' at Baardheere was above average, but deyr in 1986 and 1987 below average. At Jilib, gu' was good in 1986, but poor in 1987 and deyr poor in both years. However, xagaa rain at Jilib was high in 1986 and extremely high in 1987.

Overall, it seems that annual rainfall during the study period was close to average at Jilib, but low at Baardheere and Mareerey. Gu' and xagaa rains combined were good, but temporal and spatial distributions unusual. Deyr rains were poor, which probably emphasized the harshness of the succeeding jiilaal seasons. Lateness of gu' in 1987 further exacerbated jiilaal that year.

Table 1. Comparison of long-term seasonal rainfall (mm) at two meteorological stations in the study area with records for the JESS field study years of 1986 and 1987.

	SEASONS*			
	Gu' (Apr-July)	Xagaa (Aug-Sept)	Deyr (Oct-Dec)	Year
Baardheere				
long-term	182	11	161	384
1986	no data	(0)**	49	inc.
1987	209	0	102	312
Jilib				
long-term	357	36	182	586
1986	438	53	120	598
1987	309	178	107	597

**Seasons defined by drop in monthly rainfall total from long-term records rather than colloquial definition.*

***August record missing; July and September both zero.*

Analysis of data for this century from all meteorological stations in southern Somalia suggests that a ten-year cycle in mean annual rainfall is superimposed upon a forty-year cycle (Watson and Nimmo 1985). Successive fluctuations are not of equal magnitude in either proposed cycle, but the region is predicted to be entering low rainfall phases in both cycles during the late 1980s. Unfortunately, the data base is too weak to predict such events with confidence. Even if future data confirm the proposed cycles, rainfall in a particular year or season cannot be predicted. Nevertheless, successful policymaking and planning must take into account the fact that large fluctuations in rainfall occur. Average rainfall is not an adequate planning tool. Strategic plans must allow for the large fluctuations in rainfall characteristic of semi-arid areas and develop means of dealing with wet and dry years. Given the importance of rainfall to crop and forage production, even when irrigated systems are developed, an effective rainfall monitoring system is a high priority (see Section X).

Other commonly measured meteorological variables serve to emphasize the significance of low rainfall. Temperature and wind speed are high and cloud cover low most of the year. These factors all increase evapotranspiration, leading to severe water deficits throughout the study area. Mean annual temperatures at Luuq, Baardheere, Jilib, and Kismaayo are 30.5, 28.2, 27.6, and 26.2 °C, respectively. The coolest months are July and August (monthly means 28.3, 26.8, 25.5, and 25.3 °C, same stations) and February and March the hottest (33.4, 30.8, 29.1, and 27.9°C). Mean annual wind speeds

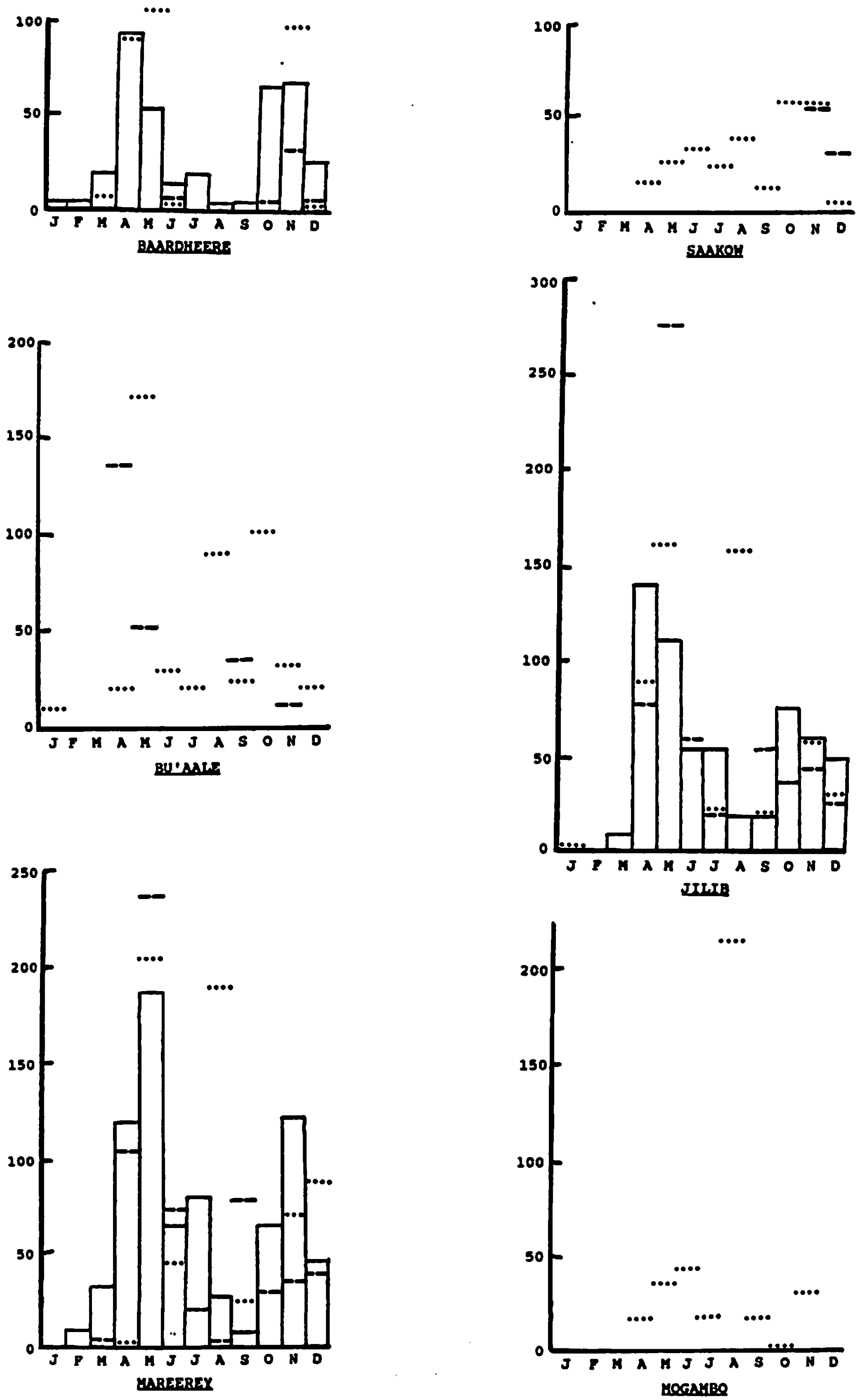


Figure 3. Comparison of long-term means (vertical bars) of monthly rainfall with rainfall received during JESS fieldwork years 1986 and 1987 (dashed and dotted horizontals respectively; 1986 records incomplete). Bu'aale, Mogambo, and Saakow are new stations with no long-term means. (Data from Food Early Warning System, Ministry of Agriculture.

are 1.0, 2.8, 1.1, and 5.4 m second $^{-1}$ for the same stations and mean daily sunshine hours 10.6 at Luuq and 8.2 at Jilib. These factors combine to produce a potential evapotranspiration rate in excess of 2,000 mm year^{-1} over most of southern Somalia (Watson and Nimmo 1985; AHT 1988).

The most important hydrological feature of the study area is the Jubba River. This river is the only "perennially" flowing water body in Somalia to reach the Indian Ocean. Even the Jubba bed is occasionally dry in late jiilaal, but subsurface flow continues. Within the floodplain, soil and available water are altered considerably. More than 90 percent of river water flows from the highlands of southern Ethiopia. Discharge is bimodal more or less coinciding with rainfall seasons in southern Somalia. However, highest river flows occur on average during deyr season, although overbank flooding can occur in both wet seasons. Average annual total flow at Luuq is 6,200 km^3. Extensive floods occur at discharges above 700 m^3 second^{-1}. Recent floods of sufficient magnitude to cause serious economic damage occurred in 1977, 1981, and 1985 (AHT 1988a). The study period was marked by a large gu' flood in 1987 which inundated most of the floodplain. This flood was the most extensive since 1977. During other seasons of 1986 and 1987, overbank flooding was negligible. Relationships between river discharge and extent of flooding are poorly understood as the river bed morphology and floodplain micro-topography have not been determined.

Within Somalia several togga flow into the Jubba during the rains. Most of these are confined to areas north of Saakow. West of the river and south of Fanoole Barrage are several drainage features associated with the Jubba. Webi Yaro (or Little Jubba) used to carry water most of the time, but parts are now dry much of the year as a result of hydrological changes caused by Fanoole Barrage. Sections of this stream are now used as the main irrigation canal for Jubba Sugar Project. The Shabeelle River, further west, flows temporarily with Jubba water during high flows and overbank floods.

South of these channels is Dhesheeg Waamo, a periodically large body of water (60 km^2). This *dhesheeg* (a water-holding depression) receives water from Lac Dera, a seasonal channel flowing from north and west. This small catchment may also receive subsurface flow from Mount Kenya via the Ewaso Nyiro and Lorian Swamps in eastern Kenya (LRDC 1985). During high floods, as in May 1987, Dhesheeg Waamo is filled from the Jubba. Prior to that flood, the dhesheeg bed was dry and the water-table several meters below ground-level. Local reports indicate that this dhesheeg was last dry in 1977, before the last major Jubba flood. These observations indicate the importance of Jubba water for maintaining the water regime of Dhesheeg Waamo.

East of Jilib the Shabeelle River ends in a series of swamps. At times of high flow, Shabeelle water may enter the Jubba along togga and by surface flooding. These swamps are important natural flood protection for parts of Lower Jubba. They are also wildlife areas worthy of protection and important dry season grazing areas for livestock.

Surface hydrology south of Fanoole Barrage and floodplain hydrology along the whole river are complex. It is important that the other water bodies and special nature of the floodplain be taken into account when planning developments on the Jubba following construction of Baardheere Dam.

B. Socioeconomic Environment

A full account of human activities in the Jubba Valley is given in Volume III, Part A of the JESS Final Report, Socioeconomic Baseline Studies (Craven, Merryman, and Merryman 1989). Virtually all biotic communities of the study area are substantially modified by human activities. For centuries people have herded livestock, grown crops, and hunted wildlife in the Jubba Valley. More recently humans have altered local surface hydrology by construction of flood bunds and Fanoole Barrage on the Jubba River. A brief account of human influences and activities as necessary background to this report follows.

JESS Socioeconomic Baseline Studies (SEBS) divides the study area geographically into three socioeconomic regions north to south—upper, middle, and lower Jubba. These correspond to TEBS River Sections I to III, IV and V, and VI to VIII, respectively (see Section IV). Most of riverine upper Jubba is characterized by a dynamic system of smallholder agriculture. Irrigation has spread rapidly along the floodplains from initial foci at Luuq, Buurdhubo, and Baardheere. All-weather roads connect these centers to Muqdisho. However, upper Jubba also encompasses a section of the river with poorer communications than any other. The riverine gorge, from the dam site to a few kilometers south of Buurdhubo, has no roads. Much of the gorge can be reached only on foot or by boat. Nevertheless 3,000 people are estimated to live there, their floodplain farming being dependent on rainfall and river flood seasons (Craven, Merryman, and Merryman 1989).

SEBS middle Jubba region also has poor communication. Tracks exist from Baardheere to Fanoole Barrage on both sides of the river, but they are cut seasonally by rain and river flooding, sometimes for several months. More complex floodplain physiography in this area allows more diverse farming systems using levee land and dhesheegs.

Larger-scale irrigation is found in much of SEBS lower Jubba region. Private banana plantations and three state farms—Fanoole Rice Project, Jubba Sugar Project, and Mogambo Irrigation Project—take up 22,000 ha of floodplain land. Smallholder cultivation, with and without irrigation, also occurs, although many subsistence farmers now have to cope with poorer land and altered hydrology as a result of the plantations.

Against this geographical background, SEBS identifies a set of "socio-ecological sectors": agricultural riverine, agricultural non-riverine or agropastoral, nomadic pastoral, and urban. These divisions are not clear-cut but form a convenient classification for socioeconomic analysis. A particular household may fall entirely within one sector, while another household may divide its time or family members between all sectors.

Riverine agriculture is that confined to the Jubba floodplain. It relies on a mixture of rainfall, flooding, and riverine groundwater to enhance agricultural production (see Section IX). In years with overbank flooding, flood recession agriculture is practiced, particularly in dhesheegs. In contrast, non-riverine agriculture outside the floodplain is entirely rainfed. This sector is most common in Baardheere and Saakow Districts where a combination of adequate rainfall and favorable soils allows sorghum to be grown in most gu' and some deyr seasons. Rainfed farms are usually owned by people who are also riverine farmers or agropastoralists.

The agropastoral sector is steadily increasing in the Jubba Valley and other parts of Somalia where crops can be grown. Livestock may be kept in the vicinity of farms, or may undertake longer migrations in search of forage with part of the family. Crops are grown both as human food and livestock fodder. True nomadism, where the whole family undergoes long seasonal migrations with their livestock, is becoming rarer. Nevertheless, camelkeepers in particular move over great distances, sometimes encompassing the length of the Jubba Valley (Janzen 1988). Most livestock undergo substantial seasonal migrations which preclude all or part of many households from contributing to other production sectors.

The urban sector, involved in commerce, trade, administration, and, to a small extent, manufacture, has strong links with the rural economy. Most urbanites own farms and/or livestock. These links amply demonstrate the diversification of most household economies. In a drought-prone country such as Somalia, and with the added vagary of floods for many Jubba residents, diversification reduces risk of total loss of production at a particular time. In a drought, rainfed farming fails, but some production in floodplain areas may be possible. Livestock can be moved to areas less drought-stricken, or most may survive a short drought. However, a prolonged drought may force surviving livestock to rely on whatever crop production is possible in riverine areas. Flooding may destroy a season of floodplain crops, but non-riverine farms and livestock insure against total loss of family income. Similarly, an urban income in a household provides a cushion against reduced rural production.

Planners need to take account of these flexible household strategies. Interventions which reduce this flexibility will put people at risk during times of environmental and economic stress.

IV. TERRESTRIAL ECOLOGY BASELINE STUDIES

A. Definition and Subdivision of TEBS Study Area

The overall JESS study area is defined as the 120,000 km² comprising the administrative regions of Gedo, Middle Jubba, and Lower Jubba (Map 1). However, for purposes of terrestrial ecological studies, a smaller area adjacent to the Jubba River was delineated for two reasons. First, the recent Southern Rangeland Survey (Watson and Nimmo 1985) provides extensive coverage of biological resources which could not be improved within the scope of JESS. Second, the focus of JESS studies is to describe areas likely to be affected by building of Baardheere Dam and related developments. With these facts in mind, it was clear that three distinct terrestrial environments called for detailed study:

- the river and its floodplain;
- the area to be inundated behind the dam; and
- areas east and west of the river and floodplain which are in easy reach for people and livestock.

The third area is defined as being within 30 km of the floodplain and is called the river-dependent zone. Thirty kilometers is a maximum distance that people or livestock are expected to move during routine day-to-day activities. An extension of floodplain in the southwest is added to include Dhesheeg Waamo and its dependent hinterland.

Map 1 shows the position of these areas and further subdivision of TEBS study area north to south into eight river sections. Boundaries of these sections reflect changes in the nature of river and floodplain, some of which are natural and others partially defined by human interventions. These river sections are described in Table 2 and referred to throughout this volume. Although geographically distinct in the floodplain, River Sections VII and VIII are usually combined in analyses because of their small size. These sections are combined as VII/VIII in all analyses of the river-dependent zone. Map 1 shows how river sections relate to administrative boundaries. TEBS river sections correspond closely with Jubba Master Plan "socio-geographic" units (AHT 1988)—River Section III approximates to unit 1; River Sections IV and V to unit 2; River Section VI to units 3 and 4a; section VII/VIII to unit 4b. River sections I and II are not included in the core master planning area.

Table 2. Description of floodplain river sections depicted in Map 1.

River Section	DESCRIPTION
I	North of inundation area to Somalia/Ethiopia border; river bed only slightly incised with broad flat floodplain.
II	Inundation area of Baardheere Dam; includes floodplain and other land below 142 m contour. River incised in limestones forming distinct gorge in southern stretch; narrow flat floodplain.
III	Dam site southward to near Barow Diinle village. Gorge at dam site gradually widens and surrounding land flattens; river weakly incised forming flat floodplain several hundred meters wide.
IV	Stretching southward to just south of Bu'aale; broad floodplain (c. 2 km) becomes differentiated into levees and dhesheegs for the first time. This section marks the transition between limestone landscape and marine plains in the river-dependent zone.
V	The river meanders extensively; imperceptibly incised in marine plain with well developed levees and numerous dhesheegs.
VI	Fanoole Barrage is the northern boundary; to the south floodplain is broad (up to 15 km) and physiography complex. Levees and dhesheegs less distinct and mixed with flatter and heterogeneous sediments formed by complex of old river channels and confluence of Shabeelle sediments.
VII/VIII	From just north of equator river is weakly incised and floodplain narrows. Course changes southwest behind coastal dunes before breaking through dune ridge (VIII) and entering Indian Ocean at Goob Weyn.

The Jubba floodplain is further subdivided in terms of physiography and sediment type as presented in the AHT (1984) set of photographic maps. With some consolidation of units to improve sampling rigor, these units are updated in the JESS map series prepared by Watson and Nimmo (1988). These floodplain land types areas follows:

- *Undifferentiated alluvia*—In northern sections the floodplain is narrow and relatively flat and uniform; no subdivisions have been made.
- *Levees*—Distinct raised levees with coarse sediments are formed along the river (al-

luvial fans of seasonal togga are included in this unit).

- *Dhesheegs*—Behind the levees, depressions in the floodplain with fine-textured water-holding sediments are common. They periodically fill with water from river flooding and from drainage of surrounding land. Some are former river channels (oxbows).
- *Flat alluvia*—Some areas of fine alluvium do not form depressions, but are flat and have (relatively) rapid surface drainage.
- *Heterogeneous alluvia*—In southern sections , floodplain physiography is complex with mixed sediment types due to old river channels and former confluence of Jubba and Shabeelle rivers.
- *Swamps—Some areas are permanently inundated with water.*
- *Irrigated estates*—Floodplain physiography is obscured by land leveling for cultivation of rice (Fanoole and Mogambo state farms), sugar (Jubba Sugar Project), and bananas.

The area under each land type in each river section is given in Table 3.

Table 3. Area (km^2) under each floodplain physiographic land type[1] by river zone (data from Watson and Nimmo 1988).

RIVER SECTION	LAND TYPES					
	Undif	Levee	Dhesheeg	Flat	Heterog	Irrig
I	93					
II	270[2]					
III	65					
IV		48	92			
V		37	110			
VI		90	189[3]	97	213	93
VII		20	24	74	76	127
VIII		11	3	24	29	
Total	428	206	418	195	318	220[4]

Undif = undifferentiated alluvia;
Heterog = heterogeneous alluvia;
Irrig = Irrigated estates.

[1] *Swamps consolidated for all sections = 17 km^2.*
[2] *Includes all inundation area behind Baardheere Dam.*
[3] *Includes Dhesheeg Waamo (112 km^2).*
[4] *Greater area under irrigation than reported by AHT (1988) due to updating by Watson and Nimmo (1988).*

B. Approach to TEBS Studies

The design and execution of TEBS studies is summarized by ARD (1988). Field and analytical methods are described in relevant sections and appendices in this volume and in Watson and Nimmo (1988). A multi-level approach including aerial photography at various scales, low-level aerial census, and ground studies was used to determine land-use and vegetation patterns. All three approaches are combined to produce a quantitative analysis of vegetation and its use for wood and livestock forage.

Aerial photography included previous coverage in 1960 (mosaics c. 1:60,000) and 1983-1984 (stereoscopic prints 1: 30,000; mosaics at 1:50,000). JESS commissioned 1:10,000 stereoscopic photographs of the strip stretching 1.5 to 2 km either side of the river and 590 sample 1:1,000 photographs distributed in a stratified random fashion throughout TEBS study area.

Low-level aerial censuses were performed three times in 1987 (26 January to 3 February, 28 March to 13 April, 29 July to 26 August). These censuses estimated livestock and larger wildlife density and distribution, land use, and various cultural features. Sampling intensity in the floodplain and proposed inundation area was approximately 10 percent; in the river-dependent zone, three percent. This work is fully described in Watson and Nimmo (1988).

Ground monitoring sites were established in TEBS study area. Vegetation was described and seasonal visits were made. A major focus of this study was to elucidate the differences between floodplain and river-dependent zone sites.

V. LAND-USE DYNAMICS

This section concentrates on land-use changes in the Jubba floodplain. Two time-scales are considered. Aerial photo interpretation is used to assess changes from 1960 to 1987. Seasonal dynamics are reviewed from low-level aerial censuses carried out during 1987. The section closes with a qualitative assessment of likely land-use changes before and after closure of Baardheere Dam.

The study concentrates on changes of importance from a development perspective. Major topics addressed include:

- where major changes are occurring;
- the nature of those changes;
- rates of change and projections from them; and
- effects of closure of Baardheere Dam.

Recommendations from this section relate mainly to future monitoring requirements which are dealt with in Section X. However, several important conclusions of relevance to planners are included in Section V.C.

Land-use changes in the upper catchment of Jubba tributaries in Ethiopia are a related issue of great significance to planning for the Baardheere Dam. Removal of vegetation from these highlands will undoubtedly increase sediment loads in the river and lead to a shortening of the effective life of the dam. Abstraction of water for irrigation in Ethiopia will affect the quality and quantity of water reaching Somalia. Unfortunately, it was not possible for JESS to conduct ground studies in the upper catchment. However, an experimental water balance modeling exercise was commissioned by JESS and is contained in this volume (Hart 1989). Suggestions for future monitoring of the upper catchment are also included in that report.

Several land-use studies which include TEBS study area have been conducted in southern Somalia during the last 30 years. Comparability and methodologies of those studies are exhaustively reviewed in LRDC (1985). All of these studies, except AHT (1984), cover much larger areas than TEBS and consequently have a low level of resolution for the Jubba River and its floodplain. From their own work and that of FAO/Lockwood (1967), LRDC compared land use in 1960 and 1983-1984 for several land-use categories. Of interest to JESS are LRDC "land regions" in Middle and Lower Jubba presented in Table 4. Notable trends in some areas include decline in denser vegetation types and increase of cultivation.

Table 4. Comparison of land-use types in 1960 and 1984 based on LRDC (1985). Vegetation types are roughly comparable with those of Section VA in this report.

LAND REGION[1]	DISTRIBUTION OF LAND-USE TYPES (% by area)					
	Crop cycle[2]		Dense vegetation		Open vegetation	
	1960	1984	1960	1984	1960	1984
Lower Jubba Floodplain	17	33	62	34	13	24
Marine Plain	<1	<1	89	96	10	3
Lac Dera Plain	0	<1	86	35	14	61

[1] *Land Regions within JESS study area: Lower Jubba Floodplain is south of Fanoole Barrage; Marine Plain is west of Lower Jubba Floodplain as far south as Dhesheeg Waamo and east of Lower Jubba Floodplain as far south as the Shabeelle floodplain; Lac Dera Plain is west of the Jubba floodplain between Bu'aale and Fanoole Barrage.*

[2] *Crop cycle includes currently cultivated, seasonally fallow, and recently adandoned land.*

All JESS and AHT studies indicate that the most important effects of building Baardheere Dam will occur in the Jubba floodplain. Developments since 1983 have been rapid in this area. In contrast, the river-dependent zone, stretching 30 km west and east of the floodplain, has undergone only minor changes as illustrated in Table 5. Data in this table are taken from low-level aerial censuses performed in late jiilaal 1984 and 1987. The first (Watson and Nimmo 1985), is an approximately two-percent sample for the Southern Rangeland Survey and the second, a three-percent sample, was commissioned by JESS (Watson and Nimmo 1988). The same observer and land-use classification was used in both surveys. However, the strata used differ as explained in the footnote to Table 5. This difference leads to limitations in their comparability. Despite this inconsistency, changes in rainfed cropping between 1984 and 1987 seem slight.

The main conclusion from Table 5 is that rainfed cultivation is concentrated on land adjacent to River

Section III (between Baardheere and Bu'aale), particularly to the east of the floodplain. This information agrees with reports of AHT (1984; 1988) and LRDC (1985). It is possible that there may have been a decrease of rainfed farming north of Baardheere and some increase south of the Fanoole Barrage during this period.

Table 5. A comparison of the percentage of land under rainfed cultivation in the river-dependent zone east and west of the Jubba floodplain.

RIVER SECTION	WEST		EAST	
	1984	1987	1984	1987
I	3.0	0.0	0.0	0.0
II	0.9	0.2	0.6	0.4
III	6.2	4.7	12.0	14.0
IV	7.0	0.2	7.1	4.3
V	0.2	0.0	1.0	0.0
VI	0.0	0.2	0.2	3.5
VII/VIII	0.1	0.3	0.8	1.9

Note: 1987 data are consolidated estimates for land 30 km west and east of floodplain. 1984 data are consolidated from several strata which fall partially within these 30 km bands, but many of which stretch considerably further. There is also some overlap of 1984 strata between river sections.

No attempt is made in this section to describe the farming and pastoral land-use systems employed in the Jubba Valley. A brief account is given in Section III.B and more detail can be found in Craven, Merryman, and Merryman (1989); AHT (1984; 1988); LRDC (1985); Watson and Nimmo (1985). Rangelands are discussed in Section VII.D.

A. Land-use Changes between 1960 and 1987

In order to describe changes in land use and vegetation in TEBS study area, the following maps were used:

- Trump's (1987) interpretation for JESS of 1960 aerial photomosaics at approximately 1:60,000. These maps cover the riverine area from just north of Saakow town to the Indian Ocean.
- AHT (1984) photomaps of land use, vegetation, and physiography of the Jubba floodplain at 1:50,000 based on 1983-1984 photography at 1:30,000. This interpretation begins just south of the proposed Baardheere Dam site and ends at the ocean.
- Trump's (1987) interpretation of 1987 1:10,000 photography of the riverine strip, mapped at 1:50,000, commissioned by JESS. The length of the river from Doolow to the ocean is covered, but restricted to a width of approximately 2 km each side of the river.

Because of different areas covered, variable quality of photographs, resolution of interpretations, and inconsistencies in interpretation, a straightforward comparison of areas under different land uses was not made. To do so would involve extensive re-interpretation and repetition of several months' work, but probably have little effect on conclusions.

Review of these maps showed that most changes occurred in the floodplain, particularly close to the river where forest is rapidly disappearing (Deshmukh 1987; presented in this report as Appendix J) and pumped irrigation is rapidly spreading (Watson and Nimmo 1988). Therefore, a comparison was carried out of length of various land types adjacent to the river (separately for east and west banks) by planimetry. The resolution of all three interpretations is such that the river-edge land type invariably stretches some distance inland, usually for several hundred meters. As a result, measurement of land-use categories along the river edge supplies good information about floodplain land use where the floodplain is narrow.

Table 6. Comparison of length of riverside land under cultivation derived from planimetry with area of floodplain under cultivation from a 10-percent aerial strip census.

RIVER SECTION	PERCENT LENGTH	PERCENT AREA
I	58	25
II	48	18
III	54	39
IV	49	36
V	53	23
VI	94	53
VI/VIII	78	54

However, the strip adjacent to the river is not necessarily representative of the floodplain as a whole, particularly in wider sections. Table 6 compares percentage of river length under cultivation from this study with percentage of floodplain area cultivated, derived from a 10-percent aerial census conducted in the same season (Watson and Nimmo 1988). As expected, riverside land is used more intensely than the whole floodplain, but the trends in proportion of land cultivated between river sections are similar in both studies indicating that mapping of riverside land use is a good indicator, but not a precise estimate, of floodplain land use.

To simplify and clarify analysis, land types in the various interpretations were consolidated into five categories:

- denser woody vegetation including all types with greater than 20 percent woody cover such as bushlands, woodlands, thickets, and forests (see Section VI.B.3);
- more open vegetation types with less than 20 percent woody cover including grasslands and wooded and bushed grasslands;
- floodplain cropping without pumped irrigation, including flood recession and unirrigated farms;
- floodplain areas with pumped irrigation including riverside smallholdings and estates downstream of Fanoole Barrage; and
- other land types, a minor category including denuded areas around refugee camps, burned areas, and areas not interpretable due to cloud or poor photography.

Several limitations should be considered when reading results of the analysis in the next section. The 1960 interpretation is based entirely on large-scale photomosaics some of which are of poor quality (see the large percentage of "other" land types—actually uninterpretable areas—in the southern river sections of Figure 5). In contrast, the 1983-1984 and 1987 interpretations had access to the original stereoscopic photographic prints. However, errors in these interpretations remain in the view of this author. In the 1984 sheets, woody vegetation cover is usually underestimated, placing many bushlands and woodlands into bushed grassland and wooded grassland categories, respectively. These errors are corrected by the author using appropriate photographs and maps in this analysis for riverside vegetation to make interpretations consistent. Both previous interpretations tend to underestimate smallholder irrigation. These errors have also been partially corrected, although some underestimation and inconsistencies may remain. Large irrigated estates (Jubba Sugar, Fanoole Rice, and Mogambo) are underestimated

Contrasting patterns of vegetation and land-use in Jubba floodplain and surrounding river-dependent zone. (AHT)

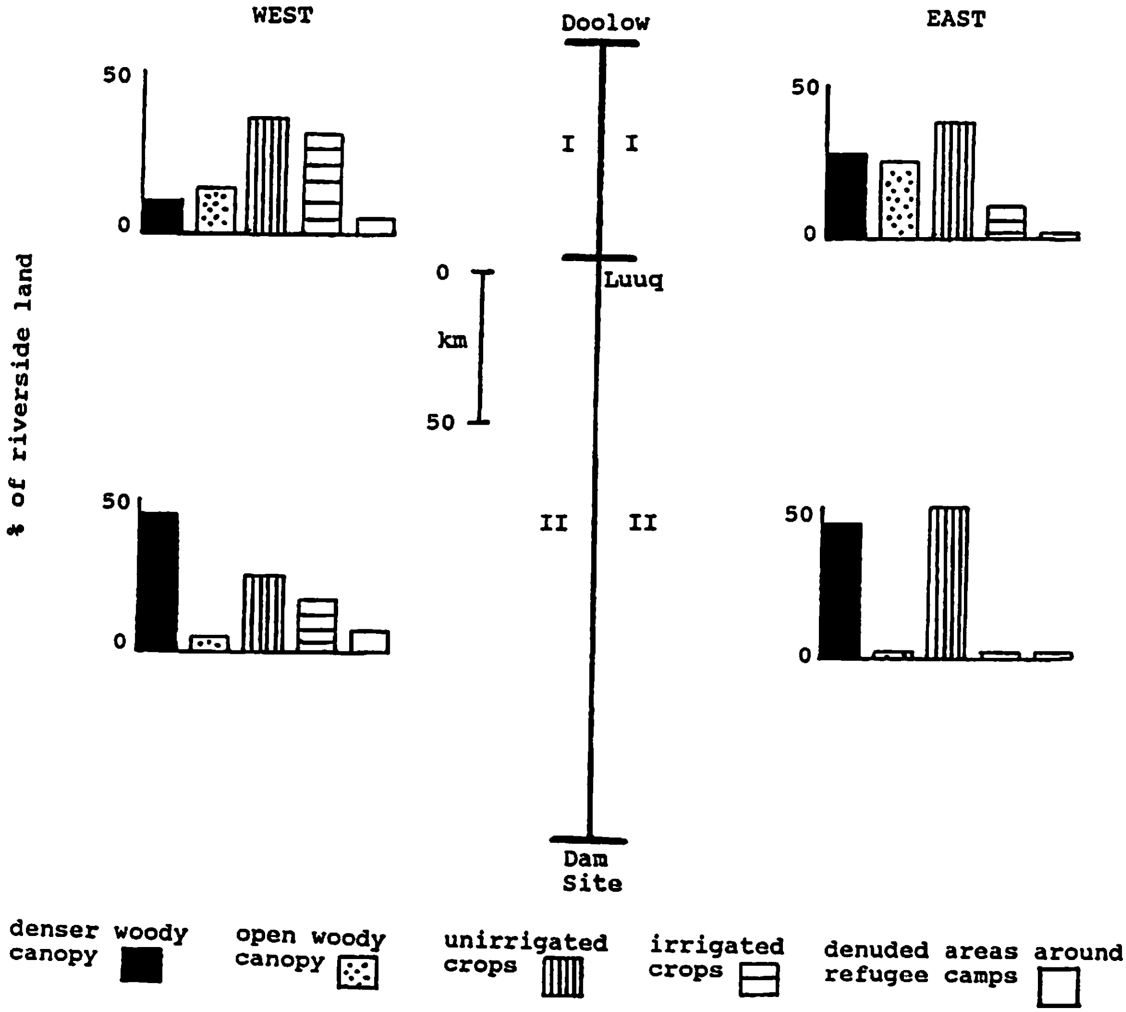


Figure 4. Percentage of riverside (east and west) under TEBS land-use types in River Sections I and II. See text for description of land-use types. Length of river sections to scale.

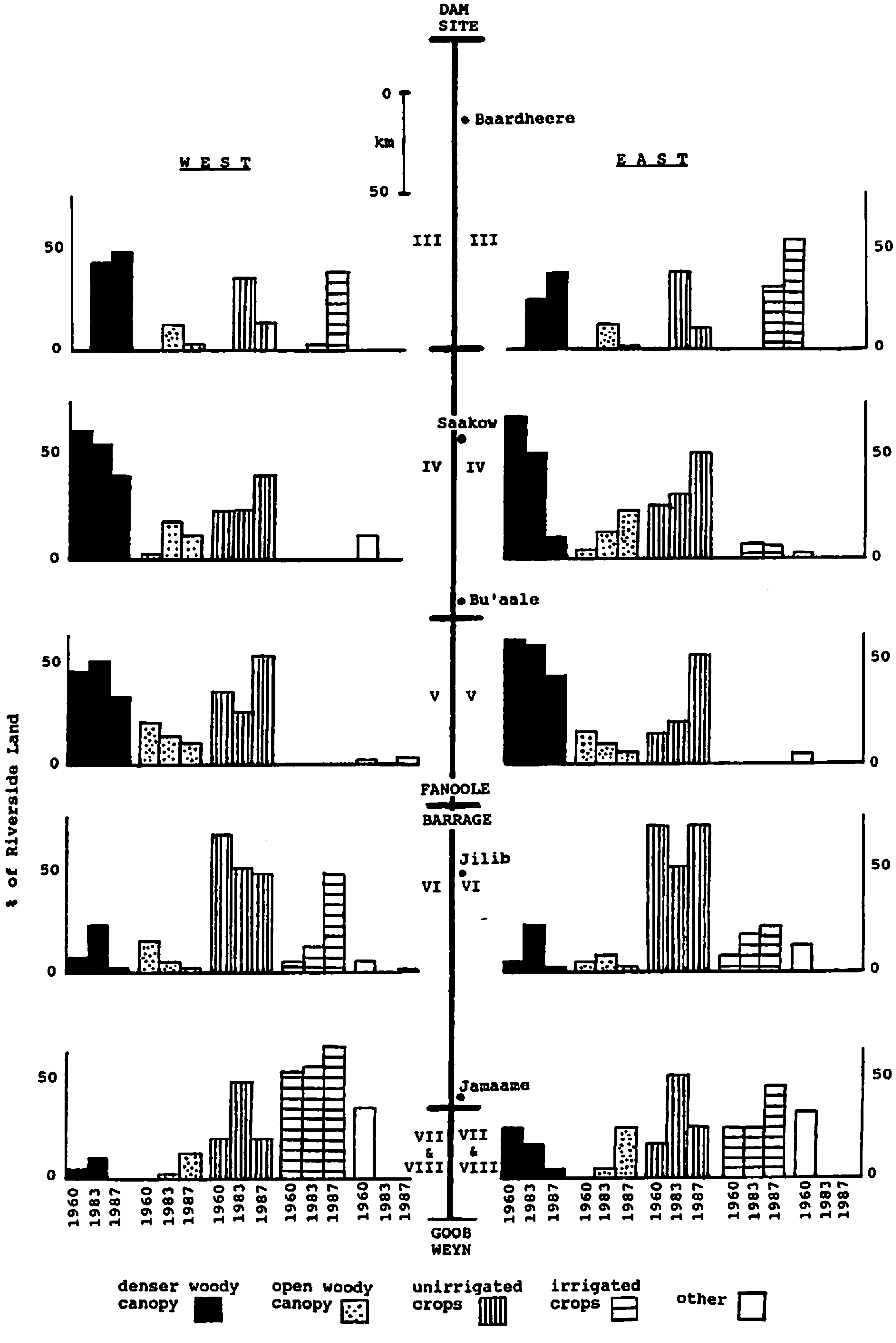


Figure 5. Distribution of riverside land (percent by length) under various land-use types in TEBS River Sections III to VIII derived from interpretation of aerial photographs taken in 1960, 1983-84, and 1987. See text for description of land-use types. Length of river sections to scale (along the river; Section VI includes eastern link around Mombassa Island).

because many fields are not next to the river and are, therefore, excluded from the area of this analysis.

In River Sections II and III, where the river cuts through limestone plateaus and hills, in some stretches there is no floodplain on one or the other side of the river. Farming is not possible alongside the river here, and the slopes are usually bushland. As a result the proportion of cultivable land in such stretches is less than in other areas. Finally, smallholder irrigation cannot be distinguished on the 1960 photomosaics. Presumably, there was much less than in 1983, or at present. Growth of smallholder irrigation, particularly in Gedo, is reported as a recent phenomenon (AHT 1984; 1988). Access to these areas has been made easier in the last decade by improved roads to Baardheere and Buurdhubo.

An additional analysis of area under dhesheeg cultivation between Saakow town and Fanoole Barrage was made because of the importance of this type of agriculture in Middle Jubba (AHT 1984; 1988). Dhesheegs are often at some distance from the river edge and are underestimated by the methods described above.

The results of this study are summarized in Figures 4 and 5 and Tables 7 and 8. Figure 4 does not compare temporal changes since only the 1987 photo interpretation covers River Sections I and II.

Nevertheless, the data are of interest because of the paucity of prior information for the area to be inundated by Baardheere Dam and the floodplain north of Luuq town. Between Doolow and Luuq the floodplain attains greater width (1 to 3 km) than it does in downstream reaches between Luuq and Saakow. Most of this floodplain is farmed. Irrigation is particularly common on the west side. Grasslands are more common here than in most downstream areas. Most woody vegetation has been cleared for cropping or, around refugee camps, for fuelwood.

In River Section II (inundation area) approximately half the floodplain adjacent to the river is farmed, irrigation again being more common to the west. The remainder of this area is mostly under denser vegetation with little open vegetation.

Figure 5 compares land-use categories for the years 1960, 1983-1984 (arbitrarily set at 1983), and 1987. An overall trend towards increased agriculture is clear, with irrigation predominating around Baardheere and south of Jilib. Most of this change has occurred in recent years. Indeed, total changes between 1960 and 1983 are usually much smaller than those between 1983 and 1987. An exception is development of the Jubba Sugar and Fanoole Rice projects, but these changes do not show up fully in this analysis for reasons explained above. Between Saakow and Fanoole Barrage changes in the first period are very slight; in some cases it seems that agriculture may have experienced a decline. In northern sections (Baardheere to Fanoole Barrage) spread of agriculture (unirrigated and/or irrigated) has been greater on the east side of the river which has better communications and more towns creating markets for produce. South of Jilib almost 90 percent of the riverside land was farmed as early as 1960.

Table 7 illustrates these trends by showing rates of change. The pace of development has accelerated enormously in the last few years. Overall, the average annual loss of vegetation and gain of farmland increased tenfold in 1983 to 1987 compared with 1960 to 1983. During the first period, increase of farmland was at 3 km $year^{-1}$, accelerating to 28 km $year^{-1}$ during the second period. At the present rate of change, all riverside land will be cultivated by the end of the century. Around Baardheere and in the south, farmland has been converted to irrigation, while in the middle sections vegetation has been cleared for unirrigated farms. The increase in denser woody vegetation between 1983 and 1987 around Baardheere seems to have been at the expense of open vegetation types. This trend may reflect the move to irrigation. Open vegetation is maintained by fires escaping from field preparation (see Section VI.D). Such practices are much reduced or absent in irrigated agriculture.

A similar pattern can be seen in the extension of dhesheeg farming between Saakow and Fanoole Barrage (Table 8). Cultivation increased slowly to almost double between 1960 and 1983. A greatly accelerated pace led to an equal increase during the next four years.

Farming of dhesheegs is a complex affair depending on time and degree of flooding as well as socioeconomic factors. For example, 4 km^2 of dhesheeg farmed in 1987 was submerged in 1983. However, the remaining dhesheeg land added to cultivation during this period was all at the expense of vegetation. Most of this clearance for dhesheeg farming has been in the stretch of river between

Table 7. Land-use changes along the Jubba River between 1960 and 1987, based on aerial photograph interpretation.[†]

[†]*Changes are expressed as kilometers or percent of riverside land by length (sum of east and west banks), by river sections north to south.*

RIVER SECTION	LAND TYPE	1960-1983** TOTAL CHANGE km	1960-1983** TOTAL CHANGE PERCENT	1960-1983** CHANGE km PER YEAR	1983-1987 TOTAL CHANGE km	1983-1987 TOTAL CHANGE PERCENT	1983-1987 CHANGE km PER YEAR
III	Denser veg				+22	+7	+5.5
	Open veg				-29	-10	-7.3
	Unirrigated				-75	-25	-18.8
	Irrigated				+82	+27	+20.5
IV	Denser veg	-30	-12	-1.3	-44	-17	-11.0
	Open veg	+31	+12	+1.4	*		
	Unirrigated	-4	-2	-0.2	+47	+18	+11.8
	Irrigated	+10	+4	+0.4	-2	-1	-0.5
V	Denser veg	+6	+3	+0.3	-28	-16	-7.0
	Open veg	-9	-5	-0.4	-9	-5	-2.3
	Unirrigated	+7	+4	+0.3	+35	+19	-8.8
	Irrigated	*			*		
VI	Denser veg	+46	+15	+2.0	-49	-16	-12.3
	Open veg	-10	-3	-0.4	-12	-4	-3.0
	Unirrigated	-52	-17	-2.2	+20	+7	+5.0
	Irrigated	+19	+6	+0.8	+36	+12	+9.0
VII/VIII	Denser veg	*			-10	-9	-2.5
	Open veg	+4	+4	+0.2	+16	+14	+4.0
	Unirrigated	+34	+30	+1.5	-28	-25	-7.0
	Irrigated	*			+21	+18	+5.3
TOTAL	Denser veg	+22	+2	+0.9	-109	-10	-27.3
	Open veg	+16	-2	+0.7	-34	-3	-8.5
	Unirrigated	-15	-2	-0.7	-1	*	-0.3
	Irrigated	+29	+3	+1.3	+137	+12	+36.3

* *indicates negligible amount*

** *1960 maps do not cover River Section III.*

Note: Arithmetic discrepancies are due to the "other" land use category (see text) and small variations in lengths measured by planimetry.

Table 8. Changes in land use of dhesheegs in Middle Jubba between 1960 and 1987 based on interpretation of aerial photography. Areas under cultivation in each year and changes between years are given.

AREA OF DHESHEEGS CULTIVATED (km^2)

RIVER STRETCH	1960	1983	1987
Saakow-Bu'aale	9.1	19.5	27.6
Bu'aale-Fanoole Barrage	26.2	43.4	68.0
Total	35.3	62.9	95.6

RATE OF CHANGE IN AREA CULTIVATED (km^2 year^{-1})

RIVER STRETCH	1960-83	1983-87
Saakow-Bu'aale	0.4	2.0
Bu'aale-Fanoole Barrage	0.8	6.1
Total	1.2	8.1

Bu'aale and Fanoole Barrage putting extreme pressure on the few remnants of riverine forest (Appendix J).

Data presented in this section show gross changes over several years or annual arithmetic average rates of change as though these figures represent uniform trends. This assumption of steady change may be reasonable for the short period between 1983 and 1987, but must be viewed with caution for 1960 to 1983. During these 23 years, fluctuations in land use probably occurred with changes in socioeconomic climate, drought cycles, and river flooding patterns. For example, two patches of dhesheeg (1 km^2) went out of production between 1960 and 1983, although greater increases occurred elsewhere. Nevertheless, the overall conclusion, that change was slow during the first period and more rapid recently, is significant.

B. Seasonal Changes in Land Use

This section reports on results of low-level aerial censuses conducted for JESS by RMR in 1987 (Watson and Nimmo 1988). The censuses were in late January to early February (mid-jiilaal), early April (late jiilaal) and August (mid-xagaa). These periods were chosen primarily to quantify livestock numbers and distribution rather than agricultural land uses. The first census covered the floodplain only, while the second and third covered the floodplain and river-dependent zone.

To get a picture of a "typical year" in the Jubba Valley requires data from many years to assess the effects of drought and flood cycles. Even such a thorough study would be of limited value because of rapid changes in land use described above. Representation of such a typical year would be a statistical abstraction, and could mislead rather than clarify. Therefore, the following account describes events in jiilaal and xagaa 1987 and cannot be generalized to other seasons and years without further information. These seasons are put in temporal context in Section III.B. Briefly, the jiilaal was harsh because of poor deyr rain in 1986 and extremely late arrival of the gu'. Shortly after onset of gu' rain, the largest river flood since 1977 occurred. Thus, the period studied experienced a prolonged dry season and a major flood.

Watson and Nimmo (1988) present a full set of tables and maps for land-use categories and diagrams for the sample strata. These strata can be combined in various ways. Figures 6 and 7 show different aggregations of strata in the floodplain. Figure 6 divides the floodplain north to south into river sections (as in Figures 4 and 5). The general pattern is similar to Figures 4 and 5, albeit dealing with land areas rather than river lengths. Furthermore, this analysis distinguishes flood recession farming, enclosed and cleared land, burned areas, and flooded areas.

From a low-flying aircraft it is not always possible to distinguish areas from which water has just receded, so underestimation of flood recession farming may occur. However, the consistent methods used produce results indicative of changes between seasons. Flood recession agriculture is at a low level throughout, except between Bu'aale and Fanoole Barrage. Most dhesheegs were dry in jiilaal, precluding this type of farming. After the flood, both riverbank and dhesheeg cultivation increased, the latter markedly in some river sections. However, large areas remained under water, limiting the extent of flood recession agriculture. These results emphasize the opportunistic nature of this form of agriculture. Some dhesheegs hold water for many years and planting follows the declining water level throughout. Others dry quickly and may be farmed as dry land most of the time.

Clearing and burning of land reached a peak in late jiilaal as land was prepared for cultivation. Fires are set to clean fields, but often escape into surrounding rangelands. The peak of fires in River Section V agrees with TEBS ground observations. Note that cultivated area drops in xagaa despite the previous clearing of land. Reduced cropping was caused by the flood between the second and third censuses, which devastated crops in most areas. Ground studies indicate that many sharecroppers' pumps were withdrawn in River Section II following inundation (TEBS field notes). Flood waters covered nearly all the floodplain initially, but had receded by the time of the xagaa census. Nevertheless, 20 to 40 percent of land was still inundated in lower river sections.

Figure 7 presents the same floodplain data, but divided into physiographic categories of undifferentiated sediments (River Sections I to III) and levees; dhesheegs; flat, free-draining sediments; and heterogeneous sediments in River Sections IV to VIII (see Section IV.B). The same patterns are evident overall. Note that flood-recession agriculture in depressions is not restricted to the fine-

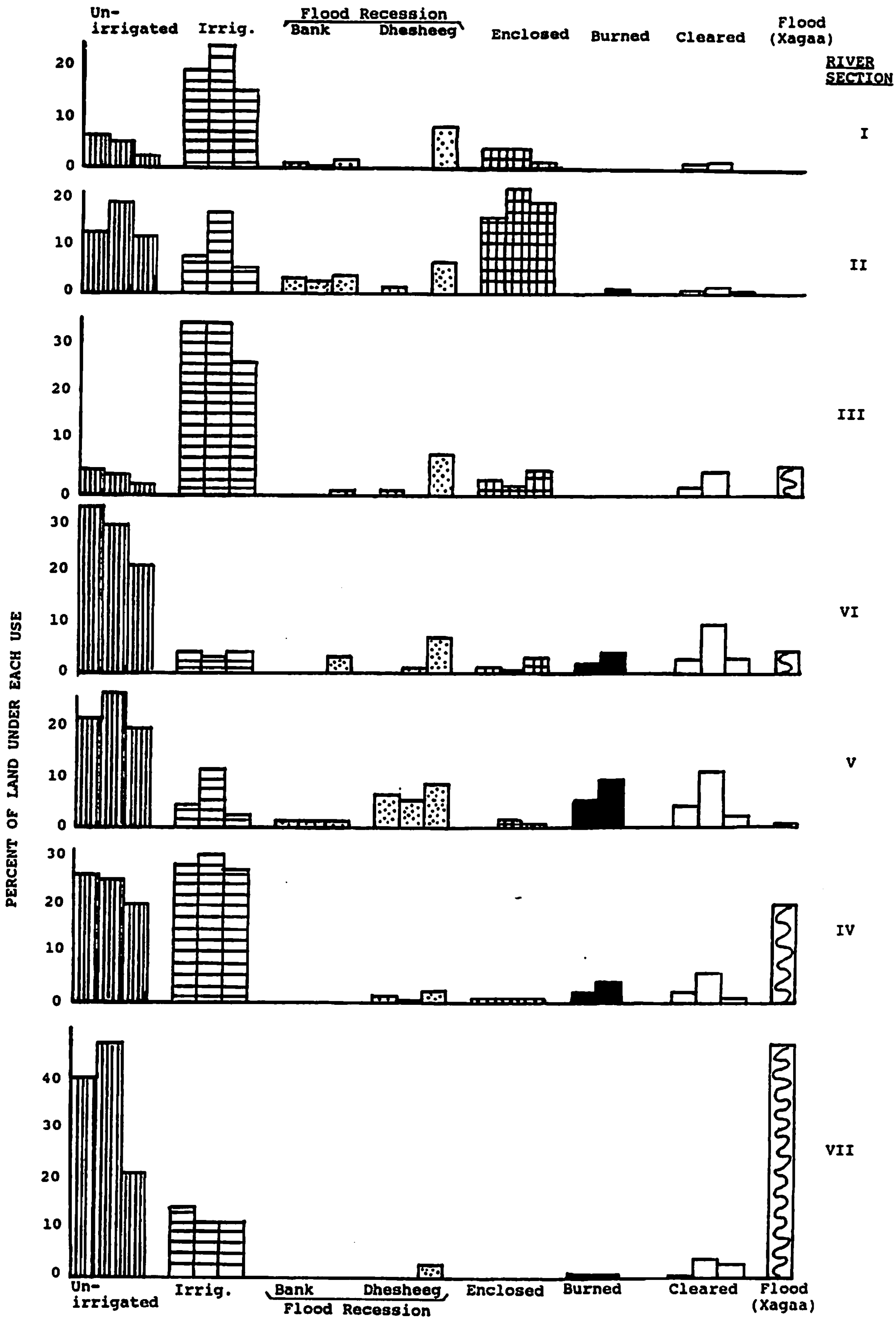


Figure 6. Percentage of floodplain area in each river section under various land uses excluding rangeland. In each case, the first column is for mid-jiilaal, the second column for late jiilaal, and the third column for mid-xagaa under each land use in 1987. Burning was only seen in the first two censuses and flooding only in the last. Data from 10-percent aerial strip census (Watson & Nimmo 1988).

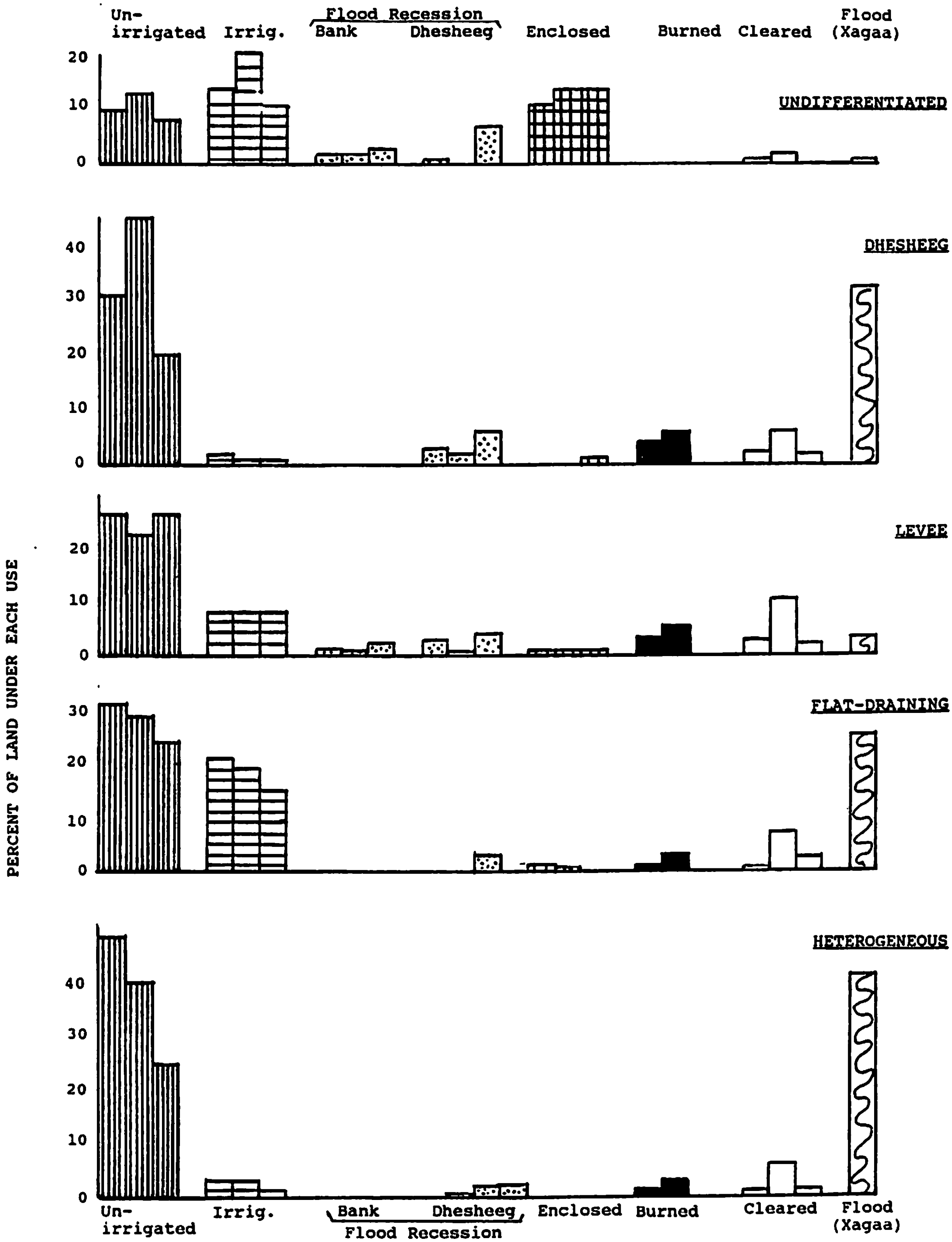


Figure 7. Percentage of floodplain area divided by land physiographic types (see text) under various land uses, excluding rangeland. In each case the first column is for mid-jiilaal, the second column for late jiilaal, and the third column for mid-xagaa under each land use in 1987. Burning was only in the first two census and flooding only in the last. The irrigated estates category, which had approximately 80 percent of land under irrigation in each season, is omitted. Data from 10-percent aerial strip census (Watson & Nimmo 1988).

grained sediments of classic dhesheegs, but that suitable depressions occur in other land types after a flood, even on the generally coarse sediments of levees. Again, the opportunistic nature of this land-use is emphasized. The only increase in unirrigated agriculture following the flood (as shown in Figure 7) is on levees. These areas drain quickly and crops are planted rapidly and continuously as water recedes exposing more land. Levees also show the greatest proportion of cleared land in the jiilaal in anticipation of cultivation.

Enclosure of land is most common in the floodplain of River Section II (Figure 7). Ground studies show that both croplands and pastures are enclosed. Further downstream, enclosures are virtually absent from most land types. In dhesheegs, the traditional farming pattern makes permanent delineation impractical. As water recedes due to evaporation and infiltration, farmers who have traditional possession of a sector of a dhesheeg perimeter plant that sector continually following the water level down towards the center of the dhesheeg. These activities produce a radial pattern of field plots and a concentric pattern of crop maturity. Most water loss from dhesheegs is by evaporation since clay soils severely impede infiltration.

Table 9. Seasonal change in land-use in river-dependent zone of TEBS study area based on aerial census in 1987 (percent of total land under each use).

REGION	RAINFED FARM		CLEARED		BURNED		ENCLOSED	
	A	B	A	B	A	B	A	B
Northern limestone								
close to river	4.9	5.6	0.2	0.2	0	0	2.5	2.2
far from river	1.8	2.7	0.1	0.1	0	0	1.7	1.8
Southern Marine Plain								
close to river	2.2	2.1	0.2	0.2	0.8	0	0.2	0.5
far from river	0.3	0.7	*	*	*	0	0.1	0.1

A = late jiilaal season B = xagaa season.

Seasonal changes in land use outside the floodplain are shown in Table 9. This table splits the river-dependent zone east-west into areas close to (0 to 15 km) and more distant from (15 to 30 km) the floodplain. North to south, the area is further divided into northern limestones and southern marine plains (see Section III.A). This transition occurs between Saakow and Bu'aale. As already indicated, the river-dependent zone is mainly rangeland with little agriculture. As expected, rainfed farms are more extensive following the gu', although changes are slight. Most farming and enclosure of land is found in areas closer to the floodplain and north of the marine plains. Of note is the small amount of burning in these rangeland areas. It seems that pastoralists rarely set fires in the study area. This observation may be due in part to a shortage of grass fuel in some parts of the river-dependent zone (see Section VII.D)

C. Conclusions

Changes of land use in the Jubba floodplain have increased markedly in recent years. Between 1983 and 1987 two trends are apparent:

- rapid decline of denser vegetation types;and
- conversion of dryland or flood-recession farms to pumped irrigation.

These recent changes have occurred, on average, at 10 times the annual rate estimated between 1960 and 1983. At the rate of agricultural expansion operating between 1983 and 1987, all riverside land will be farmed before the end of the century. The rapidity of these changes makes planning difficult. Development in the floodplain is occurring irrespective of whether plans exist or are implemented. If present trends continue most of the remaining vegetated riverside land will be cultivated and planning options reduced before the dam is closed. Because of rapidity of change, JESS baseline studies cannot be regarded as a definitive statement applicable after dam construction.

Effective monitoring to continually update information before decisions are taken is crucial. The proposed JESS monitoring program will enable important changes to be tracked. Training of technicians and planners to use monitoring information should be a high priority (see Section X; Craven, Merryman, and Merryman 1989; Tillman 1989).

Land-use changes are not uniform throughout the valley. Outside the floodplain such changes are slight. Within the floodplain there has been a marked change from unirrigated and flood recession agriculture to smallholder, pumped irrigation north of Luuq and in Baardheere District. Between Bu'aale and Fanoole, unirrigated agriculture has expanded at the expense of vegetation cover.

Filling of Baardheere Dam will take 5,000 to 10,000 ha of riverine land out of agricultural production. Approximately one-third of this land is irrigated. A further 5,000 ha is enclosed, partly as grazing reserve. In the years of dam construction, these land uses will probably increase, along with more investment in irrigation. Most of this land will be permanently inundated after the dam is closed. In the short-term, after the dam is operational, drawdown agriculture may be possible in restricted areas of suitable soil around the reservoir perimeter, particularly in the narrow floodplain south of Luuq. Over time riverine sediment may be deposited in other parts of the drawdown area, extending agricultural potential. Whether such land could be used effectively, and the rate at which deposition will occur, are unknown. *The possibility of using the drawdown area for agriculture, and monitoring the situation around the reservoir, should be incorporated into the master plan.*

After closure of the dam, floods will be less frequent and less extreme. Current projections suggest flooding at intervals of approximately five years. Most floods will occur in unprotected areas in Lower Jubba (AHT 1988). At other times, river level will be more or less constant precluding flood-recession agriculture. At present, it seems that most farming in the floodplain is not flood-recession farming (Figures 7 and 8), although there is likely to be significant variation from year to year. Even when land is not flooded or irrigated by pumps, seasonal river flood waves raise the water table adjacent to the river enhancing soil moisture for crops (Besteman and Roth 1988). The significance of this factor for crop production is unknown, but its important effect on vegetation is clear (see Sections VI, VII, and IX). When land is flooded, riverine sediments and water rich in dissolved chemicals increase soil fertility. In the absence of floods, crop yields will eventually decline unless fertilizers are added.

It must be emphasized that the dam will have a major beneficial effect by reducing large economic losses caused by destructive floods and subsequent temporary loss of submerged land. In the absence of floods, cropping will become much more predictable provided sufficient inputs of water by irrigation are supplied and soil fertility is maintained. Thus, substantial benefits from the dam will be realized if rational economic development occurs.

The adverse effects of reduced flooding will be felt most severely between Saakow and Fanoole Barrage where pumped irrigation is rare. Construction of an all-weather road between Jilib and Bu'aale may open this area to development of pumped irrigation. At present, poor communication and a largely subsistence economy limit the feasibility of using pumps. Nevertheless, some farmers in this area will suffer declining productivity as dhesheeg and riverbank cultivation become less effective. *A phased change from assisted dhesheeg farming to pumped irrigation as suggested by AHT (1986) may be the best approach to alleviate these problems (see Section IX).*

Recommendations from this section primarily concern future monitoring activities, which are discussed in Section X.

VI. VEGETATION OF THE JUBBA VALLEY

This section describes vegetation types in the Jubba Valley in terms of structural types, species composition, diversity, and dynamics. The term "natural" vegetation is avoided since human activities significantly modify most plant communities. No recommendations are included, since those relevant to vegetation are dealt with in all subsequent sections. However, conclusions and effects of closure of Baardheere Dam are included as Section VI.E. Much of the section is primarily of interest to ecologists, but the conclusions are of direct relevance to any development-oriented reader.

Particular emphasis is placed on vegetation in the floodplain and how it differs from rainfed vegetation in the river-dependent zone. Most non-floodplain plant communities and species in TEBS study area are widespread in southern Somalia, eastern Kenya, and other regions. However, the floodplain communities are very unusual within Somalia, since the Jubba is the only perennial river. Similar plant communities probably occur on the Shabeelle river, but are of limited extent due to more intensive agricultural development. In addition to species composition, differences in vegetation structure, diversity, and seasonal patterns are apparent.

Historically, it seems that much of the floodplain was forested in river sections IV to VIII. Restricted forests probably occurred in more northerly sections since forest trees can be found all along the river. *Acacia* woodlands now represent the densest vegetation in these sections. As recently as 1960, south of Saakow, almost 100 km^2 was under closed forest, but less than 10 km^2 remained along the whole river length by 1987 (Appendix J). The forest remnants are of much interest ecologically and from a conservation perspective (see Sections VI.C.3 and VIII). Such evergreen lowland forests usually occur in the tropics when annual rainfall exceeds 1,000 mm. That they occur on the Jubba in semi-arid conditions clearly indicates the importance of riverine flooding and groundwater for floodplain vegetation.

The distribution of land under native vegetation, as opposed to agriculture, in various parts of the study area is given in Table 10. As noted in Section V much of the floodplain is now cultivated (approximately one-half), whereas non-floodplain lands remain predominantly as rangelands. Enclosure of uncultivated land for range reserve or other purposes is only important in northern floodplains.

Table 10. Total area of land and percentage under native vegetation cover in the study area by river section comparing floodplain (FP) and river-dependent zone west (W) and east (E) of floodplain. Enclosed areas are without agriculture but under native vegetation cover. Data from aerial censuses (Watson and Nimmo 1988).

RIVER SECTION	TYPE	TOTAL AREA (km^2)	% OPEN[1]	% ENCLOSED
I	FP	93	66.6	6.2
	W	1,058	97.5	1.8
	E	1,058	98.2	1.4
II	FP	270	54.6	17.7
	W	4,045	98.5	1.2
	E	4,045	97.5	1.8
III	FP	65	54.8	2.7
	W	3,095	94.2	1.5
	E	3,095	78.9	4.7
IV	FP	140	56.3	<1.0
	W	1,860	99.0	<1.0
	E	1,860	95.1	<1.0
V	FP	147	66.7	<1.0
	W	1,430	100.0	0.0
	E	1,430	100.0	0.0
VI	FP	695	42.3	0.0
	W	4,769	99.8	0.0
	E	2,142	95.1	0.0
VII/VIII	FP	346	35.4	0.0
	W	2,081	99.0	0.0
	E	398	97.2	<1.0
TOTAL Study Area	FP	1,766	47.6	3.0
	W	18,338	98.3	<1.0
	E	14,298	93.1	1.6

[1] *"Open" is all land not actively mananged; non-floodplain percentages are mean of late-jiilaal and xagaa censuses 1987. Floodplain is mean of early- and late-jiilaal and xagaa censuses 1987, except for river sections III, IV, VI, and VII/VIII; in these sections substantial land was flooded in xagaa and mean of two jiilaal censuses is given.*

A. Other Studies and the JESS Approach

Recent resource surveys have mapped various attributes of vegetation in the study area. LRDC (1985) provides a vegetation and land-use map based upon 1983-1984 aerial photography at 1:500,000. From the same photography, AHT (1984) produced a detailed vegetation and land-use map based upon floodplain physiography (1:50,000; see Sections IV and V). For the Southern Rangeland Survey, Watson and Nimmo (1985) subdivided the area into "land-system units" mapped at 1:250,000, which are partly based upon vegetation characteristics; they also produced a 1:1,000,000 map of structural vegetation types. For JESS, Trump (1987) has mapped vegetation and land use at 1:50,000 of a strip 2 km either side of the Jubba. All these maps are available (see annotations in References section) and are more or less compatible. Therefore, no attempt is made in this volume to produce another vegetation map.

JESS studies of terrestrial vegetation avoid repeating other recent work, but attempt to integrate these previous efforts. A multilevel approach is used, combining aerial photography, aerial census, and ground monitoring sites. The main objectives are as follows:

- to determine how floodplain vegetation differs from non-floodplain vegetation;
- to determine how vegetation is used by the human population (covered mainly in Sections V and VII);
- to quantify the area covered by different vegetation types now and in the recent past (see also Section V and Appendix J);
- to establish a basis for vegetation monitoring (see Section X); and
- to predict likely effects of Baardheere Dam.

B. Vegetation Monitoring Sites

The Southern Rangeland Survey (Watson and Nimmo 1985) established 626 ground monitoring sites in southern Somalia. These sites cover the area fairly uniformly (subject to accessibility), but give no special emphasis to the Jubba floodplain. One hundred and fifty-five of these monitoring sites fall in TEBS study area (see Map 1; note that most sites are paired, only one location is shown), but only 18 are in the floodplain (Table 11). Detailed descriptions of vegetation structure and species composition, surface soil characteristics, range condition, and other features were recorded and photographed at Southern Rangeland Survey sites.

TEBS could not improve on this broad coverage of non-floodplain rangelands. Therefore, emphasis on new monitoring sites was for the following purposes:

- Ground sites were established for long-term and seasonal monitoring in the Jubba floodplain and nearby non-floodplain sites downstream of the dam site. Seasonal monitoring was carried out to elucidate special features of floodplain vegetation and land use.
- Ground sites were established in the poorly studied inundation area to describe vegetation which will be lost. Sites above maximum water-level and in the drawdown zone were also set up for future monitoring.
- A large number (595) of large-scale (1:1,000) vertical aerial photographic monitoring sites were established throughout the study area. These photographs represent a stratified random sample and can be used for making quantitative statements about vegetation types as well as being a valuable long-term monitoring tool.

1. Ground Monitoring Sites

Ninety TEBS ground-monitoring sites were established, distributed as shown in Table 11 and Map 1. Sites were chosen to cover the main vegetation and physiographic types identified by the AHT (1984) vegetation map. To represent all 36 of these vegetation types in a statistically valid manner would require many hundreds of samples. From the outset, it was decided that a more useful approach entailed

Table 11. Distribution of vegetation monitoring sites in the study area by river sections. The types of site are discussed in the text; SRS = Southern Rangeland Survey; FP = floodplain; W = 0 to 30 km west of floodplain; E= 0 to 30km east of floodplain.

River	JESS GROUND			JESS PHOTO			SRS		
Section	FP	W	E	FP	W	E	FP	W	E
I	0	0	0	13	14	18	0	8	14
II*	23	10	3	49	51	21	0	12	10
III	2	0	0	23	16	19	4	6	12
IV	9	0	7	40	25	22	2	12	12
V	9	2	1	34	10	16	2	8	2
VI	11	6	2	69	16	16	7	6	14
VII & VIII	3	2	0	63	14	11	3	17	4
TOTAL	57	20	13	291	146	123	18	69	68

** River Section II includes all inundation area up to 142 masl contour and is not all strictly floodplain.*

seasonal visits to a limited number of sites to obtain insights into vegetation use and dynamics. Given the rapid change in vegetation (Section V; Appendix J), statistically comprehensive descriptions of disappearing sites were deemed to be of less value than examining fewer representative sites in greater detail. Aerial photography was relied upon for a more complete and statistically valid approach (AHT 1984; Trump 1987; Section VI.B.2).

Table 12. Distribution of JESS vegetation monitoring sites in the floodplain in relation to physiographic classification (see Section IV.2).

PHYSIOGRAPHIC TYPE	GROUND SITES	PHOTO SITES
undifferentiated alluvia	11	56
levees	11	90
dhesheegs	12	51
flat free-draining alluvia	5	27
heterogeneous alluvia*	3	55
togga	4	12

** underrepresented in ground samples; heavily farmed such that 30 percent of photo samples are termed "mixed" due to lack of vegetation uniformity caused by high level of human activity.*

A typical ground monitoring site is a 20 m x 20 m square although other configurations were used (see Appendix A). Within that square all woody plants above 1 m in height were identified and measured on the first visit for basal diameter, crown diameter, crown depth, and height. Herbaceous vegetation cover was estimated seasonally for grasses, forbs, and dwarf shrubs using a point-frame technique. Standing crop of herbaceous plants was also estimated seasonally by harvesting samples and oven-drying (see Appendix A). Phenological condition (degree and timing of leaf, flower, and fruit) and degree of grazing or browsing were noted for more common species. Other observations, including a complete species list of plants in the vicinity of each site, land-use features, surface soil characteristics, and ethnobotanical information, are described in Appendices A and I.

Although no ground monitoring sites are in the floodplain of River Section I, the vegetation there has been comprehensively described by Wieland (1984) and Wieland and Werger (1985).

2. Photographic Monitoring Sites

Vertical aerial photographs of approximate scale 1:1,000 were taken for analysis of vegetation structure. Each nine-by-nine print covers approximately 5.3 ha. The central 15 x 15 cm portion (equivalent to 2.25 ha) was used for analysis to avoid distortion towards the edge of the photographs. Sampling was on a stratified random basis (the technique employed is described in Appendix B and Watson and Nimmo 1988). Floodplain strata are given in Table 12. For the river-dependent zone, stratification was with respect to distance from the river and river sections. The overall distribution of these photographs is shown in Table 11. Precise locations are given on RMR map series in the JESS Data Repository at USAID/Somalia.

Vegetation was analyzed in two ways. First, a dot grid was used to estimate cover of woody plants. Second, crown diameter was estimated for a random sample of trees and bushes on each photograph (see Appendix B).

3. Vegetation Classification

A system of classification was required that is compatible with the two monitoring site techniques and with previous work (particularly Watson and Nimmo 1985; LRDC 1985; AHT 1984; Trump 1987). In general, it is convenient to describe different vegetation types in gross structural terms such as grassland, bushland, or forest, rather than by species composition. As a second step floristics can be added, where appropriate, to give more information, such as *Sporobolus helvolus* grassland or *Acacia-Terminalia* woodland.

The most widely used structural classification in East Africa was devised by Pratt, Greenway, and Gwynne (given in its fullest form in Pratt and Gwynne 1977). This system was used in preparing Jubba vegetation and land-use maps of AHT (1984) and Trump (1987). Although the system has its weaknesses, the general descriptors are well known to East African ecologists and verbal descriptions are, therefore, widely understood. The system is based on percentage cover of ground by crowns of shrubs and trees. Such a system has the advantage of being applicable in ground studies and aerial photographs. Weaknesses of the basic system are its lack of categories between 20 percent and 100 percent woody cover, and the lack of emphasis given to the status of the herb layer. For JESS studies a modified version of the system has been devised which is briefly described in Table 13 and fully explained in Appendix C. TEBS data bases can be used to generate other cover categories if desired. For TEBS ground sites, the low-shrub layer (woody plants <2 m which normally do not grow taller) and herbaceous layer are described separately for more detail. Thus, TEBS ground site 3 is an "open bush-

Table 13. Classification of vegetation types in the Jubba Valley using structural criteria. (See Appendix C for more detail).

Step 1: Is woody canopy cover (2 m height) greater than 2 percent? (If not go to steps 2 and 3 directly).

% Woody Cover	Canopy < 5 m High	Canopy > 5 m High
2 - 19	sparse bushland or bushed grassland[1]	sparse woodland wooded grassland[1]
20 - 39	open bushland	open woodland
40 - 59	medium bushland	medium woodland
60 - 79	dense bushland	dense woodland
80 +	thicket bushland	forest

Step 2: If woody cover is less than 2 percent consider low-shrub cover (woody plants 2 m high) using % woody cover categories as in step 1 (2 to 19 percent sparse low-shrub layer, etc.)

Step 3: Herbaceous cover is measured using a point-frame and recording number of "hits"[2].

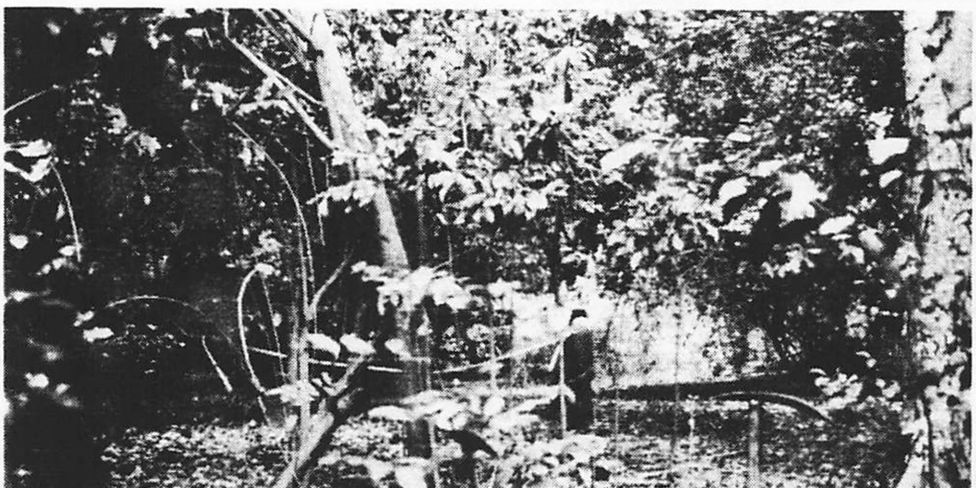
0 - 49 hits	negligible herb layer
50 - 99 hits	sparse herb layer
100- 249 hits	medium herb layer
250+ hits	dense herb layer

Step 4: If woody and low shrub cover are 2 percent and herbaceous cover negligible, site is classified as barren land.

[1] *"bushed" and "wooded grassland" replace "sparse" categories when herb layer exceeds "negligible".*
[2] *"hits", see Appendix C.*

land with open low-shrub layer and sparse herbaceous layer"; site 25 is a "medium bushland with an open low-shrub layer and dense herbaceous layer." This classification of low-growing vegetation for each site is included in JESS data bases for ground sites. Because low-shrub and herbaceous cover are less easily defined for photographic monitoring sites, only tree and bush cover are used as descriptors in most cases.

Figure 8 shows the proportion of structural vegetation types in TEBS study area based on aerial photograph sites. Since these sites are a stratified random sample, they are regarded as representative, although total sample area is small (0.77 percent of floodplain; 0.04 percent of river-dependent zone). Combining this table with the information in Table 10, area under each vegetation type can be calculated. Table 14 compares the randomly chosen photographic sites with the subjectively chosen ground sites. Grasslands, particularly in the floodplain (including wooded and bushed grasslands), seem overrepresented in the ground sample. However, it is possible that grasslands are underrepresented in the photographic samples for two reasons. First, the aerial photographs were commissioned to avoid farms and emphasize vegetation. Many floodplain grasslands may have been correct-



Evergreen tall forest once covered much of the Jubba floodplain.

ly assessed as "abandoned" or "fallow" cultivation and avoided by the pilot/photographer using his census land-use classification (Watson and Nimmo 1988). These two land-use categories comprise 30 percent of total land in the floodplain. Second is a matter of scale: a 20 m x 20 m ground plot may be placed in a grassy section of a patchy area, some of which is relatively open and some of which has denser woody vegetation. A 5-ha photograph will sample this diversity to give an overall picture of a larger area. Photo interpretations of the whole area suggest that floodplain grasslands are under-represented in the aerial photograph monitoring sites. For example, 20 percent of riverside vegetation was "open" in 1987 (Section V) compared with 7.5 percent for the whole floodplain from the monitoring photographs.

Figure 8 compares percentage of vegetation types in floodplain and river-dependent zones. The frequency distributions are strikingly similar. This similarity is a secondary feature resulting from human activity reducing woody vegetation in the floodplain. Overall, bushlands of various densities dominate both floodplain (61 percent) and non-floodplain (71 percent) vegetation (Figure 8). However, the floodplain carries more tall vegetation with 24 percent under woodlands and forest compared with 13 percent outside the floodplain.

Figure 9 is a breakdown of vegetation types by river section. In the floodplain, frequency of denser

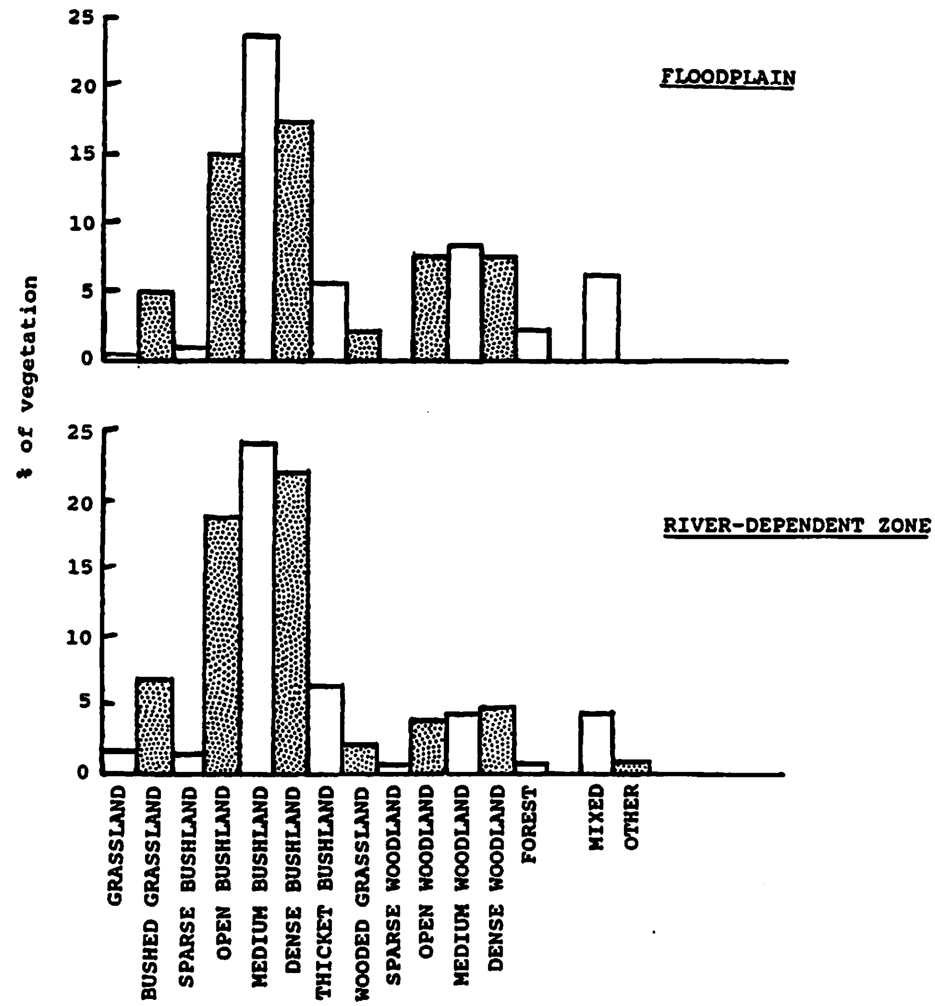


Figure 8. Comparison of percentage of vegetation in TEBS structural categories in the Jubba floodplain and river-dependent zone by river section.

Table 14. Number of TEBS monitoring sites established by ground studies and aerial photography classified by structural composition of vegetation.

VEGETATION TYPE	FLOODPLAIN GROUND	FLOODPLAIN PHOTO	RIVER-DEPENDENT ZONE GROUND	RIVER-DEPENDENT ZONE PHOTO
Forest	9	3	1	1
Dense Woodland	2	23	1	13
Medium Woodland	0	25	0	11
Open Woodland	2	14	0	10
Wooded Grassland	2	7	1	5
Thicket bushland	7	17	7	18
Dense Bushland	3	54	3	60
Medium Bushland	3	76	8	65
Open Bushland	3	48	12	51
Sparse Bushland	1	2	3	2
Bushed Grassland	5	16	11	19
Open Low-shrubland	1	-	0	-
Sparse Low-shrubland	0	-	2	-
Grassland (short)	6	1	-	4
Grassland (tall)	2	-	0	-
Mixed	-	20	-	11

Note: Some photographs could not be classified in this scheme.

vegetation tends to increase in a southerly direction. Open bushlands and open woodlands are common in northern sections, but denser bushlands (including thickets), denser woodlands, and forests assume greater importance further south. Bushed and wooded grasslands do not show consistent trends because they are closely linked with farming activities which vary in intensity in different river sections. In many sections of the floodplain, but reaching a peak of almost 20 percent in VII and VIII, the mixed category indicates that farming intensity is so high that areas of vegetation large enough to fill a monitoring photograph are difficult to find.

In the river-dependent zone, density and height of plants also increase in a southerly direction as expected given the north-south rainfall gradient. River Sections I and II are predominantly open bushlands, with few dense bushlands, thickets, or woodlands. Medium and dense bushlands are common in southerly sections and woodlands more common than in the north.

Comparisons of floodplain and river-dependent zones for each river section generally do not show great differences. Woodlands are more common in the floodplain except for River Sections VII and VIII. In these southern sections, the floodplain is heavily farmed with high human and livestock densities. These factors combine to maintain a relatively degraded woody vegetation.

Overall, differences between floodplain and river-dependent vegetation structure by proportion are not striking. However, larger differences are apparent when "patch size" is taken into account. Perusal of 1983-1984 aerial photomosaics at 1:30,000 shows clearly that while many different vegetation types occur in a few square kilometers of floodplain, forming a complex mosaic, non-floodplain areas carry monotonously similar vegetation over many square kilometers. Another difference is the transition from one vegetation type to another. In the floodplain, transitions are often abrupt between quite dissimilar types such as forest, grassland, and thicket mainly as a result of human activity. Outside the floodplain, transitions are usually gradual and sequential with, for example, bushed grassland grading into open bushland, to medium bushland. Landscapes are further differentiated because of the much higher incidence of farmland in the floodplain.

C. Distribution of Plant Species

The previous section demonstrates that vegetation structure is similar when the floodplain is compared with the river-dependent zone. When species composition is examined, differences are more striking. A comparison of species occurring on and around TEBS ground monitoring sites reveals that 131 species were found only in the floodplain and 121 species only in non-floodplain sites from a total of 313 species recorded (Appendix D). No attempt was made to make a comprehensive plant collection from TEBS study area. Most plants identified were found on or close to ground monitoring sites. A full accounting would produce many more species. For example, in the 1,700 km^2 Kora Reserve comprising riverine and dry bush communities on the Tana River, Kenya, over 700 species have been recorded (Kabuye *et al.* 1986). Table 15 lists the most abundant species found on TEBS monitoring sites throughout the study area. Although a few species are common to both floodplain and non-floodplain sites they are usually much more abundant in one or the other. For example, *Acacia zanzibarica* is predominantly a floodplain species in this area, while *A. reficiens* is dominant in the river-dependent zone. Separation of herbaceous species between floodplain and river-dependent zone is less distinct than trees and shrubs, but performance of these

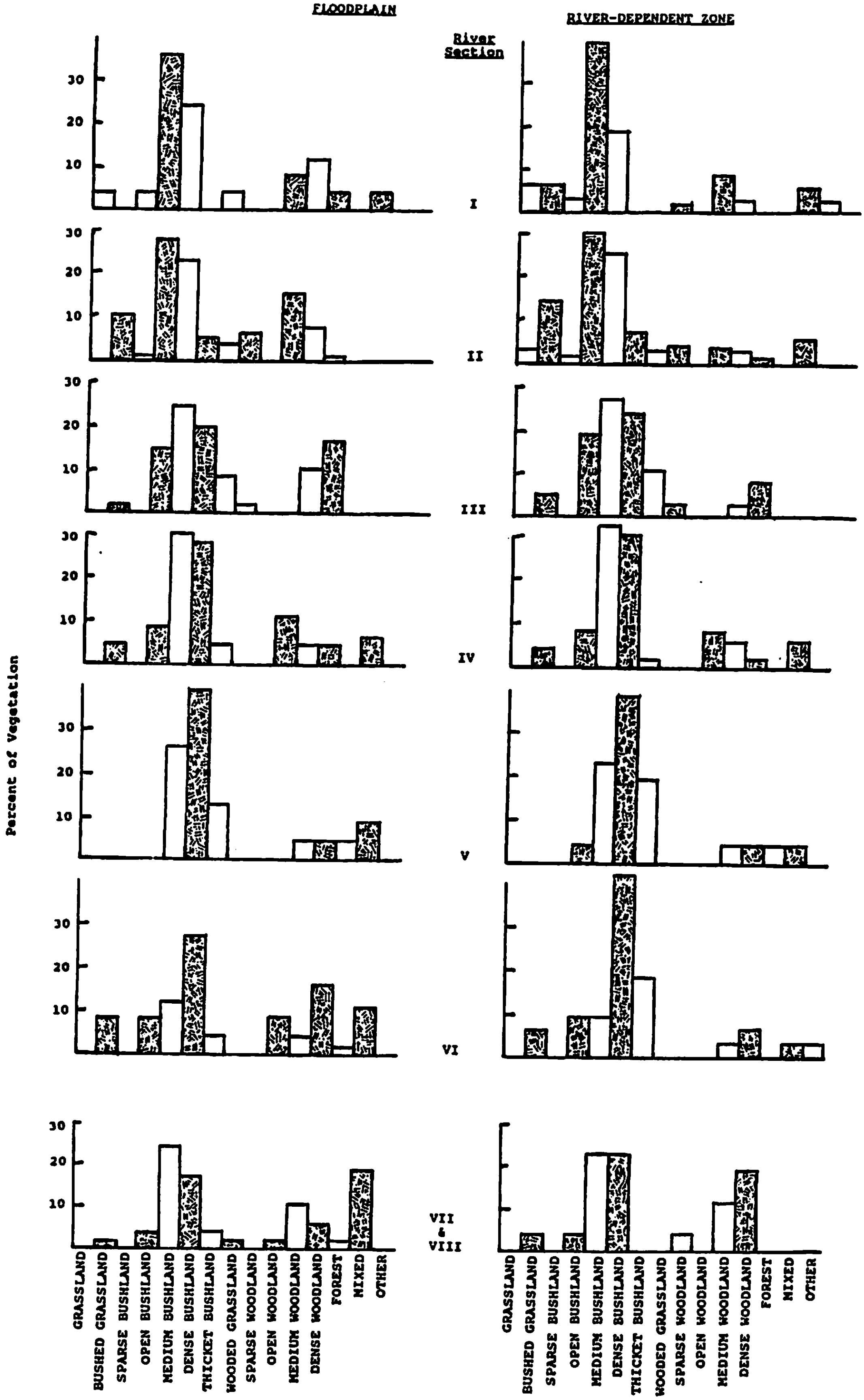


Figure 9. Composition of vegetation by structural types comparing floodplain with river-dependent zone by river section.

species is markedly different in the two environments (see Section VI.D).

Table 15. Comparison of the most abundant species in TEBS monitoring sites in and out of the Jubba floodplain.

TREES AND SHRUBS
(species constituting more than 1.5 percent of total number of individuals)

FLOODPLAIN SPECIES	% OF PLANTS	RIVER-DEPENDENT ZONE SPECIES	% OF PLANTS
Phyllanthus somalensis	24.5	*Acacia reficiens*	14.5
Acacia zanzibarica	10.3	*Commiphora* spp.[1]	7.6
Thespesia danis	8.7	*Acacia horrida*	5.6
Terminalia brevipes	7.8	*Grewia tenax*	4.0
Dichrostachys cinerea	6.3	*Premna resinosa*	3.9
Flueggea virosa	3.5	*Anisotes trisulcus*	3.8
Acalypha fruticosa	2.7	*Acacia zanzibarica*	3.7
Cordia goetzii	2.5	*Cordia sinensis*	3.5
Rinorea elliptica	2.1	*Acacia nubica*	2.5
Adenopodia rotundifolia	2.1	*Cadaba* spp.[1]	2.3
Hyphaene sp.	2.1	*Dobera glabra*	2.3
Acacia nilotica	1.6	*Combretum hereroense*	2.0
Acacia reficiens	1.5	*Acacia bussei*	1.9
Cephalocroton cordofanus	1.5	*Thespesia danis*	1.8
Lecaniodiscus fraxinifolius	1.5	*Terminalia* spp.[1]	1.8
		Euphorbia cuneata	1.7
		Acacia senegal	1.6
		Combretum contractum	1.6
TOTAL	77.2	TOTAL	66.1

HERBACEOUS LAYER
(species with score of 20 or more)

SPECIES		SCORE[2]	SPECIES		SCORE
Sporobolus helvolus	G[3]	147	*Sporobolus helvolus*	G	54
Cenchrus ciliaris	G	31	*Aerva persica*	F	40
Enicostemma axillare	F	30	*Eragrostis cilanensis*	G	34
Eriochloa meyerana	G	29	*Solanum* spp[1]	DS/F	34
Echinochloa haploclada	G	25	*Aristida* spp.[1]	G	30
Sorghum arudinaceum	G	25	*Dactlyoctenium scindicum*	G	28
Solanum spp.[1]	DS/F	24	*Cenchrus ciliaris*	G	25
Echinochloa colona	G	24	*Cadaba glandulosa*	DS	23
Commelina spp.[1]	F	22	*Commelina* spp.[1]	F	22
Indigofera schimperi	DS	21	*Enteropogon* sp.	G	20
TOTAL		378	*Sporobolus* sp.	G	20
(maximum possible		1,034)	TOTAL		330
			(maximum possible		1,073)

[1] *represents several unidentified species.*
[2] *score is derived from index of adundance described in Appendix A.*
[3] *G = grass; F = forb; DS = dwarf shrub.*

As described in Section VI.C.2, non-floodplain lands are predominantly dry bushlands, whereas the floodplain vegetation is a mosaic of forest patches, woodlands, bushlands, thickets, and grasslands. Human effects outside the floodplain are mainly through extensive livestock grazing and browsing and fuelwood collection, while in the floodplain intensive agricultural activities are the primary cause of present day structural vegetation types. Floodplain species composition is greatly altered by human activities. Periodic flooding and varied soil types also have major effects on which species are present.

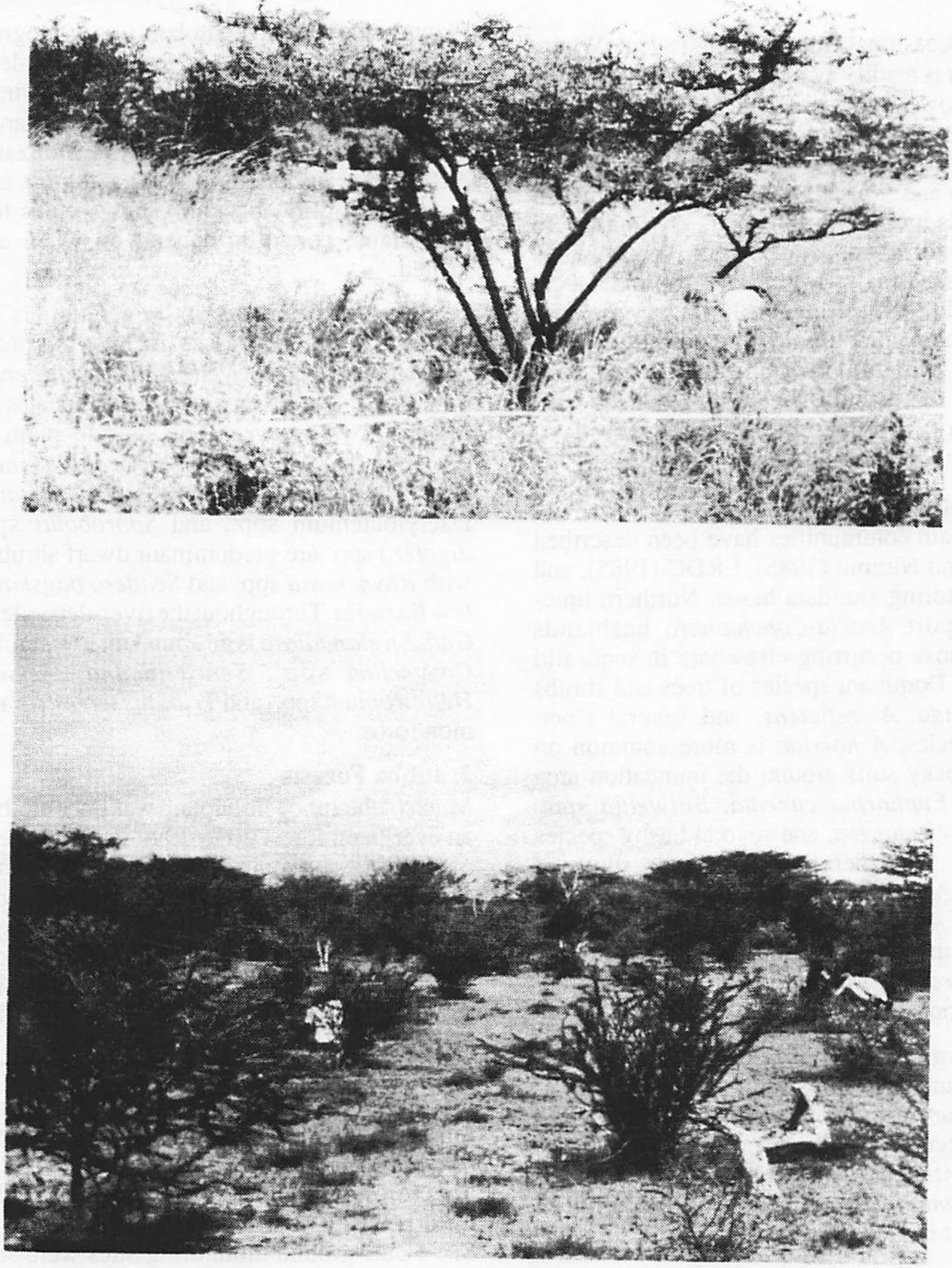
For the purpose of an outline description of species composition of plant communities, the study area is divided into broad ecological zones. Outside the floodplain, a north-south division separates major environments in terms of geology and rainfall (Section III). Major geological types are northern limestone hills and plateaus, southern marine plains, and coastal dunes. In the floodplain, major divisions are related to physiographic types such as levees and dhesheegs, which in turn vary somewhat in a north-south direction.

1. Floodplain Species

Where woodlands remain, acacias dominate the floodplain north of Baardheere. Between Doolow and Luuq, the dominant species is *Acacia tortilis* (Wieland and Werger 1985). In the inundation area, *A. zanzibarica* often forms closed stands. Along the river edge forest trees including *Tamarix aphylla, Salvadora persica, Hyphaene* sp., and occasional *Acacia eliator* and *Ficus* sp. occur.

Further south, non-forest communities are variable, depending on land-use and/or hydrology and soil. Among woody species *Acacia zanzibarica, A. nilotica, Thespesia danis, Terminalia brevipes, Dichrostachys cinerea,* and *Phyllanthus somalensis* grow on most physiographic categories. However, there is some differentiation when surface soil texture is taken into account. On heavy clays fringing dhesheegs and along some togga *T. brevipes* often forms a dense thicket. In contrast, *P. somalensis* and *D. cinerea* are more common on coarser soils. *A. nilotica* is especially common on the clays of heterogeneous alluvia south of Jilib. *Adenopodia rotundifolia* is a locally dominant tree in some woodlands on free-draining alluvia south of Fanoole Barrage.

Perennial grasses dominate in most open communities. As shown in Table 15, *Sporobolus helvolus* is strongly dominant, with five other grasses in almost equal secondary roles (although any one may be abundant at a particular site). The most



Contrasting vegetation and rangeland conditions in floodplain (above) and river-dependent zone (below).

common dwarf-shrubs are *Indigofera schimperi* and *Rhynchosia minima*. *Enicostemma axillare* is a common and persistent evergreen forb. Other common annuals include *Tragia plucknetii*, *Commelina* spp. and *Ipomoea* spp.. Most grasslands have a low-shrub layer commonly including *Phyllanthus somalensis*, *Terminalia brevipes* and *Ormocarpum kirkii*.

Of note are occasional tall grasslands (>2 m). Where groundwater is readily available, such as at the river edge, or in lower-lying dhesheegs, *Panicum maximum*, *Eriochloa meyerana*, *Saccharum spontaneum*, and to a lesser extent *Echinochloa haplochlada* and *Sorghum arudinaceum*, form tall dense swards in excess of 10 t ha ' 'ry matter. In the absence of groundwater, sucn communities maintain less than half this standing crop under local rainfall conditions (Deshmukh 1984; see also Section VII). These communities demonstrate the significance of local groundwater even to herbaceous plants. This fact should not be overlooked when considering the potential importance of groundwater for floodplain field crops.

2. Non-Floodplain Species

Non-floodplain communities have been described in Watson and Nimmo (1985), LRDC (1985), and TEBS monitoring site data bases. Northern limestones support *Acacia-Commiphora* bushlands similar to those occurring elsewhere in semi-arid East Africa. Dominant species of trees and shrubs are *A. horrida*, *A. reficiens*, and several *Commiphora* species. *A horrida* is more common on stony and rocky soils around the inundation area along with *Euphorbia cuneata*, *Boswellia* spp., *Caesalpinia erianthera*, and several bushy species of *Solanum*. On finer limestone soils south of Baardheere, *A. reficiens* is by far the most abundant species with *A. bussei*, *A. nubica*, *A. etbaica* being common, but fewer *Commiphora* are present. *Dobera glabra* is also common south of the dam site particularly on clay soils.

On the marine plains, *A. reficiens* is abundant. *A. bussei* is found in more northerly areas and *A. drepanolobium* further south. In higher rainfall river sections, species more common in the floodplain such as *A. zanzibarica* and *A. nilotica* are also found. *Cephalocroton cordofanus* and *Premna resinosa* are important in the low-shrub layer.

Other species frequently encountered throughout the river-dependent zone include several species of *Terminalia*, *Cordia sinensis*, *Grewia tenax*, *G. villosa*, *Anisotes trisulcus*, *Combretum hereroense*. and *Acacia senegal*.

The coastal dunes around the estuary are dominated by *A. tortilis* woodlands where these have not been felled. *A. senegal* is also common. The understory is dominated by *Cordia somalensis* shrubs.

Plants in the herb layer probably vary geographically in the river-dependent zone. Grass density is much lower than in the floodplain, allowing dwarf shrubs and forbs to become more abundant. However, detailed description and generalization are difficult because many grasses and most forbs are short-lived following rain. Thus species found in identifiable condition depend on when a site is visited.

In the north, herbaceous vegetation is usually sparse. Common grasses include *Aristida* spp., *Eragrostis cilianensis*, and *Tetrapogon cenchriformis*. Dwarf shrubs include several species of *Barleria* and *Indigofera*. The marine plain carries denser grass cover of *Sporobolus helvolus*, *Cenchrus ciliaris*, *Eragrostis ciliaris*, *Setaria* spp., Dactyloctenium spp., and *Sporobolus* spp.. *Indigofera* spp. are predominant dwarf shrubs along with *Rhynchosia* spp. and *Seddera bagshawei*, but few *Barleria*. Throughout the river-dependent zone, *Cadaba glandulosa* is an abundant low shrub, while *Commelina* spp., *Senra incana*, *Aerva* spp., *Heliotropium* spp., and *Tribulus terrestris* are common forbs.

3. Jubba Forests

Much of the Jubba floodplain was once clothed with an evergreen forest 20 to 30 m tall. Only remnants of this forest remain. The conservation status of Jubba forests is discussed in Section VIII, Appendix J, and Madgwick (1988). Most of this former forest land has been cleared for agriculture, although some reverts to other vegetation types if farming is abandoned (Section VI.D). In 1960 more than 10,000 ha of forest remained, but by 1987 less than 900 ha survived (Deshmukh 1987). Isolated forest trees or small clumps remain scattered throughout most other floodplain vegetation types. Species composition of the remaining forest fragments is variable. Two forest reserves at Shoonto and Barako Madow have been studied in detail by Madgwick (1988). Six TEBS ground monitoring sites were set up in other riverine forests. Table 16 lists forest tree species. This list includes only species characteristic of closed forest. SRP lists many more species found in open woodland, forest edge, and bushland communities found in the forest reserves. Of note is the longer TEBS species list obtained from more widespread forests than SRP. Ten to twelve species had not been collected previously in Somalia and one is new to science. Many newly recorded species may be restricted to the Jubba within Somalia (see Section VIII). In addition to species listed, SRP noted another 11 identified species and 16 unidentified species in the forests, which were not common on their enumerated plots.

The tallest trees (> 25 m) emerge from the canopy and include *Ficus sycomorus* and the acacias. Taller canopy species include *Afzelia quanzensis, Mimusops fruticosa, Cordia goetzii, Spirostachys venenifera, Cola* sp., and *Hyphaene* sp.. Common smaller trees and lianes are *Camptolepis ramiflora, Garcinia livingstonei, Hunteria zeylanica, Drypetes natalensis, Rinorea elliptica, Lecaniodiscus fraxinifolius, Saba comorensis,* and *Thespesia danis. Acalypha fruticosa, T. danis, and Flueggea virosa* are common in the shrub understory.

Madgwick (1988) suggests that riverine forests can be split into several soil/hydrological types with characteristic species. Typical river-edge species are *Ficus* spp., *Diospyros cornii, Thespesia danis, Hunteria zeylanica,* and *Camptolepis ramiflora.* The mid-levee is indicated by *Acacia* sp. and *Afzelia quanzensis,* while the dhesheeg edge has a dense growth of *C. ramiflora* and *Trichila emetica* saplings with scattered taller *Garcinia livingstonei, Mimusops fruticosa,* and *Lawsonia inermis* trees. Similar generalizations cannot be made readily about TEBS forest sites because of their wide geographical separation and higher level of human disturbance.

A few patches of forest occur outside of, but close to the floodplain according to the AHT (1984) vegetation maps. TEBS site 54, 20 km north of Jilib, may comprise the only remaining example. A section of Shoonto forest shown above the floodplain by the AHT maps (Appendix J) shows signs of flooding (Madgwick personal communication). The forest of site 54 is semi-deciduous and noticeably less lush than those in the floodplain. The trees are deep-rooting and may obtain groundwater (but no flooding) by runoff from higher ground or lateral penetration of riverine water-table beneath the dry surface soil. Common species found at this site includes *Newtonia erlangeri, Albizia anthelmintica, Lecaniodiscus fraxinifolius, Dobera loranthifolia,* and *Balanites aegyptica.*

Table 16. Species of woody plants (trees, shrubs, lianes) found on Somali Research Project (SRP; Madgwick 1988) and TEBS vegetation sites in riverine forests. SRP sites are in Shoonto and Barako Madow forest reserves.

FAMILY	SRP	JESS (additional species)
Anonaceae		*Monanthotaxis fornicata*
Violaceae		*Rinorea elliptica*#
Lythraceae	*Lawsonia inermis**	
Combretaceae		*Combretum illiarii* ?
Guttiferae	*Garcinia livingstonei**	
Sterculiaceae		*Cola* new species#
Malvaceae	*Thespesia danis**	
Malphigiaceae	*Acridocarpus* sp.	
Euphorbiaceae	*Antidesma venosum*	*Spirostachys venenifera*
		Acalypha fruticosa
		Drypetes natalensis#
		Flueggea virosa
Caesalpinaceae	*Afzelia quanzenzis*	
Mimosaceae	*Acacia* sp.	*Acacia elatior*#
		Acacia rovumae#
		Acacia circummarginata
		Acacia sp. af *macalusoi*#
Papilionaceae		(*Baphia* sp. ??)[1]#
Moraceae	*Ficus sycomorus**	
	F. scasselati	
Simaroubaceae	*Harrisonia abyssinica**	
Meliaceae	*Trichila emetica*	
Sapindaceae	*Camptolepis ramiflora**	
	*Lecaniodiscus fraxinifolius**	*Lepisanthes senegalensis*#
Anacardiaceae	*Sorindeia madagascarensis**	
Ebeniaceae	*Diospyros cornii**	
Sapotaceae	*Mimusops fruticosa**	
	Pachystela brevipes#	
Oleacae		*Olea* sp. af *capensis*#
Apocynaceae	*Hunteria zeylanica*	*Landolphia* sp. #
		Saba comorensis
		Pleiocarpa pycnantha ?#
Rubiaceae		*Polysphaeria multiflora*
		Pavetta transjubensis
Boraginaceae	*Cordia goetzii* *[2]	*Cordia ravae* ? [2]
Bignonaceae	*Kigelia africana*	
Palmae	*Hyphaene* sp.*	
	Phoenix sp.*	

*? = uncertain identification; * = also found on JESS sites; # = new record for Somalia*

[1] *Baphia may be mistaken for Cola new species*
[2] *Cordia ravae ? on JESS plots may be C. goetzii*

4. Species Diversity

Species diversity is usually defined as the number of species (in a given area) combined in some way with the relative importance of each species. The simplest approximation is species richness–the number of species. Diversity can be measured at the level of sample plots (local diversity) or whole landscapes (for example, the Jubba floodplain). Species diversity is of theoretical interest to ecologists and has more recently assumed importance to conservationists and some development agencies (see Section VIII).

Plant species diversity is generally less in the Jubba floodplain than in the river-dependent zone. This statement remains true whether looking at sample plots or landscape. A plot of riverine forest generally has fewer plant species than a nearby plot of dry bushland. Mean number of woody species in non-floodplain sites is 8.3; in floodplain sites, 5.6, a highly significant difference (t-test; $p < 0.002$). When diversity indices are used, taking into account relative abundance, the difference is even greater. At the plot level, differences in herbaceous species are not significantly different (mean of 6.4 species outside, 6.2 inside floodplain).

Probable reasons for lower species diversity in the floodplain include the following: First, plants must be specialized to survive periodic flooding; most species of plants in the lowland Somali flora are adapted to semi-arid conditions. Second, Jubba riverine flora is limited in geographic extent and is not close to many other similar environments. Since plant species richness is thought to be closely related to total area of a vegetation type and neighboring similar sites as sources of colonization, then non-floodplain sites are expected to have developed a richer flora.

D. Vegetation Dynamics

The natural dynamics of floodplain vegetation are connected with changes in the hydrological regime. As the river changes course, new banks and levees are formed creating new habitats for riverine forest trees. At the same time, existing forests may be swept away if blocking the new channel, or forests may slowly degrade to less dense communities if they become more distant from the river. Under present river-flow conditions, such changes take decades or centuries. For example, no significant changes in the course of the river occurred between 1960 and 1987. When the river is regulated by Baardheere Dam, it will slowly change course in response to the new hydrological regime. Significant changes will take centuries because of the low energy inherent in the regulated river (Alford 1987).

Much more rapid changes in vegetation result from current human activities. Clearance of forests in the floodplain has produced a patchwork of vegetation types described above. Removal of vegetation is not a one-way process, however. Some cleared patches are never farmed, while others are farmed and then abandoned. Abandonment usually results from flooding or changing socioeconomic conditions, rather than reflecting shifting cultivation. Abandoned land becomes revegetated. The resulting vegetation types are varied.

Grasslands usually form in areas regularly burned or heavily grazed. Most TEBS ground monitoring sites in floodplain grasslands are maintained in this manner. Fires are commonly set in jiilaal to clean fields prior to sowing crops. These fires escape into surrounding vegetation preventing establishment of most woody species. Five TEBS ground sites were burned in this way between January and April 1987 (see also Section V). Whether maintained by fire or grazing, most of these grasslands are dominated by *Sporobolus helvolus*. In some cases, a low shrub cover of one or more of *Phyllanthus somalensis*, *Terminalia brevipes*, *Indigofera schimperi*, and *Thespesia danis* develops between fires. Tall grasslands (> 2 m) occurred on two sites subjected to seasonal burning. In a dhesheeg near Kaytooy, a uniform stand of *Eriochloa meyerana* (site 21) was present while on a levee near Madhooka, *Panicum maximum* (up to 3.5 m) and *Echinochloa haploclada* were co-dominant (site 14). Fires occasionally cause a marked change in herbaceous species composition. At site 22 near Mareerey, *Sporobolus helvolus* virtually disappeared from a sward of *Sporobolus helvolus* and *Panicum infestum*, while the latter species became dominant. At a non-floodplain site nearby, *S. helvolus*, *Cymbopogon caesius*, and *Enteropogon* sp. nov (JESS 198; site 35) were replaced by grasses *Paspalidium desertorum* and *Urochloa rudis*. However, at a pair of non-floodplain sites north of Mareerey, fire did not alter the dominance of *S. helvolus*. With such a diversity of responses, it is not possible to generalize about the effects of fire on herbaceous species composition in this area. In all cases, particularly in the floodplain, rapid grass regrowth followed rain.

In the absence of fire or grazing, woody vegetation reestablishes. Site 12, on the edge of a dhesheeg north of Fanoole Barrage, was farmed until the barrage and its bunds eliminated floods in 1977. Since then a 4 m tall thicket of *Dichrostachys cinerea* has developed. Site 37, west of Baardheere is on the edge of a floodplain cultivated about 10 years earlier. Since abandonment a 4 m tall stand of *Acacia reficiens* trees has developed with an understory of *Acalypha fruticosa* shrubs. Site 38 north of Saakow is a levee that was cleared of *A. zanzibarica* woodland four years previously and planted with sesame for one season. Since abandonment, a low bush (2 to 3 m high) cover has reestablished. *A. zanzibarica* is abundant, but other species, including *Flueggea virosa*, *Spirostachys venenifera*, and *Acalypha fruticosa* are more typical of disturbed riverine forest.

In general, several vegetation types may develop following forest clearance. Where fires are frequent or grazing regular and heavy in the jiilaal, *S. helvolus* grasslands are common. With less disturbance *A. zanzibarica* woodlands are found close to the river and *A. reficiens* woodlands towards the edge of the floodplain.

An important question for conservation is whether riverine forest could regenerate on previously cleared land if left undisturbed. Observations to date are inadequate for a firm answer since the level of disturbance (fire, grazing, wood-cutting) is too high around most abandoned farm sites. Without these disturbances forest regeneration is highly probable. However, creating disturbance-free conditions is difficult, thus emphasizing the conservation status of the few remaining forest remnants (see Section VIII).

Bushlands outside the floodplain seem to have undergone a gradual thinning of woody vegetation. Between 1960 and 1983, LRDC (1985) notes an increase in open bushlands at the expense of denser types in TEBS study area (see Section V). However, these changes are slight and inconsistent from area to area (with increase in bush in some parts of the Shabeelle). Since burning is relatively infrequent and human population low, livestock are the main cause of change in the river-dependent zone under present conditions. It is probable that drought cycles affect the intensity of use, and no unidirectional trends are likely unless there are consistent trends in livestock populations or climate. In general, the river-dependent zone remains well wooded. When elephants were numerous in the area they probably played an important role in periodically opening up denser vegetation.

Shorter-term effects include periodic flooding from the river and the seasonal rainfall cycle. One major river flood occurred during JESS studies, in late May 1987. Most of the floodplain was inundated temporarily and some parts for much longer. Floodwaters covered vegetation and farmland. In the latter case, where floodwaters remained, new areas were brought into cultivation that were dry, or where flood recession could be practiced. Four JESS monitoring sites on formerly abandoned farmland were converted back to agriculture. Although the net area under cultivation in the subsequent xagaa declined due to persistent flood waters (Figure 6), the spatial pattern changed. For example, fallow land in the floodplain declined from 410 km^2 in late jiilaal to 120 km^2 in xagaa (Watson and Nimmo 1988).

Floodwaters caused remarkably little persistent change to TEBS ground monitoring sites. Some sites were visited the following August, but many could not be reached until jiilaal 1988 due to road conditions and persistent water. In some areas, dense stands of *Phyllanthus somalensis* developed shortly after the flood, but these died back during the following jiilaal. Flooding did not lead to significant establishment of forest tree seedlings as has been hypothesized for the Tana River (Hughes 1985). However, the JESS observations are short-term. It remains possible that intermittent flooding has significant effects on forest regeneration.

In the long-term, changes in river course mean that vegetation once subject to occasional flooding and a high water-table become so far removed from the river that river water has little or no influence on plants. Hydrologically, such sites are similar to those in the river-dependent zone, although the soils remain geologically recent alluvia. Two TEBS sites on old levees (sites 4 and 33) reveal that although many species presently occur in floodplain sites closer to the river, vegetation structure, standing crop, and phenology more closely resemble the river-dependent zone than typical floodplain sites in the same area. These observations are of significance when possible effects of the Baardheere Dam are considered (see Section VI.E).

Seasonal Changes

Seasonal changes in activity of plants (phenology) were studied to determine temporal patterns and differences between floodplain and river-dependent zones. A scoring system was used for woody plants at ground monitoring sites to account for the degree of leaf (buds/young, mature, senescent), flowering, and fruiting. In the herbaceous layer a point-frame method recorded the proportions of green and brown grasses, forbs, and dwarf shrubs. These methods are described in Appendix A. Assessment of phenology is important in understanding seasonal availability of human and livestock forage. Productivity of vegetation is also likely to be affected since a plant remaining green throughout the year is likely to be more productive than one that is seasonally dormant.

Seasonality of trees and bushes is marked (Figure 10). As expected, full leafing follows gu' rains. By early jiilaal, floodplain trees and bushes maintain a markedly higher level of young and mature leaves than those outside the floodplain. By late jiilaal this difference is less pronounced. In both types of environment, leaf buds and young leaves begin to appear in late jiilaal well in advance of the onset of gu'. Flowering and fruiting are more prolific in the floodplain and follow gu' or deyr rains. Total phenological activity is consistently higher in the floodplain. Differences between floodplain and river-dependent zone plants would be more marked, if evergreen forests had not been replaced with secondary growth of deciduous and semi-deciduous plants which lose their leaves in dry seasons. Variations in this pattern are expected from year to year. For example, floodplain fruiting was much less pronounced in January 1988 than in January 1987. This difference was apparent in cultivars (papaya and mango) and wild plants. It may be that the 1987 flood upset reproductive phenology of some woody plants.

In the herbaceous layer, phenological patterns clearly distinguish floodplain and river-dependent zones. Overall, herbaceous plants maintain greater cover and remain green longer in floodplain habitats than outside the floodplain (Figure 11). Cover and standing crop of floodplain grasses is often twice that of nearby non-floodplain sites. Implications of this observation are discussed further in Section VII. Grass cover is much higher in the floodplain at all times. Most floodplain dominants are perennial whereas annuals are common in the river-dependent zone. As a result grass cover withers quickly with little green material remaining by early jiilaal and little change in green or brown material between

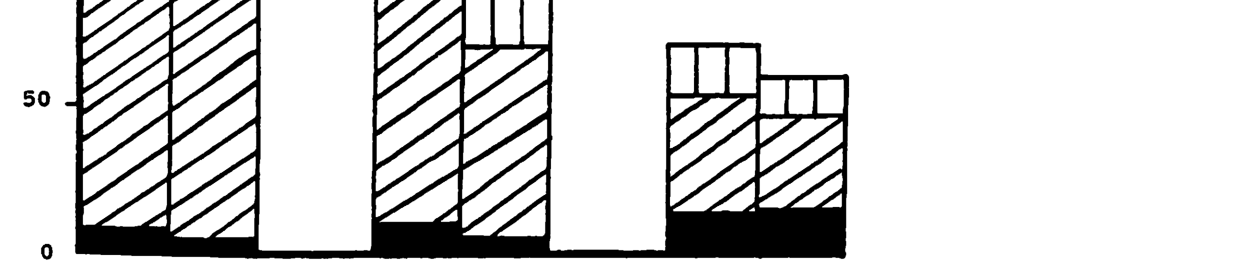


Figure 10. Comparison of phenological patterns during xagaa 1986 and jiilaal 1987 in trees and bushes of the floodplain (FP) and river-dependent zone (NFP) ground monitoring sites. Scoring system is described in Appendix

early and late jiilaal. In contrast, floodplain grass cover declines steadily through the dry season largely due to grazing. Most forbs are short-lived annuals which decline rapidly in dry seasons (Figure 11b). Higher forb cover in non-floodplain habitats is probably a reflection of lower grass cover which allows forbs greater access to light. Dwarf shrubs have greater cover in the floodplain and many persist through dry seasons as woody stems (Figure 11c).

E. Conclusions

Vegetation of the Jubba floodplain is markedly different from that of the surrounding semi-arid river-dependent zone. The difference is primarily due to greater soil water due to surface floods, lateral penetration of river water to the water table of the floodplain, and high nutrient content of river water (see Section IX). Secondary effects include the higher fertility of recent alluvial soils and

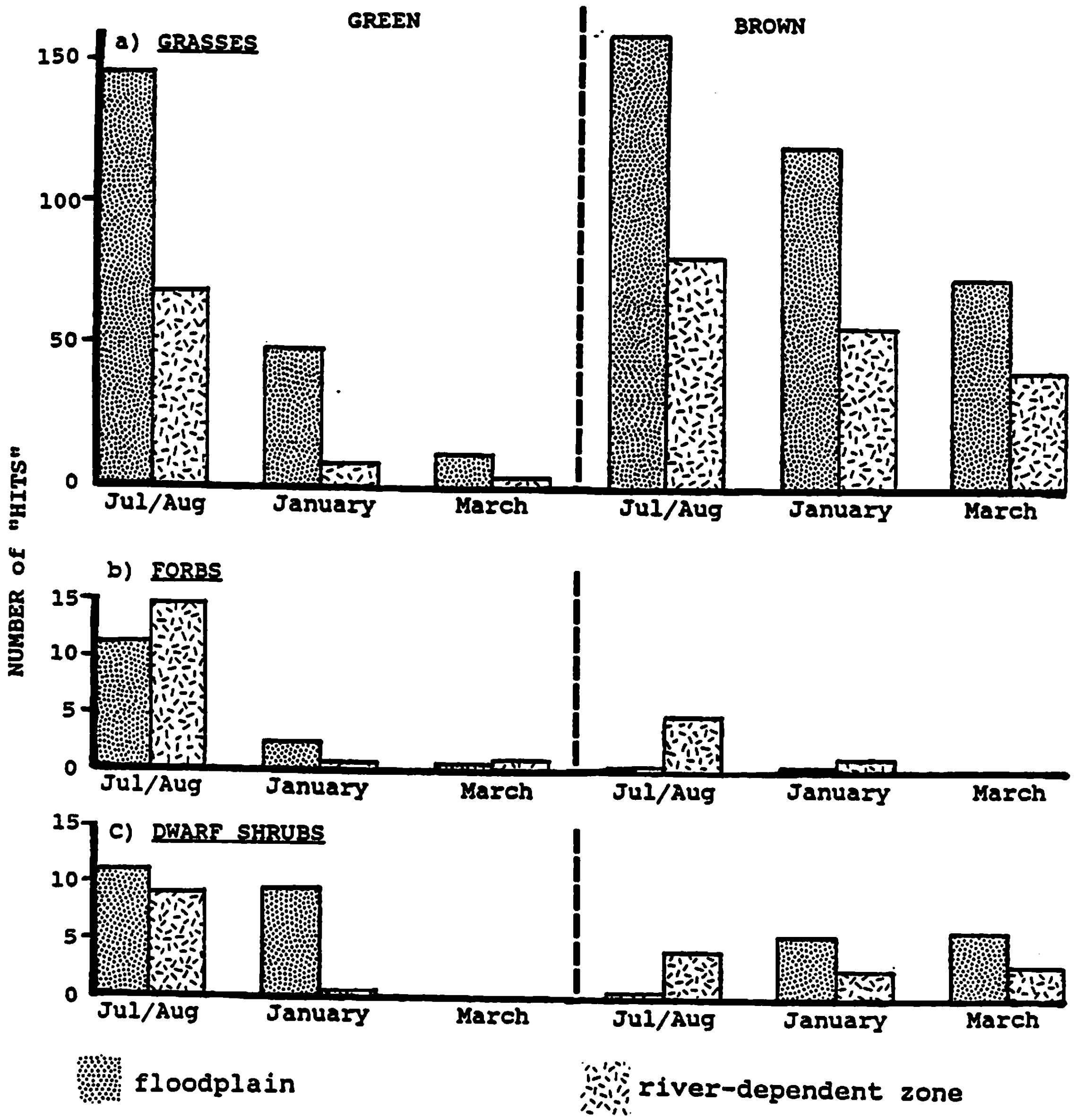


Figure 11. Comparison of herbaceous layer phenology by growth-form (grass, forb, dwarf shrub), condition (green, brown), and environment in ground monitoring sites. Note difference in scale of grasses compared with other plants. Scoring system is described in Appendix A.

microtopography, (*e.g.*, levees, dhesheegs) caused by river deposition and erosion patterns.

When human influences were small, much of the floodplain was covered by tall evergreen forest. Under rainfed, lowland equatorial conditions, such a community occurs where rainfall exceeds 1,000 mm, twice the precipitation found in some forest areas on the Jubba. The high biomass and primary production of evergreen forests is reflected in secondary communities (*e.g.*, grasslands, bushlands) resulting from forest clearance. Grassland standing crop at floodplain sites is two to 20 times that of nearby non-floodplain sites. These effects are presumably of great importance in unirrigated crop production in the floodplain (see Section IX).

Human activity has changed floodplain vegetation into a mosaic of grasslands, bushlands, woodlands, and small forest patches similar to the river-dependent zone in terms of structure. However, species composition remains very different.

Under present conditions, floodplain vegetation represents an important human resource due to its high standing crop and production, and proximity to permanent water. Fruits, many of which are eaten by people or livestock, and green forage are more abundant than in the river-dependent zone.

Construction of Baardheere Dam will change floodplain vegetation in several ways. First, agricultural development will decrease land under native vegetation. Second, a large area of floodplain vegetation behind the dam will be inundated permanently, or most of the time. Third, downstream floodplain hydrology will change.

Remaining forest remnants between Bu'aale and Fanoole Barrage probably represent the best unused agricultural land in the study area. Construction of a planned all-weather road between Jilib and Bu'aale will make this area much more accessible. As a result, the few forest remnants, which may represent the only natural plant communities along the river, are threatened. Urgent conservation measures are needed to protect remaining forests (see Section VIII).

As the reservoir fills, most floodplain vegetation and large areas of non-floodplain vegetation between the dam site and Luuq will be inundated. Loss of non-floodplain vegetation will be of little significance as similar plant communities cover vast areas outside the inundation area. Much floodplain vegetation is already degraded; losses as a human resource are discussed in Sections VII and VIII.

New vegetation communities will develop in the drawdown zone. The nature of this vegetation is impossible to predict with current information, since it will depend upon reservoir operations, soil characteristics, human activity, and species available to colonize. Most species around what will be the reservoir edge are adapted to semi-arid conditions. These plants will not survive in the drawdown zone. Rocky soils characterizing much of the drawdown area may remain almost barren unless fine alluvial sediments are deposited upon them. These soils are not necessarily infertile, however. Increased moisture availability may allow flood-tolerant woody species to grow even on coarse soils. On finer-textured soils, grasslands will probably develop on land exposed long enough by dam operating schedules. Thickets could develop in some areas where slopes, soils, and periods of exposure and inundation are suitable relative to rainfall seasons. This unpredictability emphasizes the importance of planning and monitoring if development potential of the drawdown zone is to be realized.

Downstream vegetation modification due to hydrological changes is difficult to predict without a knowledge of dam operating procedures and current floodplain hydrology. River flow releases from the dam will produce a more or less constant river level with fewer floods. Lack of knowledge of Jubba sedimentology makes it difficult to predict to what extent the river will cut down into its bed as a result of reduced sediment load. Reduced flooding and sediment deposition will lead to a gradual reduction in soil fertility which will affect plant communities in unknown ways. Predictions for the Tana River in eastern Kenya suggest a lowered floodplain water table and less lateral penetration of river water (Hughes 1984; 1985). Similar effects on the Jubba would reduce the area capable of supporting forest and resource availability from floodplain vegetation. Unirrigated agriculture would probably decline in productivity due to this reduction in groundwater.

Overall, floodplain vegetation downstream will degrade slowly to less tall and more open types due to both hydrological change and increased human activity. Hydrological effects will be most pronounced further from the river, but anthropogenic change is more likely closer to the river where irrigation is most readily practiced. Monitoring and careful planning are needed to properly manage floodplain vegetation. Outside the floodplain, vegetation change is likely to be less critical, particularly as distance from the floodplain increases, unless livestock forage and access to water is seriously reduced by developments in floodplain agriculture (see Section VII).

Recommendations relating to vegetation concern human use, conservation, and monitoring which are dealt with in subsequent sections.

VII. HUMAN USE OF VEGETATION

This section presents an assessment of current use of wild plants in TEBS study area. Three sectors are considered: use of wood (forestry), other "forest products" (ethnobotany), and livestock graze and browse (range). Information from ground studies, aerial photograph monitoring sites, aerial census, and data from other relevant studies are combined to give "best estimates" of current forest and range resources.

Although treated separately, the major topics of forestry and range are closely interrelated. Changes in forest resources may have positive or negative impacts on range resources. For example, a thinning of woody vegetation reduces forest resources and forage for browsing livestock. However, if reduction in woody cover leads to greater grass growth, grazing resources are improved. Overall reduction in floodplain vegetation, as documented in Section V, has negative impacts on forest and range resources.

A. Forestry: Wood Resources

Forestry in TEBS includes human use of wood and patterns of exploitation and management of forest products. Such wood comes from wild plants or from plantations. Plantations contribute a negligible amount quantitatively to wood production and consumption in the study area (Synnott 1988). Most wood consumed in the Jubba Valley is used for fuel or construction.

Much of the forestry discussion concerns methods used to derive quantitative estimates of wood biomass and growth rates. Detailed discussion is needed because these methods were developed specifically for TEBS. Readers with limited interest in these technical issues are referred to the tables summarizing results. Discussion of forestry as a human resource resumes in Section VII.A.3.

Assessment of forest resources requires the following information:

- volume or weight (biomass) of wood per unit area of land and its distribution relative to vegetation type;
- annual wood production in each vegetation type; and
- rate of use of wood by human populations.

1. Wood Biomass

Accurate estimation of wood biomass requires that a sample of trees and shrubs from a known area be measured, then felled, and their dry weight determined. Measurement of various dimensions of plants are then related to dry weight of wood. Such an approach is very specialized, expensive in time and labor, and is beyond the scope of JESS. However, studies elsewhere in Somalia (Bird 1988) and Kenya (Western *et al.* 1981; Epp *et al.* 1982; Herlocker unpublished) indicate that crown dimensions of trees and bushes are statistically useful predictors of wood biomass for "bush" communities in East Africa.

Various relationships between plant dimensions and dry mass of wood are examined in Appendix F. From that discussion the most appropriate relationships have been selected, and biomass for each vegetation ground monitoring site calculated. These monitoring sites are then grouped by vegetation types described in Section VI.B.3 and best estimates of biomass in each vegetation type calculated (Table 17). Also shown are the earlier JESS estimates of wood biomass of some vegetation types by Synnott (1988) which were based on data from other areas and discussions with workers in

Table 17. Best estimates of woody biomass ($t\ ha^{-1}$) of JESS structural vegetation types based on predictive equations from other studies (see Appendix F). Also given are earlier "guesstimates" for JESS by Synnott (1988).

VEGETATION TYPE	RANGE OF BEST ESTIMATES	MEDIAN ESTIMATES	SYNNOTT
forest	35-225	130	30-200
dense woodland	12- 75	45	
medium woodland		20[1]	10- 25
open woodland	3- 13	8	
sparse woodland & wooded grassland	2- 3	3	
bushland thicket	19- 33	26	6- 12
dense bushland	7- 12	10	
medium bushland	4- 7	6	3- 9
open bushland	3- 5	4	
sparse bushland & bushed grassland	1- 2	2	1- 5
mixed[2]		5[3]	

[1] no JESS ground sites, estimate interpolated.
[2] mixed refers to vegetation monitoring photographs that have a mixture of vegetation types (see Section VI)
[3] no JESS ground sites, estimate arbitrary (see Appendix F).

Somalia. Synnott's "guesstimates" are remarkably similar to the calculated values.

The most accurate work on wood biomass in East Africa was done by the British Forestry Project, Somalia (BFPS) in Bay Region. They estimated "open bushland" as supporting approximately 5 t ha^{-1} (Bird personal communication), which corresponds well with Table 17. All results presented in this section must be viewed with caution as they are extrapolated from other areas and vegetation types. It is not possible, therefore, to determine their accuracy or precision for the Jubba Valley. Nevertheless, they are the best estimates available until study area specific forest inventory is conducted. The TEBS approach is to produce reasonable, but conservative estimates of wood biomass as a precaution against overexploitation in the future.

Next, the area of land occupied by each vegetation type was used to estimate total wood biomass and biomass per unit area for each river section (Table 18). These areas were calculated from information concerning "open" areas (*i.e.*, uncultivated) in Table 10 and proportions under different vegetation types (based on a random sample of aerial photographs) in Figure 9. Enclosed, unfarmed areas were not included, since the status of their woody vegetation is unknown. Thus, there will be some underestimate of wood stocks in the restricted areas where enclosure is commonly practiced. Significant enclosure is confined mainly to the floodplain in River Section II. Ground studies indicate that enclosed land here is mainly grassland. These areas will be inundated after Baardheere Dam is closed and are only relevant for future planning purposes if wood in the reservoir area is cleared as recommended by TEBS (Section VII.C.1).

Biomass over the whole TEBS study area exceeds 30 million tonnes. However, most of this wood is in the extensive rangelands (river-dependent zone) and not in the floodplain where human population is concentrated (Table 18). Because of extensive farmlands, wood biomass per unit area is usually less in the floodplain as a whole than outside ("Total biomass" column). However, when areas under native vegetation (*i.e.*, unfarmed and unenclosed) alone are considered, biomass is generally greater in floodplain lands ("Study area" column). Note that biomass of the rainfed river-dependent zone generally increases in a southerly direction between River Sections I and V reflecting increased rainfall. Lower wood biomass in both floodplain and river-dependent zone in River Sections VI and VII/VIII probably indicates overexploitation by the denser human populations in these areas (see Synnott 1988).

These TEBS biomass estimates are substantially lower than those given in the Southern Rangeland Survey (Watson and Nimmo 1985). For example, usable wood for fuel was estimated at 14 to 18 t ha^{-1} for areas in the river-dependent zone between Buurdhuubo and Jilib in that study compared with 6 to 18 t ha^{-1} total wood biomass (equivalent to 4 to 11 t ha^{-1} of usable wood) in the present study. Reasons for this discrepancy are discussed in Appendix F.

Table 18. Summary of woody biomass estimates by river sections comparing floodplain (FP) and river-dependent zone (NFP).

RIVER SECTION		TOTAL BIOMASS ($t \times 10^6$)	STUDY AREA ($t\ ha^{-1}$)	VEGETATED AREA ($t\ ha^{-1}$)
I	FP	0.06	6.1	9.2
	NFP	1.01	4.8	4.9
II	FP	0.11	4.1	7.6
	NFP	4.82	6.0	6.0
III	FP	0.06	9.1	15.1
	NFP	6.43	10.4	12.0
IV	FP	0.08	5.7	10.1
	NFP	3.24	8.7	9.0
V	FP	0.17	11.8	17.8
	NFP	5.17	18.1	18.1
VI	FP	0.29	4.1	9.8
	NFP	9.17	13.3	13.5
VII/VIII	FP	0.13	3.8	10.8
	NFP	1.55	6.3	6.3

Distribution of biomass by vegetation types is shown in Figure 12. This figure can usefully be compared with Figure 9, where the proportion of land under each vegetation type is shown. Due to their greater biomass per unit area (Table 17), woodlands assume greater importance in Figure 12. In the floodplain, woodland and forest often contain more biomass than bushlands. However, bushlands are the major wood resource in the river-dependent zone. Of note is the significance of thickets in more southerly areas. Because of their low biomass per unit area, bushed and wooded grasslands together with sparse bushlands and sparse woodlands make negligible contribution to total biomass.

2. Production of Wood

Information on annual production of wood in East Africa is almost non-existent. Such information is

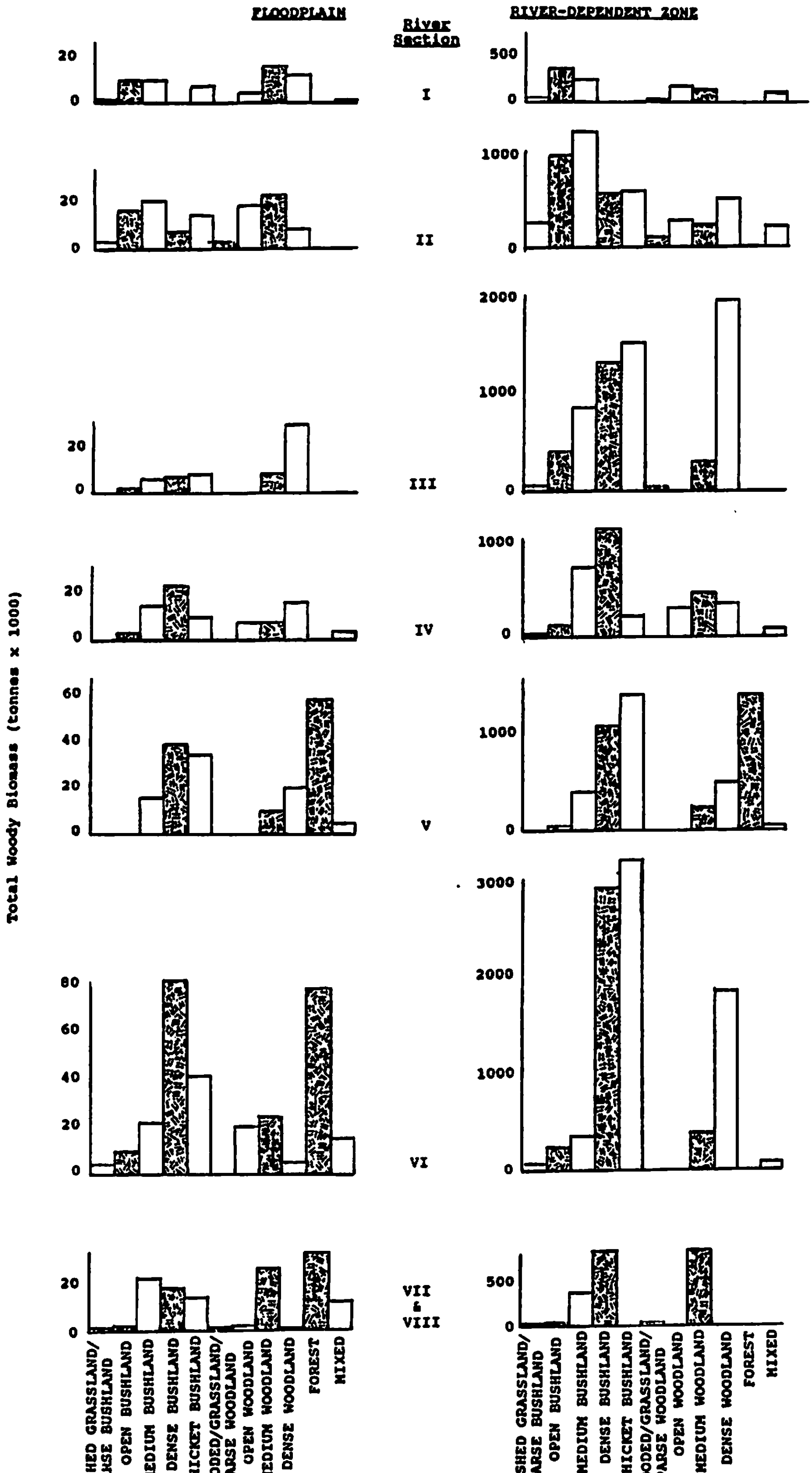


Figure 12. Distribution of total wood biomass by vegetation types in the floodplain and river-dependent zones by river sections. Note subdivisions on river-dependent ordinate are 20 times larger than those for floodplain.

essential to accurately estimate levels of sustainable offtake of wood. Limited data exist relating production of woody vegetation to its biomass. This information is reviewed in Appendix F. Table 19 lists conservative estimates of usable wood production for the TEBS vegetation types. Usable wood is defined as all branch and stem wood having a diameter greater than 2 cm. Smaller wood is little used for fuel or construction except in situations of extreme scarcity. Less conservative estimates of wood production might double the values in Table 19 and Table 20 (see Appendix F).

Table 19. Estimates of annual production of usable[1] wood by vegetation types.

VEGETATION TYPE	USABLE WOOD PRODUCTION ($t\ ha^{-1}\ year^{-1}$)
Forest	0.60
Dense woodland	0.43
Medium woodland	0.28
Thicket bushland	0.34
Open woodland/dense bushland	0.14
Medium bushland/mixed[2]	0.09
Open bushland/bushed and wooded grassland	0.05

[1] *"usable" wood is suitable for fuel; see text and Appendix F.*
[2] *mixed refers to vegetation monitoring photographs which have a mixture of vegetation types; see Section VI.*

No allowance has been made for potential higher production of floodplain vegetation (see Section VI, and specifically VI.A.3), since no predictive data exist on wood production in such environments. An indication of production potential in the floodplain is given by three JESS ground monitoring sites on which bush has regenerated following abandonment of cultivation. These sites had an average annual wood production for each unit of biomass of two to three times that estimated for purely rainfed areas (see Appendix F).

Table 20 extrapolates wood production estimates to the TEBS study area. Total production exceeds 400,000 tonnes per year. Spatial differences in production are similar to those of biomass (Table 18). Because of vegetation types, production per unit area of native vegetation is usually greater in the floodplain than in the river-dependent zone. However, because of extensive cultivation, each hectare of floodplain land overall produces less wood than an equivalent hectare of non-floodplain land. As stated above, no allowance has been made for a greater rate of production in the floodplain due to enhanced water and nutrient supply.

Table 20. Estimates of production of usable[1] wood biomass comparing floodplain (FP) and river-dependent zone (NFP) by river section.

River Section		Total Biomass ($t\ year^{-1}$)	Biomass per unit Area ($t\ km^{-2}\ year^{-1}$) All Land	Vegetated Area
I	FP	780	8.4	12.5
	NFP	15,540	7.3	7.5
II	FP	1,580	5.9	10.7
	NFP	69,684	8.6	8.8
III	FP	700	10.8	19.4
	NFP	82,050	13.2	15.3
IV	FP	1,070	7.6	13.5
	NFP	44,800	12.0	12.4
V	FP	1,810	12.3	18.5
	NFP	55,980	19.6	19.6
VI	FP	3,370	4.8	11.5
	NFP	118,460	17.1	17.4
VII/VII	FP	1,540	4.5	12.5
	NFP	22,280	9.0	9.1

[1] *"usable" wood is suitable for fuel; see text and Appendix F.*

3. Human Use of Wood

People in the Jubba Valley use wood mainly for fuel and house construction. By far the greatest demand is for fuel (Synnott 1988). Although specific estimates of fuel use in the study area have not been made, it is generally agreed that per capita consumption is approximately one tonne per year in settled Somali populations (Synnott 1988). A similar figure is also widely applicable in Kenya (Western *et al.* 1981). Traditional riverine farmers along the Tana in Kenya have an annual per capita fuelwood consumption of 1.2 t, while those in irrigation schemes consumed less than 500 kg (Hughes 1985). Reduced fuelwood use in the irrigation schemes reflects extreme scarcity of fuelwood around these more densely settled areas rather than a conscious effort to conserve supplies.

House construction uses much less wood; *munduls* (round houses) use 3 to 6 t and rectangular houses up to 10 t (TEBS data). Since houses last up to 30 years and usually contain several people, annual per capita wood consumption must be low. From studies elsewhere, Synnott (1988) suggests that less than 0.1 t $capita^{-1}\ year^{-1}$ is consumed for construction of fixed houses. Since enclosure of land by the settled population is a relatively rare phenomenon, the use of thorn bushes for fences is likely to be negligible.

Features relating to wood extraction were recorded in JESS aerial censuses (Watson and Nimmo 1988). Data are indicative of the level of activity, rather than being strictly quantitative. Wood exploitation features, including charcoal kilns, tree cutting, construction poles, and firewood stacks are far more common in the floodplain (0.74 features km^{-2}) than in the river-dependent zone (0.03 features km^{-2}).

Wood consumption by nomads is less easy to quantify, yet nomads make up 30 percent of the population in Gedo, Middle Jubba, and Lower Jubba Regions (AHT 1988). In Marsabit District, Kenya, Lusigi (1984) reports that fuelwood consumption is less than 0.1 t $capita^{-1}$ $year^{-1}$, because the sample population subsists largely on milk and does little cooking. In contrast, the same population used almost 1 t $capita^{-1}$ $year^{-1}$ of thorn bush to construct *bomas* (livestock corrals) to protect stock against predators and raiders. Jubba nomads seem to consume considerably more grain than those in Marsabit. According to SEBS, more than 40 percent of nomads in the Jubba Valley eat grain, and therefore cook daily. Thus, fuelwood consumption is likely to be higher than in Marsabit. Both the author and JESS forestry consultant, Timothy Synnott (who has worked in both areas), believe that construction of corrals is less common than in Marsabit. Pressures from predatory wildlife and livestock raiders are probably less than in northern Kenya. Density for the TEBS study area is 0.4 km^2 corrals in use and 4.1 km^2 abandoned (Watson and Nimmo 1988). Maximum density of corrals in use (3 km^{-2}) is found during jiilaal in what will be the inundation area north of Baardheere Dam and along the coastal dunes.

In the absence of more precise local data, it is assumed that annual per capita wood consumption approximates to one tonne for the whole population. Population density for Baardheere, Saakow, Bu'aale, Jilib, Jamaame, and Kismaayo Districts is 13 km^{-2} (AHT 1988). Rural, non-nomadic population averages 6 km^{-2} in these districts ranging from 3 km^{-2} in Bu'aale to 33 km^{-2} in Jamaame. However, population is distinctly concentrated near to the river. According to AHT (1988), density of settled rural people within 15 km of the river averages 44 km^{-2}. By District, 28 (Baardheere), 18 (Saakow), 19 (Bu'aale), 37 (Jilib), 48 (Jamaame), and 77 (Kismaayo) people occupy each square kilometer close to the river.

Comparing this rate of wood consumption and population density with usable wood production (Table 20), it appears that overall wood offtake is more or less matched by supply. However, riverine population density is such that demand for wood outstrips sustainable supply except in Bu'aale District (approximately equivalent to River Section V). If usable wood production is twice that listed, to give a less conservative estimate (see Appendix F), then demand for wood is about equal to sustainable supply in Baardheere and Saakow, but falls far short in Jilib, Jamaame, and Kismaayo Districts.

At present, wood supplies may appear greater than can be sustained in the future for several reasons. First, wood production in the floodplain is undoubtedly greater than in the purely rainfed river-dependent zone. However, as more floodplain is cleared for agriculture, this extra, but unquantified production will be diminished. Second, the accelerated rate of clearance for agriculture (see Section V), potentially produces much felled wood. In areas without wood shortage, much of this wood is burned *in situ*, but smaller poles and firewood are presumably collected. Third, wood resources in non-agricultural areas are being degraded. Such effects are obvious around the refugee camps in Gedo and the densely settled areas south of Jilib. It is possible that similar degradation is occurring, or is about to occur, in other areas. The overall picture of a healthy woody vegetation resource (Synnott 1988; AHT 1988) may be correct now, but degradation may be imminent under present conditions or with accelerated development.

Refugee camps present an acute forestry problem. Camps in Gedo house some 100,000 people (Watson 1988, personal communication), compared with a regional non-refugee population of approximately 250,000 (Watson and Nimmo 1985). Refugee camps are sited close together in two clusters (around Luuq and Buurdhubo) leading to exceptionally high local population densities for a semi-arid area. As a result, land around refugee camps is completely denuded of woody vegetation. As long as these populations remain at high density, it is impossible to support their fuelwood needs by local wood collection.

Most camps will be wholly or partly flooded by Baardheere Dam. Most refugees will, therefore, be moved before the dam is closed. If new camps are established their fuel needs should be supplied by the authorities in the same way as food and water.

Use of wood in construction of typical houses.

Collecting vernacular plant names in devastated vegetation around Horseed refugee camp.

Wood should be collected from more distant rangelands away from population centers, transported to the camps, and distributed to the refugees. If refugees are to be resettled among the general population, their wood needs should be an important determinant of resettlement sites and resultant population density should be taken into account.

4. Forestry Activities in the Jubba Valley

Plantations and other activities of the forestry department of the National Range Agency (NRA) have been reviewed by Synnott (1988) and AHT (1988). The latter study also outlines some activities due to start in the near future. These findings are briefly summarized in this section.

The Forestry Department of the NRA (Ministry of Livestock, Forestry and Range) has a forest officer and a nursery in each district. Facilities and level of activity vary greatly between districts. The best nurseries are in Luuq (as part of Gedo Community Forest Project), Bu'aale, and Jamaame. Most NRA nurseries limit activities to supplying trees to local people with emphasis on the annual National Tree Planting Day. With the exception of Luuq, extension services are minimal.

Forest officers are responsible for enforcing forest law. The most important law for protection of forest resources is that which restricts fuelwood collection to dead wood. While such a law cannot be enforced rigorously among subsistence wood collectors, people are aware of it and modify their activities accordingly (Synnott 1988). District forest officers are also responsible for protection of any forest reserves in their area.

Some private voluntary organizations (PVOs) also have nurseries and give or sell trees for local planting. World Concern in Jilib has experimented successfully with planting a wide variety of local and exotic species. An indication of World Concern's success is that they are able to sell seedlings while most other nurseries give them away. Church World Services and the Japanese Volunteer Service have nurseries near Luuq. Swedish Church Relief, which is involved in primary health care in Middle Jubba, also distributes seedlings.

In summary, tree planting is an established activity in some parts of the Jubba Valley. With improved facilities such plantings could become much more widespread.

The Forestry Sector Support and Training project, administered by the Food and Agriculture Organization of the United Nations (FAO) was due to begin in 1988. This project hopes to strengthen national forestry and wildlife management capabilities. Of particular interest is the regional component which will be established in Lower and Middle Jubba. Specific objectives relating to these regions are:

- Provision of forestry and wildlife development teams in Middle and Lower Jubba Regions, to provide technical assistance to local groups wishing to become involved in community village forestry, agroforestry activities, and wildlife resource management.
- Assessment of community needs with respect to forestry and wildlife in Middle and Lower Jubba Regions and an examination of the associated constraints in order to develop the regional forestry sector.
- Development of policies and related legislation designed to provide for the optimum management of forest and wildlife resources....formulation of model regional management plans for the forest and wildlife resources of the Middle and Lower Jubba Regions. (UNDP 1988)

This project should lead to a greatly improved forestry sector in Middle and Lower Jubba. The thrust for enhancing supplies of forest products is firmly on tree planting. More emphasis on management of wild vegetation would be welcome. Nevertheless, this project represents a potentially important step forward in environmental management of the study area.

B. Other Forest Resources and Ethnobotany

In addition to wood, plant communities supply many other needs of local people. Although such uses may be quantitatively small, they are often qualitatively important. Many of these items can be replaced by manufactured goods. However, supply of such goods in Somalia is often limited and the ability of most rural communities to buy such items severely restricted. Loss of some of these forest products, notably medicinal plants, could be seriously detrimental to local people who lack access to alternative health care. Reduction in wild fruit consumption due to reduction in forest cover may also adversely affect dietary balance.

During visits to ground monitoring sites, TEBS interviewed local people about their use of wild plants. A list of vernacular names of plants has also been collected (Appendices E and I). JESS data on ethnobotany are neither comprehensive nor systematic, since they were collected incidentally at monitoring sites when informants were available. More detailed information on materials used for house construction in Jilib district, use of forest plants in Bu'aale District, and medicinal plants in Lower Jubba is given by Madany (1988), Maunder (1988), and SOMAC/SAREC (1983), respectively.

In summary, TEBS recorded 196 uses of wild plants: 32 as human food, 55 as livestock fodder, 40 as building material, 33 as utensils, 24 as medicines, 12 miscellaneous. Two hundred and sixty-six vernacular names were noted: 191 species had a single local name, 53 had two names, 17 had three names, 5 had four names. All this information is recorded in JESS data repositories (see Section II).

Section VII.A treats all wood as equivalent, independent of species. In reality, certain species are favored for different uses. Virtually all species can be used for firewood, although some species are preferred. Where wood is scarce, land close to settlements is stripped of all wood, as around refugee camps in Gedo. In better stocked areas, subsistence and commercial wood collectors pick denser species, particularly of *Acacia* and *Terminalia*.

Charcoal production and consumption are low in the Jubba Valley. The favored species, *Acacia bussei*, is relatively uncommon in the area (Table 15). Most commercial supplies of charcoal in southern Somalia come from Bay Region where the species is common. Secondary species used by a charcoal producer near Bu'aale include *Acacia reficiens*, *A. tortilis*, *A. nilotica*, and *Terminalia* spp. This producer, who markets about 40 sacks per month from an area in excess of 50 km^2 (equivalent to about 0.11 km^{-2}), reports that no one else is involved in commercial charcoal production between Saakow and Jilib. He claims that he collects only dead wood, and that the resource has not diminished in his 11 years of operation (TEBS interview, 30 August 1987).

Species used in construction depend upon the type of structure. Large forest trees such as *Mimusops fruticosa* and *Acacia elatior* are used for canoes. *Ficus sycomorus* is favored for sawtimber for the construction of doors and some furniture. For house construction major support poles are *Terminalia* spp. Small wood infill comprises most of the walls. Many species are used including *Cordia sinensis*, *Flueggea virosa*, *Thespesia danis*, *Phyllanthus somalensis*, *Combretum hereroense*, *Terminalia brevipes*, *Lawsonia inermis*, and *Adenopodia rotundifolia*. More detailed information concerning house construction in Jilib District is given by Madany (1988). He lists 20 species and gives more specific uses. In areas where wood is abundant, such as between Bu'aale and Fanoole Barrage, larger sticks (2 to 5 cm diameter) are used in walls. In areas where wood is less easily obtained, smaller poles are used. In villages close to Baardheere and in the refugee camps in Gedo, average stick size is little more than 1 cm diameter. Maunder (1988) lists 15 species used for large timber, 22 species used in carpentry, 10 species with edible fruits, eight species producing usable fibers, and nine medicinal species from forests in Bu'aale District.

Many species used in building come from the floodplain. Their supply will diminish as more land is farmed. Residents of Jilib District, where most riverine vegetation has been depleted, now travel 15 to 20 km to obtain polewood (Madany 1988). Sawtimber has become scarce in much of the study area following removal of riverine forest (Synnott 1988).

Some wild plant foods undoubtedly comprise useful dietary supplements (see also Craven, Merryman, and Merryman 1989). Twenty species of wild fruits are commonly eaten. A few, such as *Grewia villosa* and *Cordia sinensis*, are collected and sold in markets. Several forbs are used in making sauces, particularly in dry seasons when other foods may be scarce. Other foods incidentally foraged include nectar from *Anisotes trisulcus* and gums from several *Acacia* species and *Dichrostachys cinerea*. Nomads collect gum on a commercial scale (Janzen 1988).

Two important drought foods are grain from wild *Sorghum arudinaceum* and tubers of the water lily *Nymphaea lotus*. Wild sorghum is restricted to the floodplain in TEBS study area and water lilies to standing or slow-flowing water. Distribution of both species will be affected by closure of Baardheere Dam. Increased cultivation will decrease wild grasses. Downstream abundance of water lilies may decrease because of reduced flooding of dhesheegs, but Baardheere Reservoir will provide extensive new habitat. It is hoped that agricultural development made possible by the dam will reduce needs for these drought survival foods.

Among TEBS records of medicinal plant species, seven were used for wounds including snake and crocodile bites, six for gastric disorders, six for headaches and fevers, four for veterinary purposes, and two for skin problems. More specifically, crushed bark extract of an unidentified *Commiphora* species is used to treat cholera and an extract of *Melhania ovata* to treat hepatitis. SOMAC/SAREC (1983) collected 52 species of medicinal plants between Jilib and Kismaayo. Their report details symptoms, preparation of medicine, and dosage.

Utensils made from wild plants include tooth "brushes," furniture, canoes, mats, sticks and tool hafts, beehives, containers, pestles and mortars, dye, rope, pillow stuffing, and koranic boards. Some plants are used for poisons and others in magic. Trees are also important for shade in villages, fields, and rangelands.

C. Conclusions and Recommendations for the Forestry Sector

The analysis of forest resources presented in this section is heavily dependent on information collected in other parts of East Africa. Much of this data is of questionable accuracy, particularly when extrapolated to areas other than that in which it was collected (see Appendix F). Biomass estimates may be moderately robust, but reliable information on growth rates is minimal. Yet it is growth rates that determine the level of optimal offtake. Information on the presumed higher growth rates of trees and shrubs in the Jubba floodplain would be especially valuable for planning forestry activities in the Jubba Valley.

Recommendation: *Better information on forest inventory and tree and shrub growth rates is urgently needed for optimal use of vegetation.*

These research needs are not peculiar to the study area, but are common to vast areas of Africa. Continued degradation of bush cover in many areas serves to emphasize the necessity of improved information on forest resources.

As population in the study area increases, overall demand for wood will increase unless substitutes are introduced. Overall wood production in the three administrative regions is currently adequate to support the present population according to the TEBS analysis. However, human population is not evenly spread, but concentrated close to the Jubba River. As a result, wood removal is greater than production in some areas and likely to become so soon in others as population increases, unless wood collection is more evenly spread than at present.

Fuelwood use is, by far, the greatest consumer of wood. However, wood requirements for construction are important as are many other forest products used for human food, livestock fodder, medicines, utensils, and myriad other things. Many of these minor forest products can be replaced by manufactured items. However, the financial ability of rural people in the Jubba Valley to make such purchases is small.

It is clear that widespread wood shortage is likely to occur as development in the Jubba Valley proceeds unless action is taken soon. Either supplies of wood need to be increased in a sustainable manner, or per capita demand for wood should be decreased.

Increasing supply presents two options which can be applied together: planting trees and management of existing forestry resources.

1. Planting Trees

This remedy seems obvious, but as Bowen (1988) aptly states:

> There is a marked reluctance . . . to accept the reality that rainfed (and almost certainly irrigated) block plantations will never be capable of meeting more than a small fraction of the country's need for fuelwood . . .

Based on biomass growth rates of native species used in this report, each person would require 2 to 10 ha to meet the estimated annual demand. Faster growing species and irrigation would obviously reduce the required plantation size, but not sufficiently to make plantations a sensible substitute for wood collection from rangelands. Plantations, particularly in the context of areas planted and maintained by smallholders, can make a valuable contribution to environmental conservation. Such plantings are often multi-purpose providing erosion control, shade, wind breaks, fodder, edible fruit, and some domestic wood needs. As such, they should be encouraged along the lines of models provided by the Gedo Community Forest Project (see Bowen 1988 for a recent appraisal).

In its three years of operation, this project has established six nurseries, 70 ha of unirrigated and 20 ha of irrigated plantation, 160 km of on-farm windbreaks, species trials; planted over 200,000 amenity trees; protected 100 ha of degraded land for rehabilitation; and trained nine NRA staff, 22 farmers, and 17 villagers. In this low rainfall area rainfed plantations seem to be of limited value, but irrigated cooperative block plantations can be successful sources of income through sales of poles and fodder. A demand for on-farm trees has been created with windbreaks being particularly popular. Alley cropping also occurs to some extent. The essential components of provision of trees, demonstration of their value, and extension services were greatly enhanced by well-trained and motivated staff (Bowen 1988).

The FAO Forestry Sector Support and Training Project (UNDP 1988) will provide a suitable framework in Middle and Lower Jubba Regions to develop new institutional and extension networks for better management of forest resources. This project should also be the focus of forestry research in the study area. Tree planting is covered well by the project, but too little emphasis is placed on management of local vegetation. In Gedo, continuity of the Community Forest Project should be encouraged in Luuq. The planned Baardheere Experimental Farm (MNPJVD) may provide a suitable site in southern Gedo.

2. Management of Existing Forestry Resources

Wild plants can supply the needs of an expanding population if wood collection is spread over a sufficiently large area. Forestry legislation, by specifying that only dead wood can be collected, helps to spread the load. Such legislation cannot be applied rigorously, nor should it be, except in plantations, but it is a rational basis for maintaining forest resources. People living at subsistence level will always have to collect wood within a few kilometers of their homes. However, people in the cash economy (in urban areas, and cash farmers) may increasingly be prepared to buy fuelwood. In such a situation, commercial fuelwood collection should be regulated in such a way that wood is brought from areas further from population centers (*i.e.*, from the river-dependent zone and further afield). Floodplain areas not being farmed may have significantly greater tree growth rates than purely rainfed areas. Such a possibility should be investigated with a view to exploiting such resources in a sustainable manner.

Experience elsewhere suggests that native bushlands can produce wood more effectively in semi-arid areas than much promoted exotic plantations. In Senegal, for example, local *Acacia seyal* bush produced up to 4 m^3 ha^{-1} $year^{-1}$ of wood (eight times the expected rate) compared to 3 m^3 ha^{-1} $year^{-1}$ by introduced *Eucalyptus camaldulensis*. Initial project assumptions were that this exotic would produce at 20 times the rate of *A. seyal* (Gibson and Muller 1985). The *Acacia* bushlands were managed such that 500 ha blocks were clear-cut for charcoal on a 20-year rotation. Regeneration is by growth of new shoots from cut stumps. Similar management practices should be investigated in Somalia.

Recommendation: *NRA forestry activities in the study area should be strengthened to increase tree planting and more effectively regulate use of vegetation for fuelwood.*

Recommendation: *Research into management techniques for semi-arid bushlands is needed to prevent unplanned resource degradation.*

Reducing wood demand, as an alternative to increasing supply, means either increasing the efficiency with which fuelwood is used, or providing alternative energy sources. Such approaches will require subsidy, initially at least, if people living at subsistence or low income are to be influenced. Efficiency of energy consumption can be increased by using fuel-efficient stoves. At present, most cooking in rural areas of the Jubba Valley is done on open fires. Simple stove prototypes made from local materials are claimed to reduce wood consumption by 20 to 40 percent (Bowen 1988). Dissemination of such stoves needs effective demonstration and very low purchase price or simple construction from local materials. The efficiency of charcoal production can be increased by improving kiln construction. It seems that kiln efficiency has decreased recently in Bay Region, further increasing pressure on fuelwood resources in that area (Bird 1988).

If affluence and communications improve, new fuels may replace wood to some extent. Kerosene is one short-term possibility, particularly in urban areas. In the longer-term, electricity from Baardheere Dam may play a significant role. However, such substitutions will not be rapid. Management of forest resources to ensure sustained production must remain the highest priority in rural energy policy.

Recommendation: *MNPJVD should consider an overall energy conservation and development project for the Jubba Valley.*

Such a project would need components of research, development, and demonstration of appropriate renewable energy or energy saving techniques. The essential first step is an energy needs assessment so that time is not wasted on inappropriate technologies or nonexistent needs. Since women perform virtually all fuelwood collection and cooking, a successful project of this sort should focus on women.

Closure of Baardheere Dam and related developments will have a substantial impact on forestry. Several factors will combine to increase pressure on forest resources downstream of the dam. Population density around the reservoir will probably be less than that currently inhabiting the floodplain to be inundated. Reduced population density will result from resettlement of reservoir area residents and resettlement or repatriation of refugees. It is unlikely that new populations will be attracted to most of the reservoir perimeter. Rainfall is too low and most soils unsuitable for agriculture and most of the fertile floodplain will be lost (see Section IX). Fishing as a common activity is unlikely to develop since the market for freshwater fish is minimal in Somalia. Fewer livestock will be able to rely on riverine forage than previously (Section VII.E).

Two population groups that will increase local density immediately are the people resettled from the reservoir area, currently estimated at 12,000 to 15,000 individuals (Craven, Merryman, and Merryman 1989) and construction crews with their associates at the dam site and around Baardheere town. In terms of forest resources, the best place to resettle the reservoir area population is the area between Bu'aale and Fanoole Barrage (TEBS River Section V). This is the only riverine area where conservative estimates of wood production suggest that supply exceeds demand. It is also the river section including priority areas for biological conservation. A dispersed settlement pattern is best for sustained wood exploitation.

Land clearance for agriculture should be carried out in such a way that wood is not wasted. New settlers will have a high demand for building wood which could be met by cleared timber. According to data presented in this section, even if as little as 25 percent of wood biomass is suitable for construction, one munduul could be built for every 2 ha of floodplain cleared. Much of the remaining wood is suitable for other purposes, including fuel. However, an additional 15,000 people would nearly double the riverine population in Bu'aale District (currently 19,000; AHT 1988) and press hard on forest resources. Saakow District has the next lowest riverine density, but is also low on wood stocks (Table 18; approximately River Section IV). The issue of resettlement serves to highlight the problems of increasing population density in regions of restricted wood supply.

Recommendation: *Where reservoir area people are resettled, land clearance procedures should include using as much of the cleared wood for construction and fuel as feasible.*

Recommendation: *To meet continuing fuel and construction needs, resettled people should be established at low population density in areas where their forestry needs can be met locally.*

Refugee camps in Gedo will be flooded entirely in the Buurdhuubo area and partially around Luuq when Baardheere Dam is closed. Some refugees are currently being repatriated; others may be resettled among the Jubba Valley populace. For this latter group the same guidelines for resettlement contained in the last two recommendations should be followed. It is also possible that new camps will be established. If vegetation degradation similar to that around the existing camps is to be avoided, a different approach to supply of building materials and fuelwood is required. Refugee support organizations should treat wood supply in a similar manner to other basic needs such as food, water, and health care.

Recommendation: *If refugees in Gedo are to be rehoused in new camps, fuel and construction wood should be supplied to the occupants, rather than expecting refugees to collect inadequate wood supplies themselves from the area around the camps.*

Wood should be collected widely from the river-dependent zone so that no one area is degraded and trucked to the camps for distribution.

Up to 4,000 people are expected to move into the Baardheere area temporarily as dam construction proceeds (Tillman 1987). Unless other arrangements are made, their requirements for wood will probably be similar to those for local residents. Such a population might be present for four to five years with a consequent extra fuel demand of 16,000 to 20,000 t of wood. The area to be inundated contains perhaps 50,000 t of usable fuelwood. Thus, clearance of this area could supply fuel needs for construction camps. However, such clearance is unlikely to be economical compared with prices and quality of locally harvested wood. Clearance of wood from the reservoir area and its local use should, therefore, be incorporated into plans for dam construction. It may be necessary to subsidize clearance.

Cutting of wood from the inundation area is not a simple procedure. Areas above the high water level should not be cleared; otherwise erosion of exposed soil may cause siltation in the reservoir. Cut wood should not be left on the ground even if it has no economic value. Any loose material will float down to the dam and may clog the turbines. These factors, and the need to supply construction workers and their associates with fuel, dictate that wood removal should begin soon after dam contracts have been negotiated, and that clearance be properly supervised.

Recommendation: *The area to be inundated by Baardheere Dam should be cleared of woody vegetation and the wood used to supply fuel needs of construction workers and their associates.*

It is unlikely that most wood will be of sufficient quality to make careful extraction for use other than fuel worthwhile. Some of the floodplain woodlands will, however, have timber suitable for construction. The fuelwood and selected construction wood could easily be floated down to the dam site or Baardheere town for storage and subsequent use. Since the wood will be used over several years, measures to protect it from decay may be advantageous. Fuelwood could be converted to charcoal for better storage. Other types of wood could be treated with waste oil from vehicles and irrigation pumps. The latter are especially common in the Baardheere area.

The present land law encourages forest destruction. Registration of agricultural land requires that "improvements" be made within a year (Besteman and Roth 1988; Craven, Merryman, and Merryman 1989). In this context, improvement means clearing of vegetation as a prelude to cultivation. In practice, registrants often clear their whole plot, but cultivate only small sections. Such practices call for amendment and proper administration of land law if forest resources are to be wisely used.

Recommendation: *Land law should be amended so that clearance without agricultural development is not regarded as land improvement. Unplanned commercial exploitation of forest resources in Middle Jubba should be prohibited.*

An all-weather road is planned from Jilib to Baardheere. The initial construction, from Jilib to Bu'aale is planned for 1989. This road will make the substantial vegetation resources between Fanoole Barrage and Bu'aale town accessible to agricultural development and extraction of forest resources. Such developments should be strongly discouraged except within the planning framework for Jubba Valley Development. Wood resources in this area should be used sustainably for local populations and their future development. This area also contains forest reserves which are a high priority for conservation (Section VIII). Construction of this road make protection measures for these reserves even more urgent. It will be necessary to increase the number of locally recruited NRA forest guards. This action is compatible with recommendations for protection of forest reserves given in Section VIII.

D. Range Resources and Their Use

The pastoral sector is the backbone of Somalia's economy both internally and with respect to foreign earnings. Sustainable use of range resources is, therefore, a vital component of Jubba Valley development.

Recent surveys suggest that range resources are not overused in southern Somalia, although degradation is apparent in restricted areas (Watson and Nimmo 1985; LRDC 1985). This conclusion contrasts with earlier estimates that much of the area has an overabundance of livestock and a degraded range resource (FAO/Lockwood 1967 and FAO 1981; cited by Watson and Nimmo 1985).

For the greater JESS study area, Gedo, Middle Jubba, and Lower Jubba Regions, Watson and Nimmo's (1985) conclusions seem appropriate. They agree with similar studies in northern Kenya. These surveys recognize that the Jubba and Shabeelle floodplains attract large concentrations of livestock in dry seasons. JESS terrestrial ecology studies and TEBS study area were designed to elucidate range resources and their use in the Jubba floodplain and the area near the floodplain (*i.e.*, river-dependent zone). They do not attempt to cover the three Jubba regions because of recent comprehensive assessments by Watson and Nimmo (1985).

Results are summarized in Figure 13, which compares forage yield (total amount of forage per hectare) with food requirement of livestock in each river section. Derivation of these estimates is described in subsequent sections. In practice perhaps half of total forage yield is available to large herbivores.

The river-dependent zone approximates the pattern expected in extensive East African rangelands (Deshmukh 1986a). Forage increases with rainfall between River Sections I and VI. On average, less than 30 percent of forage is consumed by large herbivores. Camels are more significant consumers in drier areas, and cattle in wetter.

Floodplain forage/livestock relationships are quite distinct. Average consumption is around 50 percent of forage according to Figure 13. If it assumed that only 50 percent of forage can be consumed sustainably (as suggested above and elaborated in Appendix G), then it seems that the floodplain is fully utilized. Because much land is cultivated, forage yield of wild plants shows no trend in relation to rainfall. In some river sections, it is likely that range resources are inadequate and agricultural by-products support the livestock population for a crucial few weeks in jiilaal. Another feature of note is the substantial proportion of forage consumed by hippopotamuses in some river sections. Other species of wildlife have a negligible effect on range resources.

Relationships in Figure 13 assume a year of average rainfall. In years of low rainfall, production of herbaceous forage (graze) is sharply reduced (see Figure 14), yet livestock demand remains the same, at least temporarily. In a prolonged drought more livestock are slaughtered, or die from natural causes, but livestock populations fluctuate less than does production of forage. Floodplain resources, including crop residues, are even more vital in such years. Fortunately, floodplain graze seems more resilient to "overgrazing" than that in the river-dependent zone which may have been degraded by long-term overuse (TEBS ground monitoring site data).

1. Range Resource Assessment

Data from ground monitoring sites, sample large-scale aerial photography, and aerial census are combined with studies from elsewhere to produce "best estimates" of forage availability and livestock offtake. Appendix G should be consulted to understand limitations of these methods.

Forage is divided into "graze" (herbaceous layer; grasses, forbs, and dwarf shrubs) and "browse" (leaves, buds, fruit, and young twigs of bushes and trees). Herbaceous forage was assessed directly at ground monitoring sites by harvesting (Appendix A). Forage yield is defined as dry weight per unit area of standing crop of graze or browse available at the end of a growing season and before a noticeable amount has been consumed (Deshmukh in press). This quantity is regarded as a maximum estimate of forage available to large herbivores. In practice, much less is usually available due to consumption by other organisms, inaccessibility, trampling, fire, and other factors (see Section VII.D.4).

Forage yield of herbaceous vegetation in semi-arid areas is usually closely correlated with rainfall. Figure 14 illustrates this generalization by comparing a relationship for East and southern African rangelands with the Jubba Valley. Of particular note is much higher forage yield in the floodplain compared with the river-dependent zone. Floodplain sites produce more forage than the general prediction, attributable to high fertility caused by groundwater and nutrients from the river. Groundwater is implicated because there was no overbank flood in the season when most data were collected (further discussion in Section IX).

Non-floodplain sites, particularly in drier northern areas, produce less forage than the general prediction (Figure 14). This finding may indicate that herbaceous vegetation in the river-dependent zone is degraded. Supporting evidence is as follows. First, bare ground is evident at many ground sites after gu' rains and before the area is grazed. In the north, many sites had negligible herbage (the proportion of such sites is factored into Figure 13, but not Figure 14; see Appendix G). Second, herbaceous cover is independent of woody canopy cover. In more productive situations, herbaceous cover decreases as woody cover increases due to competition for soil water (*e.g.*, Wijngaarden 1985). Third, herbaceous forage is abundant in some areas (such as thickets) inaccessible to livestock while surrounding land has poor grass cover.

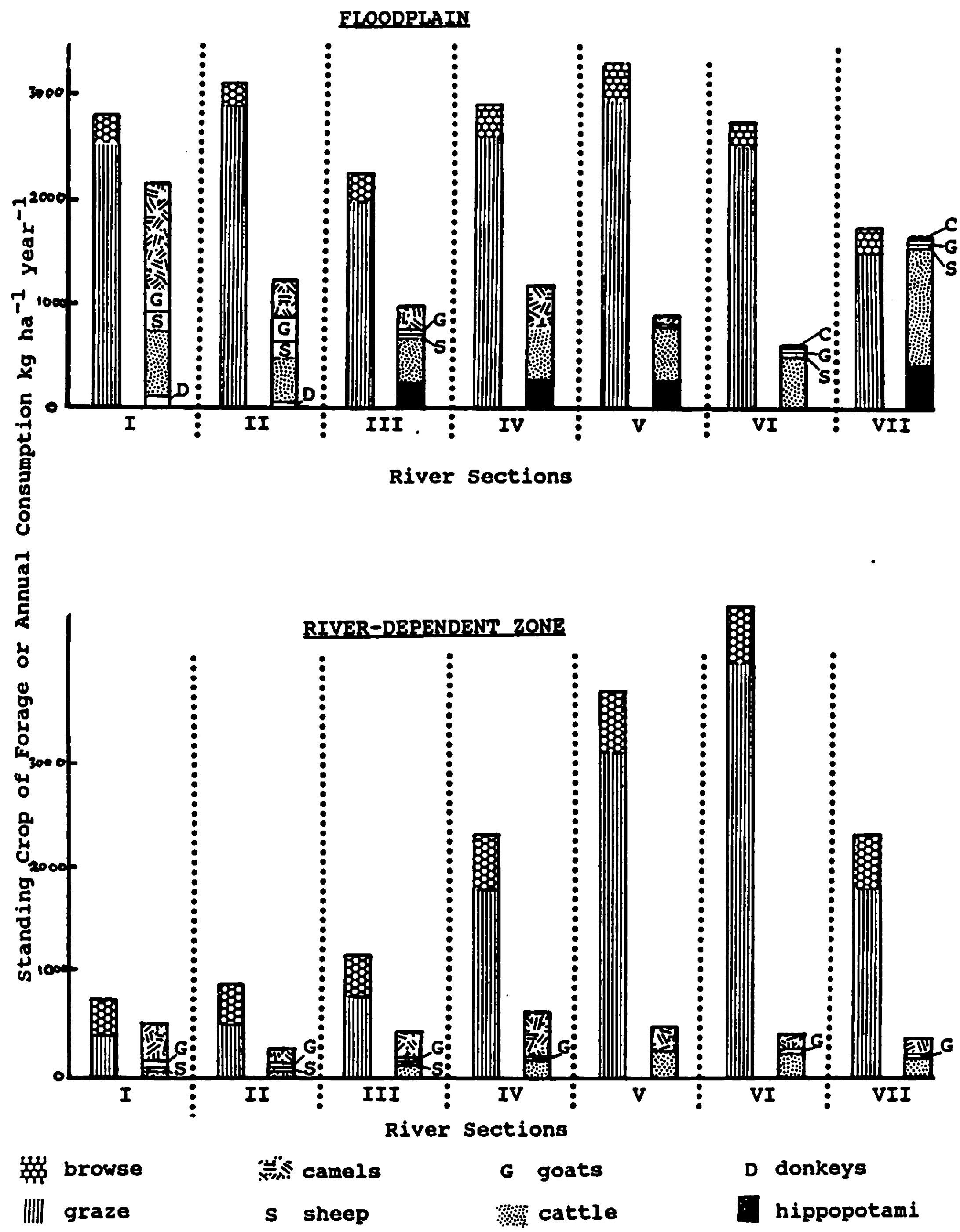


Figure 13. Estimates of total forage yield and its consumption by large herbivores in each river section in the floodplain and river-dependent zone.

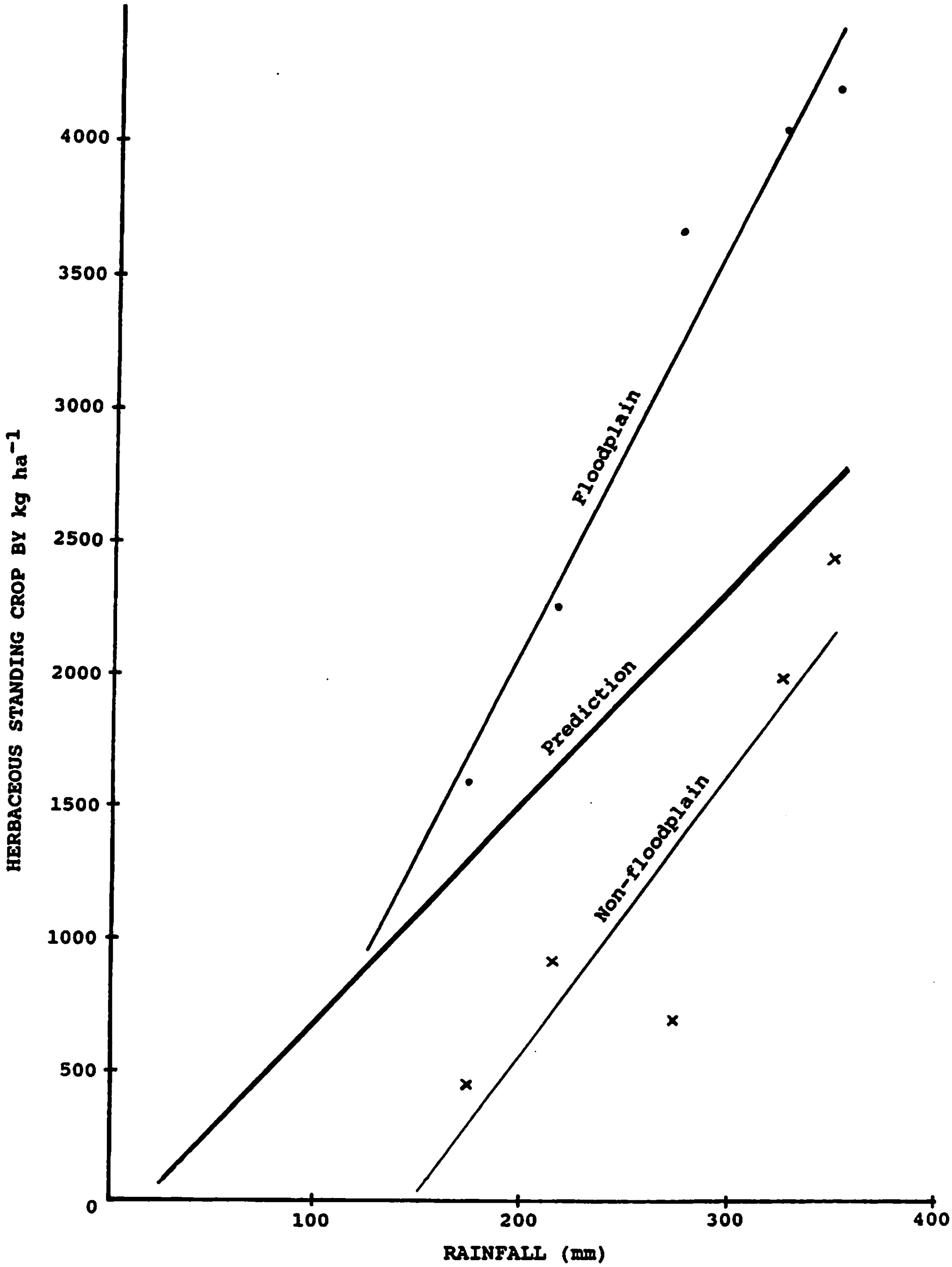


Figure 14. Peak herbaceous standing crop (forage yield) related to rainfall in the Jubba floodplain and river-dependent zone and a general relationship for eastern and southern Africa (see Appendix G).

It is likely that the river-dependent zone, at least in more northern stretches, has been overgrazed in the past, leading to a current situation of low productivity. Proximity to the river, with its seasonally large concentrations of livestock, may be the cause of degradation in these less resilient areas. Most of these TEBS ground sites are close to the floodplain and may not represent the whole river-dependent zone. However, aerial censuses show a fairly uniform livestock biomass throughout the river-dependent zone, indicating that grazing pressure is probably uniform too (Watson and Nimmo 1988).

Forage yield of browse is estimated from a relationship devised by Ecosystems (1985). Data come from Marsabit District in northern Kenya, a semi-arid area with vegetation similar to non-floodplain areas of southern Somalia. The regression model combines rainfall and percentage woody canopy cover to predict browse yield (see Appendix G). Direct effect of amount of rainfall is much less important in this model than that for graze yield. However, canopy cover in uncleared areas is also related to rainfall (*e.g.*, Figure 9) reinforcing the overall importance of rainfall in semi-arid areas. No data are available on the likely greater production of browse by individual plants in floodplain environments. A conservative assumption of no extra floodplain production has been adopted. As with forest production, it is better to underestimate rather than overestimate resources for planning purposes.

Table 21. Total forage yield from browse (foliage) in JESS vegetation types.

Vegetation type	Forage yield (kg ha^{-1} year^{-1})
Forest[1]	990
Dense woodland[1]	840
Medium woodland	560
Open woodland	320
Sparse woodland/wooded grassland	160
Thicket bushland	920
Dense bushland	720
Medium bushland	530
Open bushland	330
Sparse bushland/bushed grassland	120
Mixed	780

[1] *Browse from these categories for reasons of "quality", tsetse fly infestation, and height are regarded unavailable to livestock (see Appendix G).*

Estimates of forage yield for TEBS study area (Figure 13) take into account rainfall in each river section (Section III.A.2), area under each vegetation type, and land use in a similar way to the forestry estimates (see Appendix G). Estimates of browse for each vegetation type are given in Table 21 and are discussed further in Appendix G.

2. Livestock Populations and Consumption of Forage

Estimates of livestock populations and biomass are based on three aerial censuses conducted for JESS by RMR (Watson and Nimmo 1988). Censuses were conducted in mid-jiilaal (January/February), late jiilaal (March/April), and mid-xagaa (July/August) 1987. The first census covered only the floodplain, but the others included the entire TEBS study area. The xagaa census is regarded as "wet season" as it reflects livestock distribution shortly after gu' rains. Relatively little livestock concentration in the floodplain seems to occur in late xagaa compared with jiilaal. Xagaa rain and lower seasonal evapotranspiration than in jiilaal allow most nomadic stock to remain outside the floodplain. Negligible grazing was apparent in floodplain ground monitoring sites towards the end of xagaa (TEBS data).

As with forage production, livestock biomass in East African rangelands is usually related to rainfall. Figure 15 compares such a relationship for 10 areas (seven pastoral districts in Kenya; three non-riverine regions in southern Somalia) with data for the Jubba. Jubba administrative regions are in accord with the general relationship as is the TEBS study area as a whole, although livestock occupancy of Middle and Lower Shabeelle Regions is substantially higher (see Map 1 for location of regions).

When TEBS study area is considered, most sections of the river-dependent zone are somewhat higher in biomass than the general relationship in both wet and dry seasons. Overuse of the river-dependent zone in some sections, as suggested above, is supported by this higher than "normal" livestock biomass (Section VII.D.1). Lower biomass in River Sections V and VI is probably related to tsetse infestation (V and VI) and large state farms occupying much land and excluding livestock (VI). More startling than the situation in the river-dependent zone is livestock biomass in all floodplain sections (Figure 15). These biomass estimates bear no direct relationship to rainfall and are exceptionally high particularly in the dry season. They leave no doubt as to the importance of maintaining livestock access to the river and its floodplain.

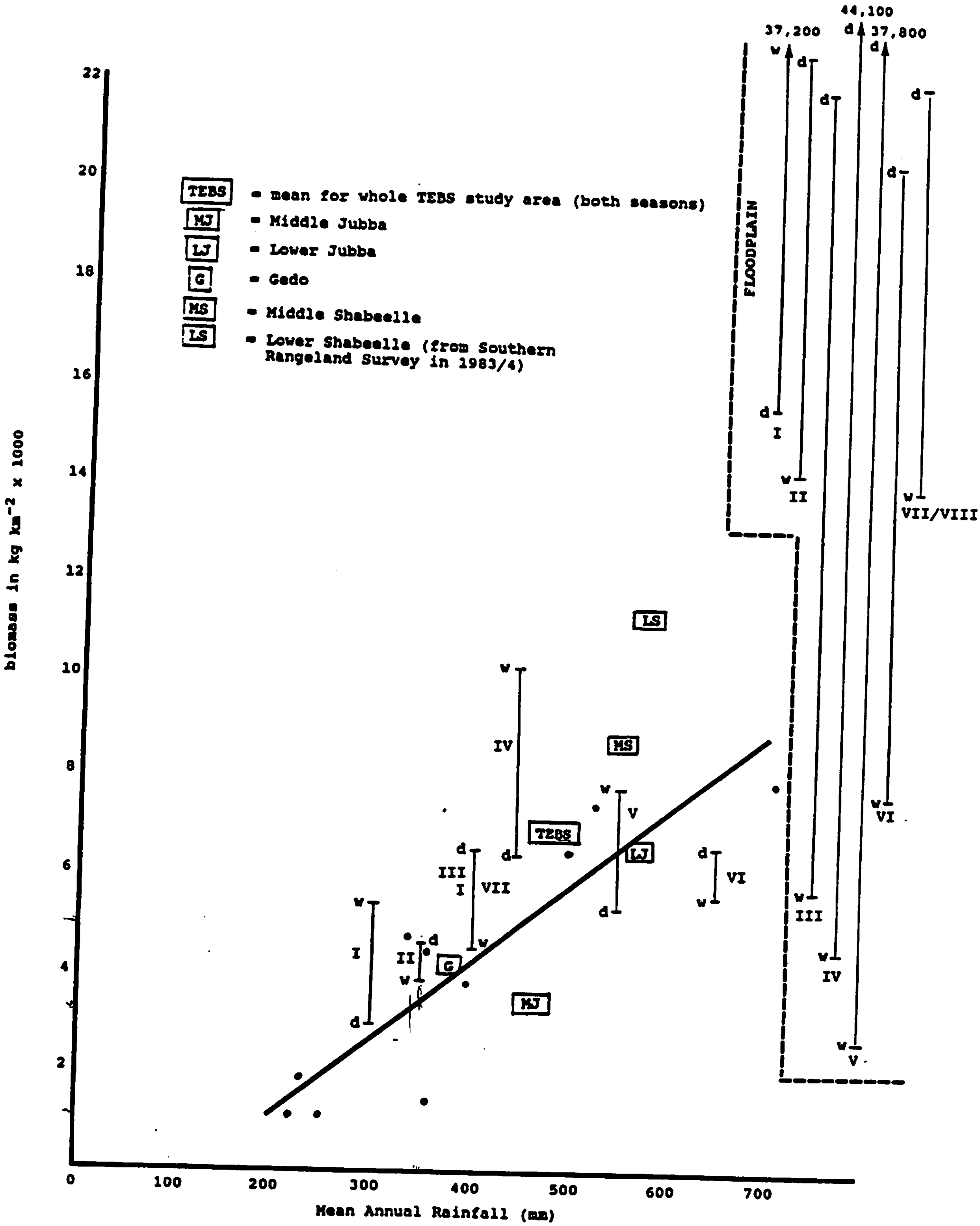


Figure 15. Relationships between mean annual rainfall and biomass of livestock in eastern Africa. Solid line and filled dots represent a regression analysis of seven pastoral districts in Kenya and three non-riverine regions of southern Somalia. Vertical bars in the body of the graph are wet (w) and dry (d) season censuses for TEBS river-dependent zone. The separate section to the right of the graph is for floodplain by river section (Roman numerals). (Data from Coe, Cumming, and Phillipson 1976; Ecosystems 1985; Lusigi 1984; Watson 1972; Watson and Nimmo 1985; Watson and Nimmo 1988.)

A more detailed account of livestock density is afforded by examination of Figure 16. Higher floodplain biomass is seen in all species in most river sections. The exception is camels in River Sections V to VIII. In these higher rainfall areas, non-floodplain areas have equal (V) or greater (VI and VII) peak biomass than the floodplain. Cattle, sheep, and donkeys are the most floodplain dependent species. These species are at greater density in the floodplain for virtually all seasons and river sections. Sheep and donkeys are more common in River Sections I to IV, but have almost negligible biomass elsewhere.

Most species show greater floodplain biomass in late jiilaal than in other seasons in most river sections. Spectacular increases include camels in River Section IV and cattle in River Section V. Very high biomass and forage consumption (Figures 13 and 15) in River Section I, particularly in xagaa suggest that this area is seriously overstocked. A similar situation is the floodplain of river sections VII and VIII (Figure 13). These anomalies may be an artifact of sampling times. It is possible that high biomass is not maintained for long periods as is assumed in annual consumption estimates (see below). It is also reported that some animals in River Section I move seasonally across the border to Ethiopia (Janzen 1988).

A closer look at where highest floodplain concentrations of livestock occur is provided by data on individual strata. These data are best examined on map sheets of Watson and Nimmo (1988). High floodplain density of camels in early jiilaal in River Section II results from large numbers drinking at or in the river. Presumably many of these animals would move away after watering. Similar river concentrations of camels occurred in late jiilaal in River Sections III and IV. In the latter section, the other camel concentration was in dhesheegs.

In River Section V, cattle were concentrated in dhesheegs with virtually no livestock on levees. These levees remain the most forested along the river and, therefore, devoid of graze, but with high tsetse populations, whereas dhesheegs are often cleared and partly farmed or grassed. Dhesheegs are also favored by cattle in River Section VI, which has lowest cattle density on the sugar estates. Cleared but unplanted sections of Mogambo and Fanoole rice schemes also have large cattle populations. By xagaa, many animals have moved to levees, probably because free drainage of soils makes them more attractive after the rains and the extensive flooding that year. In River Section VII, heterogeneous alluvia are favored, particularly earlier in jiilaal. These areas are a complex of farms in use and under fallow with a mixture of palatable grasses and attractive *Acacia nilotica* browse.

Overall, seasonal changes in floodplain livestock biomass are compensated by movements into and out of the adjacent river-dependent zone. Total biomass of TEBS study area increases by only 8 percent when wet and dry seasons are compared, indicating that net movements into the area are small compared with redistribution within. However, when species are considered, camel biomass remains constant, whereas cattle and sheep increase by around 20 percent, in the dry season. Movements of livestock are covered in more detail elsewhere in JESS (Janzen 1988; Watson and Nimmo 1988; Craven, Merryman, and Merryman 1989) and by LRDC (1985).

Annual consumption of forage by livestock (and hippopotamuses) is calculated using daily food intake relative to body mass and population estimates of each species in various sections of the study area (see Appendix G). To project from daily intake rates to annual consumption in a particular area it is necessary to know the number of days that area is occupied by a particular mixture of livestock species. For computation purposes, it is assumed that both mid- and late-jiilaal censuses of livestock biomass are maintained for 60 days each, and xagaa for the remainder of the year in floodplain sections. Since there is no mid-jiilaal census in the river-dependent zone, late-jiilaal densities are applied for 120 days and xagaa estimates for the remaining 245 days. This procedure may be responsible for anomalies such as calculated overstocking in River Sections I and VII (Figure 13). Short of conducting more censuses, it is not possible to determine the magnitude of this type of error.

3. Comparison of Forage Yield and Livestock Consumption: The Problem of Carrying Capacity

A simple comparison of forage yield and its consumption by livestock gives a first approximation of range carrying capacity (Figure 15). However, such simplicity is confounded by food selection and quality (browse or graze, palatable or unpalatable); seasonal movements, water sources, and forage availability (has all the food been consumed in the place needed even if there is plenty elsewhere); and

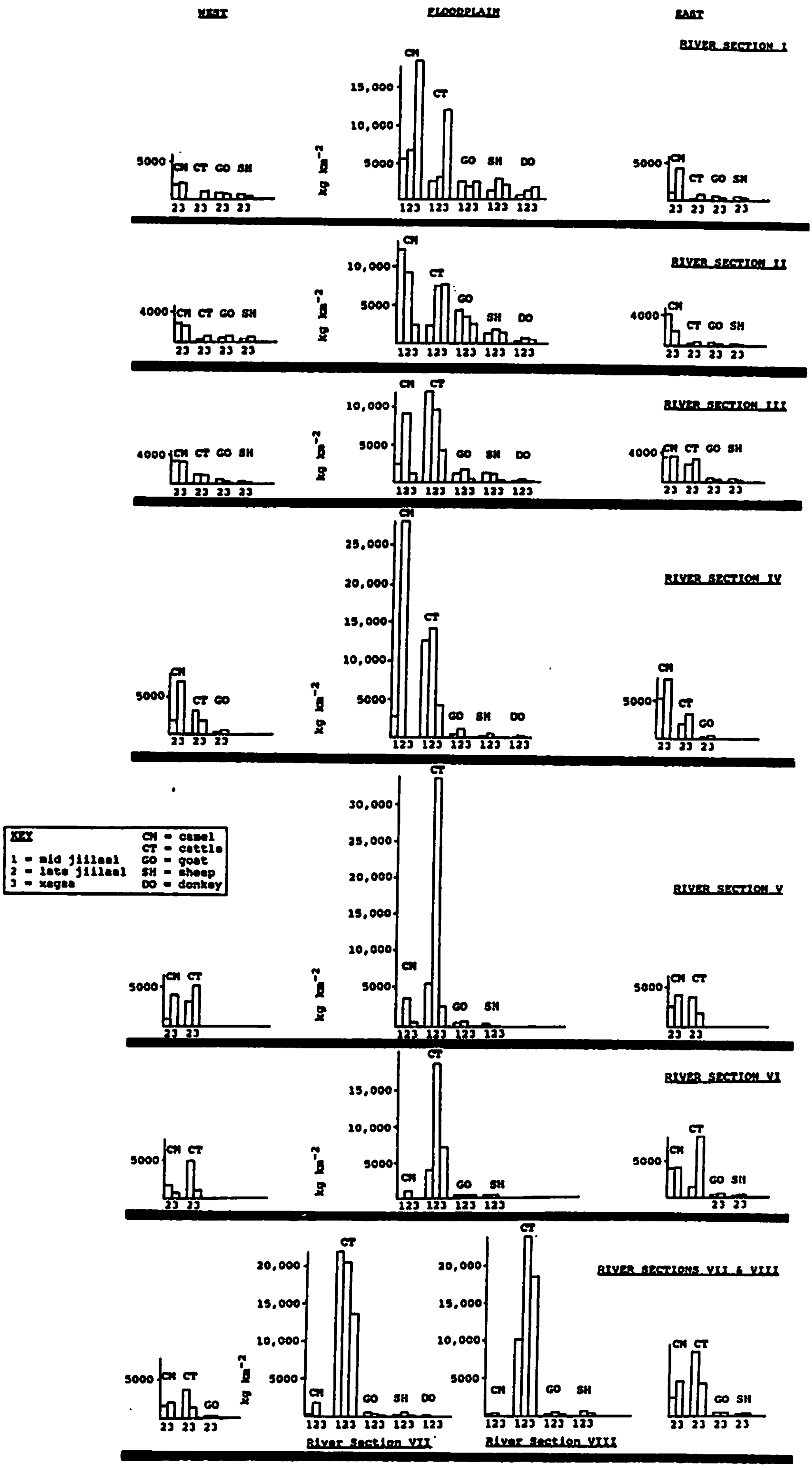


Figure 16. Livestock biomass by species, season, river section, and floodplain versus river-dependent zone for TEBS study area in 1987. (Watson and Nimmo 1988.)

longer-term drought cycles. No satisfactory scientific method has been devised for estimating optimal livestock production and range management for nomadic pastoral systems of Africa. The nomads themselves know far more than any short-term study can achieve. However, steadily increasing human population, accompanied by slower net increases in livestock biomass and loss of former grazing lands, puts increasing pressure on range resources. These problems are perhaps tacitly acknowledged by gradual shifts in pastoral strategy, notably towards agropastoralism (Craven, Merryman, and Merryman 1989). Such limitations should be borne in mind while reading the following account.

Analysis of forage consumption, detailed in Appendix G, proceeds as follows. Cattle, donkeys, and sheep are considered grazers; camels and goats, browsers. It is well known that all species consume at least some graze and browse, but this simplification is an initial step in analyzing food availability. The method avoids the necessity of defining precisely the relative proportions of graze and browse consumed by each species. Such information is not available for the study area.

First, browse available to goats is compared with their annual food requirement. Because of their small stature, it is assumed that only 25 percent of total browse is available. Any browse not consumed by goats is then available to camels who have access to an additional 25 percent of browse higher in trees and shrubs (*i.e.*, 50 percent of total browse is reachable by camels). Any browse not consumed by goats and camels is potentially available to other livestock. If browse consumption exceeds browsable forage, then the shortfall must be made up from graze. If there is an excess of browse, it may be used by grazers. A similar computation is made for forage available to grazers (as half of forage yield) and their consumption. Any excess of graze is then available to browsers. Using this approach the overall balance between forage available and that consumed can be examined (details, assumptions, and references in Appendix G).

Table 22 summarizes results of the analysis. Taking a year of average rainfall, available forage exceeds livestock demand in most areas. Of note is the relative shortage of browse, particularly in northern sections where camels are most abundant. The proportion of graze consumed by camels in the study area is unknown, but data from elsewhere show that sufficient graze can be consumed to validate the assumptions behind Table 22. Watson and Nimmo (1985) suggest 20 percent for southern Somalia. However, in Marsabit, northern Kenya, dwarf shrubs (considered here as graze) make up almost 50 percent of camel diet and herbaceous plants a further 20 percent (Lusigi 1984). Overall, the only shortfalls in forage occur in the river-dependent zone of River Section I and the floodplain of River Sections VII/VIII. A possible cause of these anomalies relating to timing of censuses is discussed in the previous section. More than enough forage remains in the river-dependent zone of River Section VII/VIII to supply the deficit in the floodplain. It may be that movements of livestock (particularly cattle) make use of the river-dependent zone. Overstocking remains a possibility in River Section I since this area experienced five to 10 times the jiilaal livestock mortality per unit of surviving biomass as other river sections in 1987 (Watson and Nimmo 1988).

Table 22. Analysis of balance between available forage and forage demand by livestock comparing floodplain and river-dependent zone by river sections. "Normal year" where graze and browse are accounted for separately is for average rainfall. "Drought" is for a dry year and only overall balance is presented (see Appendix G).

		BALANCE ($kg\ ha^{-1}\ year^{-1}$) 'NORMAL YEAR'			DROUGHT
River Section		Browse	Graze	Overall	Overall
I	FP	-1,087	+1,230	+143	-380
	NFP	-232	+82	-150	-282
II	FP	-513	+808	+295	-474
	NFP	+12	+66	+74	-112
III	FP	-82	+474	+392	+232
	NFP	-51	+223	+172	+25
IV	FP	-202	+774	+572	+538
	NFP	-161	+717	+556	+232
V	FP	+136	+856	+992	+255
	NFP	+57	+1,328	+1,385	+793
VI	FP	+85	+615	+700	+274
	NFP	+121	+1,863	+1,984	+1,183
VII/VIII	FP	+63	-1,205	-1,142	-1,368
	NFP	+95	+769	+864	+534

In a drought year (see Table 22, right column, and Appendix G), graze production is much reduced leading to forage deficits in all parts of River Sections I and II and very small surpluses in most other areas. Bearing in mind factors presented in the next section, it seems likely that mortality of livestock will be high in drought years, as in most nomadic pastoral systems.

4. Factors Influencing Forage Use by Livestock

All graze and browse is not equally palatable. Some plant species are unpalatable or even poisonous. Table 23 gives palatability ratings for the most abundant species in TEBS study area. Many dominant trees and bushes are of rather low palatability. *Acacia reficiens*, the most abundant species of all, is regarded as unpalatable in Marsabit District, Kenya (Lusigi 1984). However, there is no doubt that it is browsed in TEBS ground monitoring sites during jiilaal, even though it is not favored. Most abundant floodplain grasses are palatable. They maintain a high standing crop into the dry season and are completely grazed down at many sites.

Temporal and spatial factors also affect availability and quality of forage. Cattle need to drink at least

*Table 23. Palatability ratings of most abundant plants on JESS ground monitoring sites.**

FLOODPLAIN		RIVER-DEPENDENT ZONE	
Trees and shrubs			
Acacia zanzibarica	LP	*Acacia reficiens*	LP
A. nilotica	P	*Commiphora* spp.	P
Terminalia brevipes	P	*A. horrida*	P
Thespesia danis	U	*A. zanzibarica*	LP
Dichrostachys cinerea	HP	*Grewia tenax*	LP
Lecaniodiscus fraxinifolius	?	*Cordia sinensis*	P
Phyllanthus somalensis	U	*A. nubica*	LP/UP
Acacia reficiens	LP	*A. bussei*	LP
Salvadora persica	P	*Anisotes trisulcus*	P
Spirostachys venenifera	U	*Combretum hereroense*	LP?
Herbaceous layer			
Sporobolus helvolus	HP	*Sporobolus helvolus*	HP
Cenchrus ciliaris	P	*Aerva persica*	U
Enicostemma axillare	U	*Eragrostis cilianensis*	HP
Eriochloa meyerana	?	*Aristida* sp.	LP
Echinochloa haploclada	P	*Dactyloctenium scindicum*	P
Sorghum arudinaceum	HP		
Echinochloa colona	P	*Cenchrus ciliaris*	P
Commelina spp.	P	*Cadaba* spp.	U
Indigofera schimperi	P	*Commelina* spp.	P
Heliotropium aegyptiacum	U	*Enteropogon* sp.	P
		Sporobolus sp.	P

HP= highly palatable; P= palatable; LP= low palatability; U= unpalatable; ?= unknown palatability.
Source: From Herlocker & Kuchar (1986) or Jubba Valley residents
**Abundance based on canopy cover, not number of plants as in Table 15; species restricted to forests are omitted.*

every two to three days, limiting the distance they can travel from water. The Jubba is by far the most important water source in the study area during jiilaal. In this season, herbaceous forage in the river-dependent zone is low in quantity and quality (Figure 13) relative to the floodplain. Therefore, cattle are virtually restricted to the floodplain during late jiilaal in more northerly areas, as illustrated in Figure 15. Similar factors affect browse availability. Although camels can wander for many days without water and, therefore, gather forage from a wide area, quality and quantity of browse are much reduced in jiilaal, particularly in the river-dependent zone. Since most common trees and shrubs are deciduous, browse is poor in dry seasons. Browsers are forced to eat younger twigs or leaf and fruit litter from the ground. Thus, although there may be a positive forage balance overall, spatial and temporal factors will always reduce the amount that can be consumed in reality.

Wild herbivores also consume graze and browse. Densities and distribution of terrestrial wildlife are such that they are unlikely to have a noticeable impact on livestock forage (Section VIII). However, the amphibious hippopotamus is a significant floodplain grazer in River Sections IV to VII (Figure 13). Extrapolation from sample census data suggest that hippopotamuses account for 40 percent of floodplain forage consumption in River Sections V and VII/VIII. However, total aerial counts, which probably give a better estimate of hippopotamus numbers, suggest a maximum of 25 percent of floodplain forage consumption in River Section V (Watson and Nimmo 1988; Appendix G; Figure 13). Where hippopotamus density is high, control programs, as suggested in Section VIII, may be as beneficial to pastoralists as to farmers.

Fires also consume forage, often removing all herbaceous vegetation and causing trees and bushes to shed leaves. Where fires are frequent, woody cover is gradually reduced, thereby reducing browse production, but potentially increasing graze production. During the JESS study period, fires were most frequent in the floodplain during jiilaal and relatively unimportant in the river-dependent zone. Fires are usually set during field preparation, but often escape into surrounding rangelands. Occurrence of fires is documented in Section V and in Watson and Nimmo (1988). Loss of vegetation by burning is probably of marginal significance to overall forage balance. Most fires are in River Sections V and VI, which have the greatest positive balance (Table 22).

Another important restriction on forage availability is the presence of biting flies which spread livestock diseases. Of particular importance in riverine areas are tsetse flies and the trypanosomiases they transmit. Distribution of tsetse is shown in Map 2. Cattle are badly affected, yet are largely dependent on floodplain habitats. Camels are also sensitive, but less restricted to the floodplain. LRDC (1985) reports that trypanosomiases account for 22, eight, and two percent of recorded deaths in cattle, sheep, and goats, respectively, in the riverine areas. Heavier trypanosomiasis-related mortality occurs during droughts when animals suffer nutritional stress. Infestations are at their worst in wet seasons and decline during jiilaal.

These facts help to explain livestock movements inferred from Figure 16. In River Section III southward, cattle move out of the floodplain in xagaa into the tsetse-free river-dependent zone. Tsetse are thought to be absent north of Baardheere. As a result, cattle are able to remain in the floodplain through xagaa in River Sections I and II. In fact, cattle density was higher during the wet season in these sections than in the dry season (Figure 16). Heaviest tsetse infestations occur in floodplain lands south of Saakow (LRDC 1985). Some grassland TEBS ground monitoring sites remain ungrazed throughout the year, reportedly due to extreme tsetse infestation. Because of forage availability, livestock must use the floodplain during jiilaal. To alleviate effects of disease, herders vaccinate their livestock when occupying tsetse-infested areas. Other livestock diseases such as anthrax, rinderpest, and hoof-and-mouth occur, often more so in the floodplain, but their effects have not been quantified (see LRDC 1985; Watson and Nimmo 1985; AHT 1988).

Factors affecting forage availability discussed above all effectively reduce carrying capacity of the study area. In contrast, the availability of crop residues provides an additional and nutritious food source for livestock. Sorghum and maize produce three to four times as much stover as grain (AHT 1988; Hubbel personal communication). Since grain production averages about 1 t ha^{-1} year^{-1} (AHT 1988), these croplands produce as much potential livestock fodder (3 to 4 t ha^{-1}) as a hectare of rangeland (compare Figure 14). Sorghum and maize stover can be grazed in fields or collected and stored or transported more easily than wild grasses. Beans and sesame also produce consumable residues, but at a lower rate than grain crops. Rice straw is a potential fodder, but is not made available at the state farms of Fanoole and Mogambo.

The Ministry of Agriculture estimates 71,000 t, 97,000 t, and 58,000 t of maize and sorghum residues are produced in Gedo, Middle Jubba, and Lower Jubba respectively (AHT 1988). Most of this production is in the floodplain, although significant rainfed sorghum farming occurs in the river-dependent zone of River Sections III and IV. Assuming, for illustrative purposes, that all production does occur in the floodplain, then approximately 1 t ha^{-1} of crop residues is available throughout the whole floodplain using the Ministry of Agriculture production statistics. On a smaller geographical scale, MMP (1987) calculates that in a proposed smallholder development at Hombooy (Middle Jubba Region), 6000 ha of mixed croplands will produce 12,000 t of crop residues each year. This estimate is compatible with extrapolation from the Ministry of Agriculture data. Comparing this estimate with forage balance indicates the potential importance of crop residues to the livestock economy.

Aerial censuses reveal that about 20 percent of cattle, 10 percent of sheep, seven percent of goats, and seven percent of camels foraged in current or fallow croplands throughout the TEBS study area late in the dry season (Watson and Nimmo 1988). Only cattle (two percent overall) were seen feeding on crop residues transported from the fields. However, about 30 percent of cattle were eating such residues during late jiilaal in River Section I. Watson and Nimmo (1985) regard the livestock/crop residue relationship to be relatively poorly developed in the Jubba Valley compared to the Shabeelle Valley. This point is illustrated by extremely high livestock biomass maintained in the Shabeelle administrative regions (Figure 15). Clearly there is potential to increase livestock production in the Jubba if herders and farmers become more closely integrated.

E. Conclusions and Recommendations for the Range Sector

Rangeland is the most extensive land use in the study area. Range and livestock development are, therefore, crucial to the future of the Jubba Valley. Overall, it appears that the TEBS study area supports a higher biomass of livestock than the greater JESS study area. This difference is attributable to the river as a permanent source of water and availability of dry season forage in the floodplain.

Models of forage production and consumption indicate that most rangelands are not overstocked in years of average rainfall. However, it appears that parts of the river-dependent zone are somewhat degraded. In contrast, floodplain grasslands show great resilience to flood, fire, and grazing. In drought years forage resources are pressed hard and livestock losses are inevitable. Crop residues, produced mainly in the floodplain, provide an important source of fodder alleviating seasonal and drought stresses. During stress periods additional forage is also made available by cutting the higher branches from palatable trees and bushes which livestock could not reach otherwise.

The most important immediate effect on range resources of closing Baardheere Dam will be loss of rangelands in the inundation area. At present this area supports 22,600 kg km^{-2} of livestock in jiilaal. Approximately half this biomass comprises cattle and sheep which are restricted to the floodplain during this season and much of the year. Relative to TEBS study area, approximately seven percent of sheep and goats and two percent of cattle and camel biomass occur in the inundation zone. Approximately 24 million kilograms of annual forage yield will be lost. Presumably, most livestock will leave the area since rangelands around the inundation zone will be a poor source of forage initially, at least, compared with the lost floodplain. Since more northerly areas already seem overstocked, it is likely that most movement will be southward. River Sections IV to VI could absorb the extra animals without greatly altering forage balance. However, stresses will be greater in drought years. Also, animals moved will be exposed to greater health hazards since tsetse is absent from River Section II, but prevalent to the south. Livestock mortality per unit of living biomass was similar in River Sections II, IV, and VI during jiilaal 1987, but twice as high in River Section V (Watson and Nimmo 1988), suggesting that increased health risk will be a real phenomenon in some areas.

The reservoir drawdown zone may become a seasonally usable rangeland. Soil types in this zone are not known quantitatively. Much of the area is stony or rocky, but there are also stretches of finer soil (Appendix I). Over time, fine riverine sediments may be deposited in the drawdown zone. If that happens, seasonal grasslands will probably develop, providing a good dry season grazing resource. It may be possible to enhance establishment of palatable grasslands by seeding. Drawdown agriculture is another possibility (Sections V and IX) which would produce livestock fodder as a by-product. Until the reservoir edge and drawdown zone are demarcated, it is not possible to predict the potential of such developments. However, the reservoir perimeter should be as much a focus of development planning as downstream areas (see Section IX).

Tsetse may become established around the reservoir even though they are thought to be absent now. Tsetse distribution is closely linked to air temperature and humidity (Rogers 1979). A large body of water will decrease air temperature and increase humidity, thereby improving conditions for flies. If bush increases around the perimeter of the reservoir due to increased soil moisture, fly habitat will be further improved. These possibilities should be borne in mind as part of the country's tsetse eradication program.

If the drawdown zone becomes a focus for livestock, crocodile populations will probably become a serious threat to people and animals. Crocodile control programs may be desirable (see Section VIII).

Downstream of the dam, agricultural development will reduce floodplain rangelands. Given the crucial nature of these rangelands as a dry season resource, greater integration of livestock and agriculture will be required to maintain livestock production. Some new rangelands may become usable if tsetse eradication is successful in compensating somewhat for losses of land to agriculture.

Recommendation: *Agricultural development should take place in such a way that suitable crop residues are available to livestock.*

At present such a situation is found to some extent among subsistence farmers and small-holders. In the large state farms on the Jubba, crop residues are not made available to livestock. Great potential exists to enhance the livestock economy if proper integration is allowed to develop and is encouraged. Such processes of integration depend on appropriate farming systems and sociological interactions. Planning to optimize such developments is difficult. Farming systems should be developed that

Dhesheeg and river livestock watering points will need to be maintained.

allow grazing and/or collection of crop residues of suitable crop species. However, the sociological interactions are unpredictable with present information. An important requirement will be local government officials who are skilled in resolving conflicts between pastoralists and farmers.

As suggested in other sections, floodplain vegetation will be degraded as a result of reduced flooding, groundwater, and nutrients supplied by the river. Similar developments will occur in unirrigated or unfertilized floodplain agriculture. Potential loss of production is illustrated by Figure 14. Comparison of the floodplain regression with that predicted for typical rainfed areas in East and southern Africa suggests a 20 to 50 percent reduction in herbaceous forage yield may occur. The floodplain regression omits tall grasslands in particularly favorable sites which yield up to 20 t ha^{-1} $year^{-1}$. These effects can be countered in the agricultural sector by irrigation and artificial fertilizers, but range production will decrease. Use of crop residues to feed livestock will become yet more important.

Another effect of increased floodplain agriculture on livestock will be reduced access to the river and dhesheeg watering points. Allocation of land should be managed in such a way that conflicts between farmers and herders concerning access to drinking water are minimized. One possibility is to use some dhesheegs specifically for livestock watering, leaving levees free for agricultural development. According to Janzen (1988) herders prefer dhesheegs to the river for watering. Since dhesheeg flooding will be reduced or absent after the dam closure, selected dhesheegs could be filled with water by cutting channels from the river, as is now the case at Dhesheeg Radiile near Bu'aale, or by employing pumps. Major watering points are mapped by Janzen (1988), LRDC (1985), and Watson and Nimmo (1985; 1988). Decisions as to which watering points are to be maintained or developed need to be worked out at the local level between farmers, herders, new projects, and government officials, rather than being imposed as an overall plan for the whole river.

Recommendation: *Maintenance of livestock watering-points along the Jubba River should be an integral part of floodplain development. The possibility of using selected dhesheegs for this purpose should be investigated.*

Dhesheeg Waamo presents a special problem. Although its hydrology is poorly understood, it fills when the Jubba has large floods, as in 1987. At other times, its waters are topped up from the Lac Dera catchment and possibly by underground flow from the Lorian Swamps in Kenya. In the absence of Jubba waters the dhesheeg dries up, as in jiilaal 1987 when the water-table was several meters below ground (TEBS field observations). Dhesheeg Waamo is an important part of the jiilaal livestock concentration area in Afmadow District (LRDC 1985; Peter Little personal communication). JESS estimated 30,000 kg km^{-2} of livestock in Waamo during mid- and late-jiilaal censuses and 12,000 kg km^{-2} during xagaa, indicating high and relatively persistent occupation of Waamo (Watson and Nimmo 1988). After dam construction Dhesheeg Waamo will receive less water from the Jubba, possibly none at all, resulting in detrimental effects on forage and water availability for livestock. Yet there will be excess water in the river every few years which will probably cause costly floods in farmlands of Lower Jubba (AHT 1988). It may be possible to have controlled diversion of water from the river to Dhesheeg Waamo, particularly when excess water has to be released from Baardheere Dam. AHT (1988) predicts that such releases will occur approximately in one year out of five. It is not known how often Dhesheeg Waamo floods from the Jubba in the pre-dam situation. Therefore, without further investigation it is not possible to predict how effective a five-year flood would be in maintaining this wetland ecosystem. The Italian administration opened two channels (Far Waamo and Farta Mogambo) between the Jubba and Waamo to divert Jubba floods from banana plantations downstream (LRDC 1985). Although not noticeably effective at present, it is possible that these channels could form the basis of an enhanced diversion scheme.

Recommendation: *The possibility of diverting post-dam flood waters into Dhesheeg Waamo should be investigated to maintain forage and water requirements for livestock in Afmadow District.*

River-dependent zone rangelands are degraded in northern river sections such that herbaceous forage yield is smaller than its potential. The possibility of rehabilitating these areas should be considered. Initially, a small project using livestock exclosures would be adequate to demonstrate whether, and to what extent, natural regeneration is possible. If successful, the project could be extended to larger areas, perhaps by attempting to introduce grazing rotation schemes. However, such schemes are notoriously difficult to enforce and administer in pastoral nomadic settings. To have any hope of success, such a project would require good extension, demonstration, and local participation components. The Central Rangelands Project of the Somali National Range Agency has met with some success in similar endeavors, but only with massive financial input.

Recommendation: *The possibility of rehabilitating herbage yields in the river-dependent zone should be investigated.*

Long-term trends in livestock populations between 1952 and 1984 in southern Somalia were assessed by Watson and Nimmo (1985). They concluded that cattle numbers had increased, that sheep had probably increased, but that trends in other species were difficult to discern given the weakness of early data. Increase in total livestock biomass is highly probable and may even have doubled during the period. Watson and Nimmo (1985) attribute these changes to an increase in mean annual rainfall from 1959 to 1983 as part of a 40-year cycle, and land-use changes. They warn that the mid-1980s may see the beginning of a rainfall decline if the 40-year cycle is verified.

Most trends in livestock biomass between 1983-1984 and 1987 are too small to discern given the different sampling strategy of the two sets of surveys. However, it seems that sheep numbers have increased since the 35,000 km^2 TEBS study area is estimated to contain more in jiilaal 1987 than 117,000 km^2 of Gedo, Middle Jubba, and Lower Jubba in jiilaal 1984 (Watson and Nimmo 1985; 1988). Much of the extra sheep production is in River Sections I and II. Sheep numbers may, therefore, decline again after construction of the dam. It is of interest to understand the significance of increase in sheep numbers so that suitable measures can be taken to counter negative impacts of the dam.

VIII. CONSERVATION AND WILDLIFE

Recently, biological conservation in tropical countries has been promoted as a necessary part of economic development. The "World Conservation Strategy" was an important international document setting the scene for this decade (International Union for the Conservation of Nature and Natural Resources; IUCN 1980). The central hypothesis is that maintenance of natural ecosystems is essential for sustained economic development. As the decade proceeds, the increasing rate of species loss has shifted specific attention to conservation of biological diversity. These concerns have sufficient political impact to affect policies of major development agencies such as the World Bank and USAID. Many agencies now require that environmental effects of development projects be assessed and areas of conservation importance be protected. Recent U.S. government legislation specifically draws attention to protection of tropical forests and "biodiversity" in USAID-funded projects.

Two quotations from a respected African ecologist and conservationist are especially relevant to conservation issues in the study area.

> African ecosystems are not as fragile and vulnerable as is popularly believed...But current accelerated rates of change leave little room for complacency regarding the identification of real rather than perceived conservation priorities.

> Biotic diversity is not linked to the distribution of elephants, rhino....The massive investment campaigns directed at these species does more for the souls of donors and the egos of the elephant experts than ...for biotic diversity, which is centered on less exciting communities of.....wetlands, lakes and rivers. (Huntley 1988).

Indeed, the major conservation opportunities in southern Somalia are concerned with river-related ecosystems such as the Jubba forests, Shabeelle Swamps, and the seasonal river complex of Bushbush, rather than the vast rangelands that dominate the area. It is rangelands that are resilient, as suggested in Huntley's first statement. Wetlands are also resilient if protected from major hydrological interventions such as dams or draining for agriculture. Both the Jubba forests and the Shabeelle Swamps may be affected by dam developments in the near future.

This section considers the status of terrestrial large mammal populations and demonstrates that most are at such low densities that effective conservation measures cannot be taken in the Somali context. Aquatic wildlife, specifically crocodile and hippopotamus, are of pest status in some areas and should be controlled. Related issues such as subsistence hunting, tsetse control, wildlife as pests, effects of Baardheere Dam, and tourist potential are discussed. All these issues demonstrate the need for more effective environmental and conservation policy in Somalia.

Historical transitions in awareness about biological conservation from hunters to natural historians to scientific ecologists to politicians and policymakers have left a tangled web of ill-defined terms such as: wildlife, game, wildlands, biodiversity, and genetic diversity. For the purposes of addressing a development-oriented audience, rather than a biological one, "wildlife" will be used to refer to non-domestic mammals, birds, and reptiles. "Biological diversity" or "diversity" will refer to the number of species in a given area or community. "Biological conservation" or "conservation" refers to maintenance of species or groups of species (communities) in their natural environment. Other confusing terms will be kept to a minimum and defined where used.

Most of this volume has referred to TEBS study area (Section IV). When "study area" is used alone in this section it will mean the wider JESS study area, the administrative regions of Gedo, Middle Jubba, and Lower Jubba (Map 1). Scientific names of animals not given in tables, but reported from the study area are presented in Appendix H.

A. Conservation Prospects in Somalia

Somalia has missed the opportunity to create large and effective wildlife conservation areas. Wildlife densities are now low compared with other countries in the region which have a system of functioning reserves. In Somalia, significant economic returns from biological conservation cannot be expected in the foreseeable future. A country which struggles to supply basic human needs to its population cannot be expected to finance large-scale conservation measures. However, these conditions do not preclude the possibility of developing an effective conservation policy with support from external donors.

At present, biological conservation activities come under the Ministry of Livestock, Forestry, and Range. Matters relating to vegetation are mainly within the National Range Agency (NRA), while the Wildlife Department is directly under the Ministry. Range, forest, and wildlife reserves are provided for under Somali law. This structure is not ideal for conservation activities. The Ministry's basic remit is exploitation of natural resources through livestock production and forest products, rather than environmental conservation and protection of diversity. The need for a separate government body to oversee environmental and conservation activities has been expressed frequently, most recently at the National Workshop on Desertification and the Environment in Somalia (March 1988). Such a body would formulate a coherent environmental policy including a national conservation strategy.

Given the paucity of larger wildlife, funding, and skilled people, conservation in Somalia should be carefully prioritized. Large tracts of land need not be separated as pure conservation areas. Protection and management of smaller, carefully selected reserves will be much more effective. Terms such as "national park" and "biosphere reserve" are not used here because they have specific international meanings which may not be directly applicable to conservation management in Somalia. Appropriate designations should be decided as part of a national system of conservation areas rather than determined by the specific situation in the Jubba Valley.

In determining conservation priorities for Somalia, particular attention should be paid to:

- endemic species;
- rare species, internationally;
- rare species, of restricted distribution within Somalia; and
- plant and animal communities which are unusual, especially diverse or rapidly diminishing in extent.

Conservation sites should be selected and managed in ways that seek optimal balances between rural populations and conservation objectives.

Recommendation: *External funding and technical assistance should be sought to support a coherent conservation program in Somalia.*

Substantial economic benefits from conservation cannot be expected in the near-term. Tourism is almost nonexistent in Somalia and could only be developed slowly. Potential attractions compared with neighboring Kenya are limited. More specialized tourists interested in birds, vegetation, a unique culture, or getting away from other tourists might be attracted to Somalia, but such people will not have a significant impact on foreign exchange earnings. Massive investment in improving communications infrastructure and tourist facilities would be required to attempt to attract large numbers of people. Cost effectiveness of such investments could not be guaranteed.

Extractive use of wildlife is also limited in scope except for proposed cropping of crocodiles (see Section VII.B.2). Game hunting can be lucrative, but would need to be carefully controlled. Animals especially attractive to hunters, such as elephant, rhinoceros, buffalo, lion, and leopard are all rare in Somalia. Subsistence hunting will undoubtedly continue to provide a useful supply of protein to rural populations. Such hunting cannot be controlled effectively over large areas, but it may be appropriate to restrict the species killed, or prevent hunting entirely in more limited areas of special conservation value.

Commercial game cropping or ranching as a means of supplying meat to local or export markets is not feasible in Somalia. Animal populations are too sparse for commercial operations to compete in price with meat from livestock. Local religion and taste dictate stringent selection of species and slaughter techniques which are difficult to operate in the field. Game meat for export would be far too expensive and is unlikely to meet foreign hygiene requirements if slaughtered in the bush.

B. Wildlife Populations

1. Large Terrestrial Animals

Seasonal aerial censuses of TEBS study area show that domestic livestock dominates large mammal biomass. Terrestrial wildlife numbers (large mammals and ostrich) and biomass are low throughout the census area (Table 24). The more common species, such as lesser kudu and gerenuk, are largely independent of surface water and do not, therefore, rely on the river. Other abundant species, such as warthog, bushpig, and baboon are ubiquitous and achieve pest status in many areas.

Table 24. Biomass (liveweight) and population estimates of domestic and wild large animals in the TEBS study area. Data from aerial census March-April 1987 - DRY; July-August 1988 - WET (Watson and Nimmo 1988).

SPECIES	BIOMASS ($kg\ km^{-2}$)		POPULATION	
	DRY	WET	DRY	WET
Domestic				
camel	2,945	3,078	335,000	350,000
cattle	3,040	2,503	584,000	481,000
goat	374	341	718,000	655,000
sheep	237	195	455,000	374,000
donkey	42	21	10,000	5,000
TOTAL	6,638	6,138		
Wildlife[1]				
gerenuk	5.7	17.3	7,850	23,730
waterbuck	0.6	0.5	190	160
lesser kudu	16.7	33.0	14,460	28,500
oryx	0.7	3.8	260	1,460
ostrich	0.7	0.2	300	90
giraffe	47.4	68.3	2,050	2,950
warthog	4.0	7.3	3,990	7,200
bush pig	0.9	2.8	870	2,780
elephant[2]	56.8	0.0	780	0
elephant skeleton			2,990	4,300
baboon troop	12.5	15.4	430	530
vervet troop	0.3	0.0	60	0
TOTAL	146.3	148.6		

[1] *wet season estimates included small numbers of duiker (310), reedbuck (50), oribi, (100) and honey badger (80), which have a negligible effect on total biomass.*
[2] *elephant estimates result from a single sighting of six animals in one stratum.*

The Jubba River and floodplain are not significant dry season concentration areas for larger wildlife. Predominance of livestock, ever-increasing agricultural activity, and poaching have led to elimination of much riverine wildlife. Highest jiilaal floodplain densities of wild herbivores were in dhesheegs of River Sections VI and VII which had approximately 1,100 $kg\ km^{-2}$ of terrestrial larger mammals. Most of this biomass comprises warthogs and baboons. The same areas had 78,000 $kg\ km^{-2}$ and 23,000 $kg\ km^{-2}$ of domestic stock, respectively (Watson and Nimmo 1988). Note that elephant population estimates are not reliable, as they result from a single sighting in one stratum. The far greater number of elephant skeletons over living animals indicates the impact of poaching. Average large wildlife biomass is less than 150 $kg\ km^{-2}$. By comparison, a typical conservation area with similar rainfall in other East African countries has approximately 3,500 $kg\ km^{-2}$ of wildlife (Deshmukh in press). A floodplain area would support even higher biomass.

Outside the floodplain, larger wildlife are more common in the wet season (Tables 24 and 25). Biomass estimates for the dry season are severely skewed by a single occurrence of elephants. However, population estimates show large numbers of gerenuk, lesser kudu, and oryx moving into TEBS study area after the rains. Presumably, these species are further east and west during jiilaal, clearly demonstrating their independence of the Jubba. Highest large mammal densities in the river-dependent zone were found in the distant marine plains 12 to 30 km from the floodplain west of the river in Sections V, VI, and VII/VIII. Biomass above 1,000 $kg\ km^{-2}$ was found south and west of Dhesheeg Waamo in xagaa (1,050 $kg\ km^{-2}$), west of River Section V in jiilaal (1,430 $kg\ km^{-2}$) and in lower Shabeelle floodplain in jiilaal (1,290 $kg\ km^{-2}$).

Geographical distribution of larger wildlife populations in TEBS study area is shown in Table 25. A striking feature is the paucity of animals in floodplains of river sections north of Fanoole Barrage. Only warthog and baboon were seen. Most species are at higher density in southern sections, probably reflecting higher rainfall in these areas. Gerenuk and lesser kudu are common throughout most of the river-dependent zone, but giraffe are concentrated in the south. Oryx and elephant are rare, with small herds of the latter entering TEBS study area sporadically.

Trends in large animal populations south of Bu'aale can be approximated by comparing aerial census data from jiilaal 1976 (Abel and Kille 1976), 1984 (Watson and Nimmo 1985), and 1987 (Watson and Nimmo 1988). Different sampling techniques and strata were used in these studies. Thus, comparisons are merely indicative. Lesser kudu and gerenuk populations are similar; giraffe and oryx are significantly reduced; and elephants are virtually eliminated. Abel and Kille (1976) also saw rhinoceros which are now probably extinct in TEBS study area. These trends are confirmed by interviews with Jubba Valley residents. Elephants are rarely seen, although they were common 20 years ago. The only JESS ground sighting was a small herd at Dhesheeg Radiile in jiilaal 1987, which

Table 25. Geographical distribution of population estimates of larger wildlife comparing floodplain (FP) and river-dependent zone (NFP) by river section north to south. Estimates are the higher observed in late jiilaal (unmarked) or xagaa (*) censuses (Watson and Nimmo 1988).

River Section		GER	WAT	KUD	ORX	OST	GIR	WART	PIG	ELE	BAB	VERV
I	FP	0	0	0	0	0	0	0	0	0	0	0
	NFP	1,280*	0	100*	0	0	0	230*	0	0	0	0
II	FP	0	0	0	0	0	0	320	0	0	56*	0
	NFP	9,260*	0	220*	400*	0	0	610	0	0	180*	0
III	FP	0	0	0	0	0	0	110*	0	0	10	0
	NFP	1,760*	0	2460*	580*	0	0	690*	0	0	40	0
IV	FP	0	60	0	0	0	0	110*	0	0	20	0
	NFP	2,750*	0	2,920*	0	0	0	2,280*	0	0	110*	0
V	FP	0	0	0	0	0	0	80*	0	0	40	8
	NFP	1,150*	0	4,930	260	0	490	480*	0	790†	100*	0
VI	FP	360	0	420	0	0	0	930	670	0	40	0
	NFP	3,980	0	9,200*	480*	112	1,650*	1,660*	160*	0	90	0
VII/VIII	FP	290	160*	280*	0	190	0	1,000	1,340*	0	30*	0
	NFP	4,850*	0	2,530	0	0	1,300*	410	1,210*	0	0	0

GER = gerenuk; WAT = waterbuck; KUD = lesser kudu; ORX = oryx; OST = ostrich; GIR = giraffe; WART = warthog; PIG = bushpig; ELE = elephant; BAB = troop of baboons; VERV = troop of vervet monkeys.

Note: Neither columns nor rows can be added for total estimate since data are composite of two censuses.
† elephant estimates result from a single sighting in one stratum.

was subsequently shot. As recently as the early 1980s, a herd of 250 destroyed 100 ha of cane at Jubba Sugar. However, most informants have seen no elephants for several years.

Table 26 lists larger mammals not encountered during aerial census, but seen by JESS field teams and by the Somalia Research Project (SRP). No quantitative statements can be made beyond the observation that dikdik are very common. From the conservation perspective, six of these species are rare in Somalia and dibatag is endemic to the Horn of Africa. Most of these sightings were in, or close to, the floodplain. Species which have been recorded in the past (Whittaker *et al.* 1985), but were not seen during JESS, include black rhinoceros, plains and Grevy's zebra, and Grant's and Soemmering's gazelles. Presumably these species are now very rare or absent from TEBS study area.

Somalia has 12 endemic species of larger mammals (Whittaker *et al.* 1985). Of these, only Hunter's hartebeest has its center of distribution in the study area (Clauser *et al.* 1969). As noted above, Soemmering's gazelle was previously reported in the study area and dibatag were occasionally reported during JESS surveys.

Construction of Baardheere Dam will have little effect on larger wildlife. Populations in the inundation area are negligible except for the ubiquitous warthogs and baboons (Table 25; FP River Section II). Depending on development of vegetation around the reservoir perimeter, wildlife habitat may

Table 26. Larger mammals seen during ground visits to the Jubba Valley by JESS and by Somalia Research Project (Varty 1988a).

COMMON NAME	SCIENTIFIC NAME
greater bushbaby	*Galago crassicaudatus*[1]
lesser bushbaby	*G. senegalensis*
blue monkey	*Cercopithecus mitis*[1]
Kirk's dikdik	*Madoqua kirki*
Guenther's dikdik	*M. guentheri*
Salt's dikdik	*M. saltiana*
Red forest duiker	*Cephalophus natalensis*[1]
dibatag	*Ammodorcus clarkei*[2]
Cape buffalo	*Syncerus caffer*[1]
lion	*Panthera leo*
leopard	*P. pardus*[1]
caracal	*Felis caracal*
African wild cat	*F. sylvestris*
large-spotted genet	*Genetta tigrina*[1]
common genet	*G. genetta*
African civet	*Viverra civetta*[1]
spotted hyaena	*Crocuta crocuta*
striped hyaena	*Hyaena hyaena*
bat-eared fox	*Otocyon megalotis*
black-backed jackal	*Canis mesomelas*
aadvaark	*Orycteropus afer*
porcupine	*Hystrix cristata*

[1] *Of limited distribution and probably rare within Somalia;*
[2] *Endemic to Horn of Africa (Whittaker et al. 1985).*

increase, particularly if human population is reduced by resettlement. Downstream of the dam wildlife habitat will decrease, but as detailed above, the floodplain is no longer an important dry season refuge.

2. Large Aquatic Animals

Crocodile and hippopotamus are abundant in the river and some dhesheegs and swamps. Despite being confined to the vicinity of the river, their combined biomass exceeds threefold that of all other larger wildlife throughout the TEBS area. Population size and density were estimated in the sample aerial censuses and during total aerial surveys of the river (Watson and Nimmo 1988). Five-hundred and eighty-seven hippopotamuses and 1,537 crocodiles were seen during a total count in jiilaal 1987. Hippopotamus were evident in all river sections from III south, but reached highest density in Section V. Crocodiles were seen in all sections with most in Sections IV, V, and VI. Allowing for sampling procedures in the various surveys, the Jubba is probably home to 3,000 to 6,000 hippopotamuses and 40,000 to 150,000 crocodiles (Watson and Nimmo 1988). Crocodile density is exceptionally high.

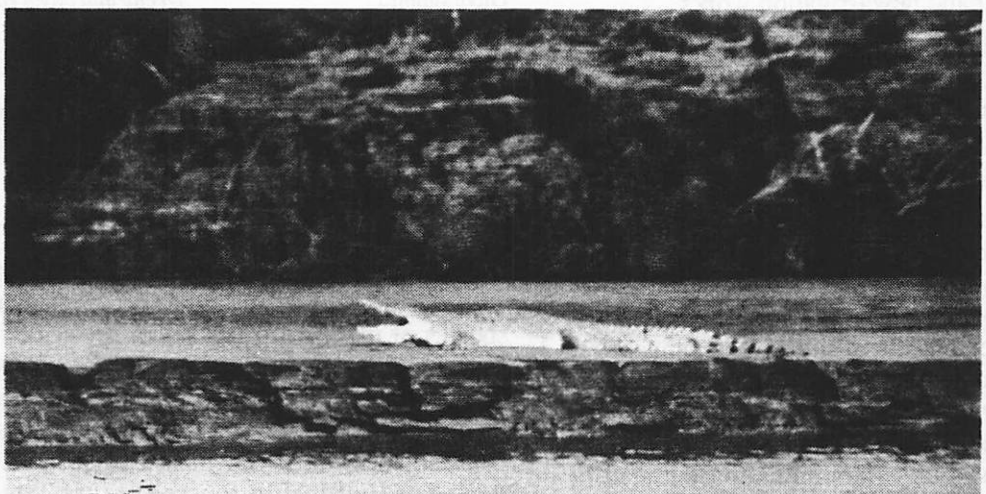
After filling of the reservoir behind Baardheere Dam, a large new water body will lead to an increase in populations of crocodile and hippopotamus. Fish populations undergo a rapid increase behind new dams, creating a large food supply for crocodiles. Although some currently favored basking and nesting sites on sand banks will disappear, the large lake perimeter will provide many new ones. The extent of increase in hippopotamus populations is more difficult to predict. Suitable herbaceous forage may be relatively scarce around the reservoir in the early years (see Section VII.E)

Freshwater turtles and their nests were also seen during aerial surveys and fisheries studies. They remain unidentified.

3. Smaller Wildlife

Birds in Middle and Lower Jubba were assessed by JESS and, in forests between Bu'aale and Fanoole Barrage, by Somali Research Project. Smaller mammals of the Jubba forests were also studied by SRP.

JESS studies concentrated on birds which breed in Europe and Asia, but spend the northern winter in Africa (palearctic migrants). Distribution of these



Crocodiles are significant predators of people and livestock.

birds is well-known in breeding grounds and wintering grounds in Kenya and to the south. However, migration routes and possible wintering grounds in the Horn of Africa are poorly known. JESS ornithologist David Pearson conducted surveys in March and November 1987. His main objective was to discover whether the Jubba Valley is a significant wintering ground and whether large numbers of migrants use the valley as a route to wintering grounds further south. In addition, likely impacts of developments linked with Baardheere Dam were assessed.

Pearson's reports (1987a; 1987b) should be consulted for details. Approximately 20,000 migrant wading birds were estimated to be in the valley south of Jilib in November, primarily around irrigated rice schemes. The most numerous species were wood sandpiper (*Tringa glareola*) and ruff (*Philomacus pugnax*). Little stint (*Calidris minuta*), together with wood sandpiper, were common in March, but further north in dhesheegs between Bu'aale and Fanoole Barrage. African waders were also well represented in both surveys. Although some wader habitat in dhesheegs may be lost after construction of Baardheere Dam, it is likely that new habitat far in excess of that lost will be created by the reservoir and new irrigation works.

Marine mud-flats in Kismaayo are feeding grounds for 4,000 additional waders. This area is an important feeding-ground in a regional context. Although not currently threatened, activities in Kismaayo should be monitored to ensure that these mud-flats remain intact.

Nineteen species of migrant land birds were recorded in both March and November, although species composition differed somewhat. It is unclear to what extent these birds are dependent on evergreen floodplain habitats. In March, when conditions were very dry, many were found in dry bushlands of the river-dependent zone. However, in November these birds were more concentrated in the evergreen vegetation.

Five new records of bird species for Somalia were recorded during these brief surveys indicating the paucity of previous studies. Overall, Pearson (1987a; 1987b) concluded that palearctic migratory birds were unlikely to be adversely affected by construction of Baardheere Dam.

Bird studies by SRP were concentrated in forest reserves at Shoonto and Barako Madow (Wood 1988). Thirty-eight species were caught in the forests and a further 72 species recorded in or adjacent to the reserves. Of the 38 species, Pearson (1987a) observed five in non-forest, but riverine habitats. Thirteen SRP species are considered rare, or very restricted in distribution within Somalia. Eleven species are regarded as likely to be lost to Somalia if the remaining riverine forest is lost (Table 27). A further 13 species are vulnerable (Wood 1988).

Table 27. Birds and mammals from Shoonto and Barako Madow forests that are rare, or of restricted distribution, in Somalia (Wood 1988; Varty 1988a). Mammal species are in addition to those in Table 26.

COMMON NAME	SCIENTIFIC NAME
BIRDS	
Pel's fishing owl	*Scotopelia peli*
Brown-hooded kingfisher	*Halcyon albiventris*
Eastern bearded scrub robin	*Cercotrichus quadrivirgata*
Red-capped robin chat	*Cossypha natalensis*
Black-headed apalis	*Apalis melanocephala*
Ashy flycatcher	*Muscicapa caerulescens*
Black-throated wattle-eye	*Platysteira peltata*
Little yellow flycatcher	*Erythrocercus holochlorus*
Crested flycatcher	*Trochocercus cyanomelas*
Olive sunbird	*Nectarinia olivacea*
Dark-backed weaver	*Ploceus bicolor*
BATS	
Parisi's slit-faced bat	*Nycteris parisii*[1]
Commerson's leaf-nosed bat	*Hipposideros commersoni*
Eisentraut's bat	*Pipistrellus eisentrauti*[1]
House bat	*Scotoecus albigula*

[1] *very rare internationally*

In addition to larger mammals listed in Tables 24 and 26, SRP recorded eight species of bats, two species of mongoose, and seven species of rodent in riverine forests at Shoonto and Barako Madow (Varty 1988a). Thirty-two mammal species were recorded from the forests and a further nine species from adjacent areas. Of these, and in addition to those listed in Table 26, four species can be regarded as being rare or of restricted distribution within Somalia (Varty 1988a). Two bat species are thought to be very rare internationally.

Sixteen species of rodents and two species of shrew are reported as possible endemics in Somalia or neighboring areas of Kenya (Whittaker *et al.* 1985). Of these, only the Somali shrew is reported from the Jubba and its status as an endemic is no longer viable following collection in Ethiopia, Sudan, and the Arabian peninsula (Varty 1988a).

Literature surveys show that 29 species of amphibians and 127 species of reptiles are recorded in southern Somalia (Whittaker *et al.* 1985). Of these, one amphibian and 29 of the reptiles are endemic to Somalia, but none restricted to the study area. Information on numbers and distribution is inadequate to assess the conservation status of these animals.

Little is known of terrestrial invertebrates in the study area. Nineteen species of butterflies were recorded by SRP, but no other specific studies are known. Riverine habitats of the Tana river in Kenya are particularly rich in arthropod species (Collins *et al.* 1986). Three-hundred and fourteen species of ground dwellers were found on river beaches and floodplain, 75 percent of which are absent from the adjacent non-floodplain dry bush in the dry season. Several species were new to science. Given its isolation from similar rivers, the Jubba is also likely to have endemic arthropods. Collins *et al.* (1986) consider that river regulation has adverse effects on some arthropods. Many of the 78 species restricted to open sand banks may not survive if these habitats become vegetated as a result of a more constant river level. Similar effects on the Jubba are likely after construction of Baardheere Dam when fluctuations in water level will be reduced.

4. Relationships Between Wildlife and Local People

Inhabitants of the study area interact with wildlife on a daily basis. Some interactions are beneficial to humans, such as consuming animals or their products. Others are detrimental. Many wild animals are pests to crops. Some are predators of people or their livestock. Many other species are encountered more or less frequently, but their relationship with people is neutral.

It is unlikely that rural subsistence farmers and pastoralists are directly responsible for the dramatic decline in some larger wildlife species. Most slaughter is the result of poaching, defined here as killing wild animals for non-subsistence trade in wildlife products. However, increased farming along the river has undoubtedly reduced habitat for some wildlife species. Opening up riverside lands also increases livestock occupancy, thereby increasing competition for forage. Reduction of large predators may be more linked to subsistence farmers, because less wildlife will force predators to switch to livestock, and farmers are more likely to eliminate these predators.

Hunting for food is widespread in the study area, but is a dominant means of subsistence for relatively few people. Non-hunters also benefit by the purchase of game meat. More than 80 percent of SEBS respondents claimed that they never eat game; only four to seven percent eat hunted meat often (daily/weekly). More than 15 percent of riverine farmers and nomads eat game occasionally, whereas urban consumption is negligible.

It is likely that hunting and consumption of game is underreported since hunting is technically illegal in most of the study area (see Map 2). Douthwaite (1985) found increasing reluctance to answer questions about hunting south of Saakow. In Dhoobley, near the dam site, half of the men questioned (10 respondents) had hunted in the previous week. For all respondents, game was the last meat eaten. Between Baardheere and Saakow almost 60 percent (37 questioned) ate game, but only one man admitted to hunting. For five, the last meat consumed was game. South of Saakow to Fanoole Barrage, all those questioned denied hunting or eating wild animals. However, other surveys indicate that hunting remains common in the southern districts. In Douthwaite's (1987) survey lesser kudu was the preferred prey (64 percent), followed by gerenuk and dibatag (each 11 percent), giraffe (7 percent), and bushbuck and waterbuck (4 percent).

SRP administered a questionnaire to hunters in five villages in Bu'aale District (Varty 1988a). Both riverine forest and dry bush species are taken with emphasis on riverine habitats during dry seasons. Lesser kudu, dikdik, and gerenuk are most common prey in the bush and red forest duiker, bushbuck, and waterbuck in riverine areas. Most villagers use traps or bow and arrow. They also buy game meat from "shifta" (non-locals with firearms), who are also said to be responsible for most poaching in the area.

Although reliable quantitative data are lacking, it is probable that hunted meat is an important dietary supplement for Jubba residents. Low protein consumption by farmers and dry-season shortages of grain in some years accentuate the significance of wildlife as a food source.

Wildlife as a nuisance to most rural people is perhaps a more common experience than as food. Crocodiles are important predators of people and livestock throughout the area. Quantitative data are not available, but people in most villages speak of recent crocodile attacks. Given the extremely high crocodile population, such predation is to be expected. Although at low density, lion and spotted hyena are also cited as attackers of livestock.

The most common terrestrial large mammal species habitually found in the floodplain—warthogs and baboons—together with amphibious hippopotamuses, are important crop pests. These species are always cited when farmers are questioned. Other recognized pests are porcupine, bushpigs, waterbuck, bushbuck, vervet monkeys, and various rodents. *Quelea* birds are serious pests of rice and sorghum, but do not attack maize, the main subsistence crop in the riverine area. Other birds are not generally regarded as pests, although sacred ibis (*Threskiornis aethiopica*) occasionally attack sesame.

At present, activities of the Wildlife Department are largely directed at protecting wildlife from poaching and hunting. Such a role induces conflict rather than cooperation with rural people. Control of wildlife that is a genuine threat to people or their economic activities is a necessary activity of any wildlife department. A more forceful wildlife control policy should be adopted, directed particularly at ubiquitous pest species such as hippopotamus and warthog. Even more urgent is a crocodile control program to reduce human predation. Crocodile skins have a high monetary value. Provision of controlled concessions to harvest crocodiles could provide the Wildlife Department with a substantial income. Since crocodile and hippopotamus populations will increase in the reservoir behind Baardheere Dam, properly managed cropping will not seriously endanger the populations. To enable legal international trade in the skins, IUCN clearance is required since Nile crocodile are included in the Convention on International Trade in Endangered Species (CITES). Such a program would need good regulatory and management skills. It may be preferable to offer a concession to a reputable wildlife management company since local expertise in wildlife biology and skin preparation is lacking. Research into breeding biology of crocodiles on the Jubba is an essential prerequisite to a cropping program.

Recommendation: *A crocodile cropping program should be introduced and methods of preparation and marketing of skins be investigated.*

Recommendation: *The Wildlife Department should more effectively control crop pests, concentrating on those species with large populations.*

Honey production is a significant economic activity involving wild animals. Traditional beekeeping is widespread in the Jubba and Shabeelle floodplains (Douthwaite 1985). Honey-hunting is also carried out, but to a lesser extent. Beekeeping is only practiced by sedentary farmers, but nomads also hunt "wild" honey. In 1983 more than 35,000 hives were thought to be in use along the Jubba. Income from sale of honey ranged between 330 and 10,000 SSh per year per beekeeper. An estimated 150,000 l of honey was produced, with a total value of 7 million SSh (Douthwaite 1985). The price of honey has risen from 50 SSh in 1983 to 200 SSh in 1986 (Varty 1988b). Beekeeping is a secondary activity of farmers. As such, it provides a substantial source of income for many individuals.

Most hives are placed in large forest trees close to villages, but occasionally hives may be as much as a six-hour walk from home. Beekeepers may own as many as 100 hives, the median number being 30. Hollowed logs are used as hives. Colonization rates by bees range from 50 to 100 percent and each produces approximately 5 to 10 l per year (Douthwaite 1985). In 1983 beekeeping was increasing markedly, particularly in forest areas. Agricultural areas are less favorable due to a shortage of suitable trees and theft. However, honey production is said to have declined in several villages recently, apparently as a result of poor flowering of important pollen species (SEBS field notes). This change may reflect natural flowering patterns which respond to floods and droughts, but it could be a trend caused by agricultural expansion in the floodplain and loss of wild plants.

Beekeeping should be encouraged in the study area, perhaps with external assistance. Patterson (undated), prepared a project proposal which could be implemented in the Jubba Valley. He suggests investigation of hive types under Somali conditions to determine the most appropriate that can be constructed with local materials. The project would emphasize demonstration of improved beekeeping techniques and equipment.

A possible threat to honey production is a plan to eradicate tsetse fly in the Jubba using insecticide spraying (see also Section VIII.D). Experiments and surveys of effects of spraying on bees in the

Shabeelle were conducted in 1983 and 1984 (Douthwaite 1985). In 1983, bee mortality, hive desertion, and consequent economic loss were substantial. In 1984, losses were reduced because of the season and time of day that spraying was executed. Future spraying should be programmed to minimize bee losses and compensation should be paid for lost honey production. If necessary, re-introduction of bees to sprayed areas should be carried out.

Recommendation: *Honey production should be encouraged and further developed. Steps should be taken to minimize the effects of tsetse eradication on bee populations.*

C. Vegetation Resources and Conservation

Most of the study area is vegetated by dry bush rangelands. These areas have been livestock grazing and browsing areas for centuries. Vegetation is not seriously degraded over most of this area, although gradually increasing livestock and human populations may lead to problems in the future. No special conservation measures are proposed beyond those relating to forestry and range management.

Of more concern is the Jubba floodplain. Although most of the forest has gone, vegetation communities remain significantly different in species composition from non-floodplain lands (Section VI; Appendix D). Of 313 plant species recorded in JESS surveys, 131 were restricted to the floodplain. Many of these 131 species are known to occur in habitats away from TEBS study area, but their distribution in Somalia and East Africa can only be ascertained by a study of herbarium records. Such a study was not possible during JESS because identifications were not complete until the end of the project. JESS plant collections were primarily monitoring site-based and do not claim to be comprehensive. Even so, many new records for Somalia were found (see Table 16).

Further research to determine the wider distribution of Jubba floodplain plants is worthwhile. J. Gillett (personal communication) suggests that three species (*Cola* sp. nov., *Pavetta tranjubensis*, *Acacia maculusoi*) may be confined entirely to the Jubba; two species (*Camptolepis ramiflora*, *Adenopodium rotundifolium*) are very rare elsewhere; and a further six species (*Rinorea elliptica*, *Harrisonia abyssinica*, *Lepisanthes senegalensis*, *Polysphaeria mutliflora*, *Spirostachys venenifera*, *Drypetes natalensis*) may be restricted within Somalia to the Jubba. Gillett emphasizes that herbarium records need checking to verify this list. An appropriate research project would be to check herbarium records at the East African Herbarium (Kenya National Museums), the Royal Botanic Gardens (Kew, U.K.), and the herbarium in Florence, Italy. Additional fieldwork may then be desirable to assess the distribution of species which appear to be of restricted to the Jubba floodplain. International conservation bodies such as IUCN or World Wide Fund for Nature (WWF) are appropriate bodies for financial support.

Recommendation: *External funds should be sought to support a research project into the distribution of Jubba floodplain plant species.*

Species diversity at the level of study plots is generally lower in the floodplain than in nearby dry bushlands (Section VI). However, this fact does not reduce conservation value of riverine habitats because they greatly increase the diversity of the study area as a whole. Many floodplain species are rare or of restricted distribution in Somalia, thereby increasing their conservation status.

Terrestrial vegetation in the floodplain between Baardheere Dam site and Luuq town will be lost entirely. Most of the inundation area surveyed by JESS comprises secondary woodlands, bushlands, and grasslands interspersed with croplands. One species of sedge (*Cyperus* sp. nov; JESS collection number 279), apparently new to science, was collected on the eastern floodplain south of Luuq adjacent to TEBS ground monitoring site 64. The species may occur in other areas, since the Jubba floodplain remains poorly collected. It is possible that this plant will find new habitats around the edge of the reservoir. Although the species is unlikely to have any special economic value or aesthetic appeal, it could easily be salvaged and propagated elsewhere as its precise location is known. A project to conserve this sedge could be combined with other proposals concerning vegetation conservation. Distribution could be clarified if field work is required by the floodplain species distribution project recommended above. If salvage proves desirable, the sedge could be transplanted to Shoonto forest reserve. This reserve has relatively diverse floodplain physiography and a suitable habitat could probably be found. Costs involved in this salvage operation are very low.

Recommendation: *Action should be taken, in conjunction with other proposals concerning vegetation conservation, to protect the new sedge species found in JESS surveys.*

Downstream of the dam, floodplain vegetation is expected to undergo gradual impoverishment due to changes in hydrology and land use described in previous sections. Land-use changes are already rapid and measures are urgently needed to conserve the remaining forest patches in particular.

Conservation of Riverine Forests

Riverine forest along the Jubba declined from 9,350 ha in 1960 to 900 ha early in 1987. New forest clearance has occurred since then leaving a few small remnants (Appendix J). Even less forest remains on the Shabeelle, where the last few hectares are conserved in Balcad Nature Reserve. Jubba forests are of great conservation value as they contain many plant species previously unrecorded in Somalia (Table 16). Biogeographically, they represent the northernmost sections of East African lowland and coastal forests. The nearest comparable riverine forests are on the Tana river 400 km southwest, in Kenya. These lowland forests are threatened by loss or degradation throughout the East African region, thereby accentuating the international case for conserving forest on the Jubba (Douthwaite 1987; Madgwick 1988). Woody vegetation of seasonal rivers in Bushbush is probably different in structure and species composition to Jubba forests (Madgwick 1988; Kuchar and Mwendwa 1982). The Bushbush vegetation is equally worthy of conservation as discussed in Section VIII.D. The so-called Boni forest, straddling the southern Somali-Kenyan border, seems to be a mixture of woodlands, bushlands, and thickets (Kuchar and Mwendwa 1982; Abel 1976).

Madgwick (1988) compares species composition in Barako Madow and Shoonto forests (Map 2; Figure 17) with those of Tana forests. She concludes that Tana forests are more diverse because of a more dynamic river system. However, JESS collections from different forest patches significantly increase the number of common larger woody plants in the Jubba forests. Of the additional JESS species in Table 16, only six of the 18 are recorded by Hughes (1985) for the Tana forests. (The six species are *Flueggea virosa*, *Drypetes natalensis*, *Spirostachys venenifera*, *Acacia elatior*, *Lepisanthes senegalensis*, and *Polysphaeria multiflora*.)

Until recently, it was thought that Jubba forests contained several species of endemic trees (see discussion in Kuchar 1988). However, taxonomic revisions indicate that most of these plants belong to well-known and widespread species. One of these species, *Camptolepis ramiflora* (absent from Tana forests) remains of interest since it is previously known as a rare plant of the Tanzanian coast. JESS has collected what appears to be a new species of *Cola* (site 8; JESS collection number 242), thus reopening the possibility of Jubba endemics.

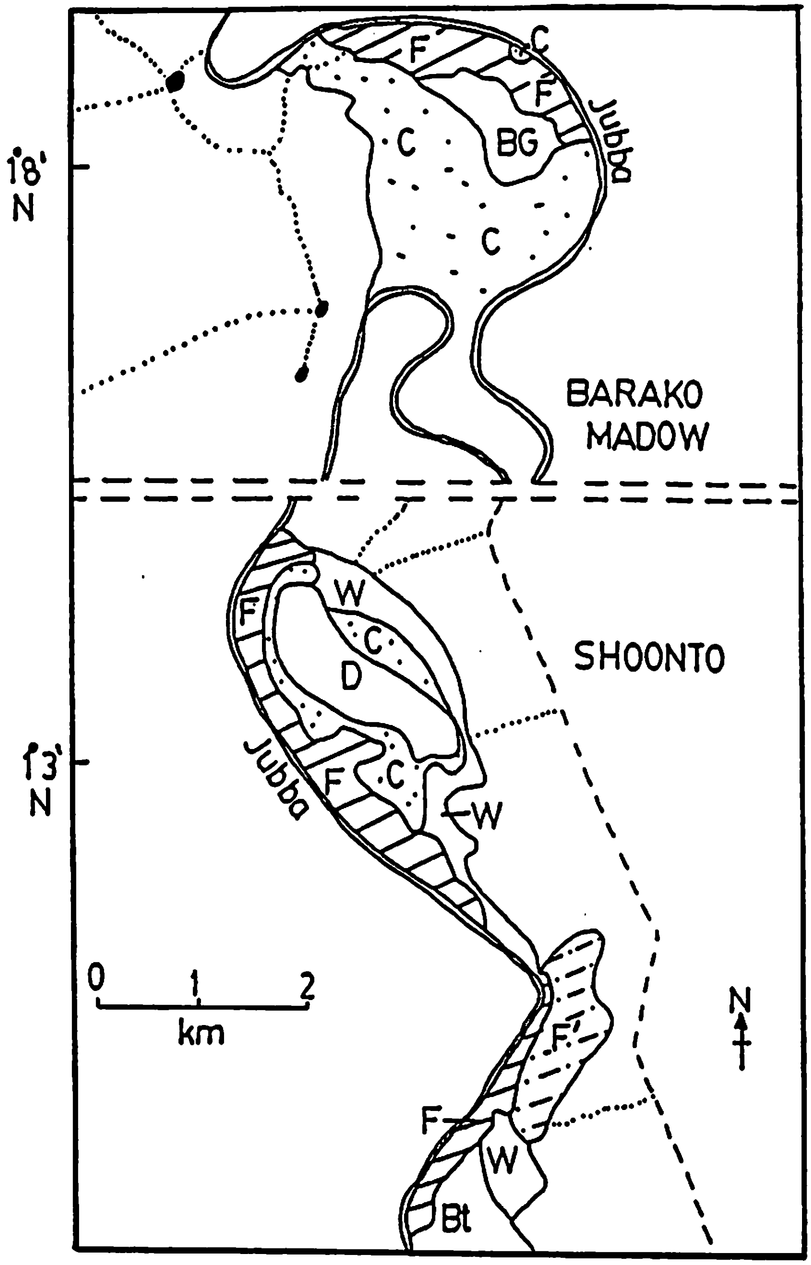
Effects of Baardhhere Dam on these forests are discussed at length by Deshmukh (Appendix J), Synnott (1988), and Madgwick (1988). Although they disagree over details, these authors agree that survival prospects for the forests are good, if they are properly protected.

The two largest remaining blocks of forest are already designated as forest reserves (see Map 2; Figure 17). Some effort has been made at demarcation and various management proposals have been put forward by SRP (Madgwick and Wood 1988) and the Somali Ecological Society (unpublished document). These proposals call for external funding. Such funding may soon be recommended by the World Bank as part of its proposed system of loans to the Baardheere Dam Project.

These forest reserves should be the focus of riverine forest conservation on the Jubba. The following measures should be undertaken as soon as possible:

- checking of boundary markers;
- prevention of any agricultural land registration in the reserves; and
- hiring of extra guards from neighboring villages to prevent cutting of trees and hunting.

Other conservation measures, variously proposed by Deshmukh (Appendix J), Madgwick and Wood (1988), and the Somali Ecological Society could then be assessed when external funding is available. Vegetation alone dictates that these reserves are worthy of protection. However, they also contain many animal species which will benefit from conservation activities. Long-term survival of larger rare animal species is questionable in such small protected areas, but this is no argument against making the attempt, since the vegetation at least will remain long beyond any normal planning horizon.



KEY
F = floodplain
F'= forest above floodplain
W = woodland
BG = bushed grassland
Bt = thicket bushland
C = crops
D = open water in dhesheeg

Figure 17. Vegetation and land use in and around Barako Madow and Shoonto forest (Deshmukh 1987)

Future actions to be considered should include the following:

- The reserves should be zoned so that the best forest areas are completely protected, while some minor extractive use is permitted in less pristine areas.
- Trees should be planted from other Jubba forests in degraded areas of the reserves to increase survival prospects of plants native to the area, but not presently in the reserves. In particular, propagation of the new *Cola* species should be attempted, followed by other species from the "JESS additional list" of Table 16.
- River profiles should be assessed to determine whether Shoonto dhesheeg will flood from the river when Baardheere Dam is completed. If not, a channel or pumping system should be used to flood the dhesheeg as it is an important site for wading birds. Addition of water to the dhesheeg may alleviate the expected impoverishing effects on vegetation of altered hydrology after the dam is built.
- The periodic flood recession cultivators using Shoonto dhesheeg should be compensated for their loss of occasional farmland.

Administration of these reserves should be incorporated into the activities of the new FAO-executed forestry project in the NRA which will be active in the area (see Section VII.A.4). The Somali Ecological Society is also interested in playing a role in Jubba forest conservation and has experience at managing a nature reserve on the Shabeelle. The society can provide voluntary expertise and labor and help to publicize the reserves. Legal recognition is currently being sought which would enable the society to obtain and manage funds from external donors. If sufficient funds are available, the Somali government should consider turning these forest reserves into a "demonstration project" in conservation management with assistance from the Somali Ecological Society and the FAO project. The reserves will be accessible to visitors when the proposed all-weather road from Jilib is complete. Management techniques for protection and restoration of ecosystems, integration of conservation into rural development, research, and education could all be incorporated into plans for the reserves.

An additional nature reserve should be designated, at least temporarily, encompassing JESS ground monitoring site number 8 (Map 2). This small area (10 to 20 ha) of forest is completely undisturbed, despite being within walking distance of Bu'aale town. The area is probably too small for permanent protection, but it contains six species on the JESS list of Table 16, including the new *Cola* sp. and three other new Somali records. Local informants indicate that the area may already be an informal reserve, since it is favored as a meeting place for important events. This reserve would serve as a source of seed for attempted propagation of species absent in Shoonto and Barako Madow forests. Other species on the list should be sought from forest remnants around Kaytooy.

Recommendation: *Shoonto and Barako Madow forest reserves should be given increased protection immediately. Future management options depend on external funding, but should take account of the proposed SRP management plan and the additional measures suggested in this report.*

D. Conservation Proposals for JESS Study Area

Numerous recent missions from World Bank, WWF, and IUCN have excited interest in biological conservation in Somalia. In July 1988, a World Bank consultant specifically looked at wildlife conservation measures that might be appropriate in relation to construction of Baardheere Dam. One possibly relevant World Bank policy is that of "compensatory wildlands." Where World Bank projects take over "wildlands," a suitable and similar area, at least equal in size, is to be set aside for conservation. Unfortunately, the definition of wildlands ("natural land and water areas in a state virtually unmodified by human activity"; Goodland 1988) excludes most of Africa outside parts of the rainforest and montane zones. The Jubba reservoir area is substantially modified both in the floodplain and surrounding bushlands by agricultural and pastoral activities. Indeed, virtually all savanna conservation areas throughout Africa are excluded by the World Bank definition of wildlands. Thus the policy is not strictly applicable to the Baardheere Dam Project. However, the principle, of relating conservation activities to development projects is a good one. For example, World Bank interest in conserving Shoonto and Barako Madow forests is an appropriate response to Baardheere Dam construction.

Various conservation areas have been declared or proposed in Gedo, Middle Jubba, and Lower Jubba (Map 2). These are already in existence (although the exact legal status is unclear in most cases), but are barely recognized on the ground.

1. Bushbush Controlled Area and Jubba Left Controlled Area.

These vast areas cover most of Middle and Lower Jubba Regions. Regulations covering "Controlled Areas" (Article 9; chapter 1; Book 1. Fauna [Hunting] Conservation) include:

> . . . no person shall . . . hunt any game animal without a Game Licence for such animal ...obtained from the Minister . . .

At present no licenses are being issued as a result of a hunting ban, although occasionally hunting by foreign dignitaries is permitted.

Such regulations are unenforceable in practice over such large areas with low density of animals. Unenforceable regulations bring the law into disrepute. Periodic campaigns against poachers may be worthwhile, but measures against subsistence hunters are not. Since poaching is illegal in all areas, these "Controlled Areas" should be abandoned. The concept of smaller controlled areas may be useful when and if a national conservation strategy is enacted. JESS and related studies indicate that the only Somali-endemic large mammal inhabiting these areas is the dibatag. Previous surveys indicate that a few Soemmering's gazelle may remain. However, the distributional center of these animals where any conservation effort should be directed, is northwest of the Shabeelle.

Recommendation: *Bushbush and Jubba Left Controlled Areas should be abandoned.*

2. Bushbush National Park/Game Reserve

Although reportedly now designated as a national park, Bushbush (Map 2) does not meet international requirements for such designation since it contains people; nor are funds currently available to manage the area as a national park. Conservation funds currently being sought by the Wildlife Department to protect this area should take the following remarks into account. Proposals to formalize national park status are ill-advised.

Bushbush has long been recognized as a prime candidate for conservation in southern Somalia. The area is diverse in landscape, vegetation, and fauna. Watson and Nimmo (1985) show a fine-grained pattern of more than 10 different land systems. Vegetation is varied including wooded thickets, strips of riverine forest, marshlands, and grasslands (LRDC 1985). In 1984-1985 biomass of larger terrestrial wildlife was high, with much of the area supporting more than 1,000 kg km^{-2} and local concentrations exceeding 5,000 kg km^{-2} (Watson and Nimmo 1985). Species included gerenuk, duiker, Hunter's antelope, lesser kudu, giraffe, and elephant. In 1975 topi, bushbuck, buffalo, and rhinoceros were also seen (Abel and Kille 1976). Hunter's antelope is endemic to the Somali/Kenyan border.

Incursions by livestock are limited by tsetse infestation. Across the Kenya border is the Boni National Reserve enhancing the conservation potential of Bushbush. Abel (1976) proposed a management plan for the area as a national park. Permanent residents include coastal people involved in fishing, trade and farming, inland cultivators, and subsistence hunters. Abel (1976) considered that the hunters " . . . (are) not at all harmful . . . " and illustrated their conservation ethic by adding " . . . they have allowed the rhinoceros population to remain at quite high densities." (Since 1976, rhinoceros numbers have declined sharply primarily as a result of poaching, not subsistence hunting.) He then states that "the park will mean the end of this culture" and "Other areas where they can continue their traditional way of life do not exist."

Combining these statements makes it illogical to suggest moving these subsistence hunters. Their activities are compatible with conservation. However, protective measures should be enhanced by preventing land registration for cultivation, reinforcing anti-poaching activities, and preventing attempts at tsetse eradication in a suitably defined conservation area. These management activities should be carried out by local people with some external monitoring to ensure that mutually agreed objectives are pursued. Such proposals require a minimum of funding which should be sought from external sources.

Recommendation: *Efforts should be made to protect the Bushbush area intact with local populations integrated into management proposals.*

3. Barako Madow and Shoonto Forest Reserves

These two reserves, including recommendations for conservation, are dealt with in Section VIII.C. Two other forest reserves in Middle Jubba reportedly in existence are Nus Duuniya and Kaytooy. Unfortunately, forest in these areas is practically gone. Had effective measures been taken sooner, Kaytooy would have been especially worthy of protection.

4. Other Proposed Conservation Areas.
Abel and Kille (1976) outlined several areas of conservation potential as forest or wildlife reserves (Map 2). Of these, Wildlife 1 and 2 have little to offer from the biodiversity standpoint. Wildlife 3, Dhesheeg Waamo, while an important perennial to semi-perennial wetland, is heavily used by pastoralists and those practicing flood-recession agriculture. For these reasons and those discussed in Section VIII.B.1, additional wildlife areas should not be designated, with the exception of the Shabeelle Swamps (Wildlife Area 4; exact position to be determined). Conservation of these swamps is desirable as much for their wetland/vegetation status as their wildlife. In addition, these swamps are an important natural flood protection device. They absorb Shabeelle flood peaks and reduce flooding downstream. Suitable areas should be selected bearing these criteria in mind. Hydrological considerations will need to be taken into account when planning conservations measures. Watson (personal communication) points out that the swamps are slowly drying and that wildlife is much reduced and human use intensifying. A dam on the Shabeelle has recently been completed in Ethiopia. Since flood peaks in Somalia will probably be reduced, the future hydrological status of these swamps is unclear. Monitoring of river releases from Ethiopia may be required to assess the future of the swamps.

According to LRDC (1985), extensive swamps exist southwest of Guudo Ferry at Madax Maroodi, Baar Madax, and Balli Weyne. These areas appear to have good wildlife populations (Watson and Nimmo 1985; Parker 1987). Human population density is thought to be low, although the northern edge is important for livestock in dry seasons. To the south, pastoral use is restricted by dense woody vegetation (LRDC 1985). A conservation project is already planned and about to be funded for swamps higher on the Shabeelle northwest of Haaway (Wildlife Department 1988). However, this project is poorly conceived and should not be used as a model for other areas in Somalia. Complex zonation of permitted land use and related proposals make this project unworkable with foreseeable management and extension services. A recent World Bank consultant (Blower, personal communication) proposes that areas in the lower Shabeelle Swamps be conserved to compensate for land lost behind Baardheere Dam. He emphasizes the need for competent assessment of boundaries and management proposals. Since such expertise and experience is not available locally, he proposes that WWF be contracted to carry out such work. These proposals are worthy of support.

Recommendation: *Appropriate areas in the lower Shabeelle Swamps should be conserved for their wildlife populations, for the scarcity of such wetlands in Somalia, and because of their importance in downstream flood control.*

Planned forest reserves are referred to by Abel and Kille (1976), but are not discussed. Area "Forest 1" (Map 2) appears unexceptional in vegetation according to recent maps (Watson and Nimmo 1985; LRDC 1985). A better prospect may be *Acacia tortilis* woodlands on the coastal dunes (Forest 2, Map 2). Protection of this area (currently commercially exploited for firewood), would help to prevent sand dune erosion, which is an increasing problem along the coast.

A recently proposed Jubba Valley Controlled Area (Map 2) is not worthy of consideration for reasons given above in discussion of the other Controlled Areas.

The new FAO project on forest and wildlife support in Lower and Middle Jubba (UNDP 1988) should be the best umbrella for conservation activities in the study area. Bushbush, Jubba forests, and other possible reserves would have a local institutional framework with multilateral donor support.

Recommendation: *Future conservation activities in the study area should be administered within the framework of the FAO/NRA Forestry Sector Support and Training Project.*

Tsetse Control and Conservation
National policy is to eradicate tsetse flies and, therefore, most trypanosomiases in Somalia. Distribution of flies is limited to the Jubba and Shabeelle riverine areas and a distinct population in the southwest corner of Somalia along the coast and Kenyan border (Map 2). Eradication of tsetse will increase livestock production in these areas, but have potentially detrimental effects on biological diversity. Specific problems relating to beekeeping have been mentioned (Section VIII.B.4).

Other wildlife may also be adversely affected. Insecticides used in spraying operations kill insects other than tsetse and may, therefore, affect insectivorous animals. Monitoring feeding behavior of insectivorous bats and a bird (little bee-eater; *Merops pusillus*) in the Shabeelle suggests that effects on their insect prey are not great (Douthwaite 1985). Fish mortality can also occur, but again adverse effects seem to be small or temporary in the Shabeelle (Douthwaite 1985). However, as Wood (1988) points out, to small and isolated populations of fish- and insect-eating birds, a temporary effect on food supply may lead to local extinction. Small conservation areas such as the Jubba forests are particularly vulnerable to such effects.

Since it is not certain whether tsetse eradication from the Somali riverine systems is feasible, conservation areas should be the last to be treated. Such treatment should then go ahead only if eradication is proving entirely successful. The least harmful techniques available should be used in eradicating tsetse from these areas. Such techniques will be apparent from experimental work being carried out by National Tsetse and Trypanosomiasis Control Project (NTTCP) and from Douthwaite (1986).

Bushbush as a conservation area presents a somewhat different situation with respect to tsetse. Jubba and Shabeelle fly populations are isolated from others in East Africa and benefits of eradication could be permanent (Map 2). The fly population of Bushbush is contiguous with coastal and Tana River tsetse in Kenya (LRDC 1985). Therefore, the southeast corner of Somalia will be continually re-infested from Kenya. Rather than treating this fact as a problem, it should be grasped as a conservation opportunity. Protection of wildlife and vegetation from encroachment by livestock in Bushbush will be more secure if tsetse remain in this restricted area. Tsetse control using the new and very effective pheromone traps could protect livestock in southeastern Somalia outside the Bushbush conservation area. These traps are currently being used successfully in a German Agency for Technical Cooperation (GTZ) supported project in southern Somalia.

Recommendation: *Tsetse fly eradication efforts should be restricted to the Jubba and Shabeelle systems and not be attempted in the Bushbush area adjacent to the Kenya border.*

E. Conclusions

Limited wildlife, financial, and human resources dictate that Somalia should adopt a restricted program of biological conservation. Most of southern Somalia will inevitably remain as rangeland with the higher potential areas increasingly devoted to agriculture. Nevertheless, a well-conceived and carefully executed conservation strategy would be beneficial.

Section VIII.A lists criteria that should be applied when selecting conservation areas. The proposals for the JESS study area listed in preceding sections were written with these criteria in mind.

Endemic species. The major center of Somali faunal endemism is well to the north and east of the study area. Of the larger mammals, only Hunter's antelope is relevant and could be suitably protected in the proposed Bushbush conservation area. Information on smaller animals is inadequate to recommend conservation measures. Reserves in Bushbush, Jubba forests, and Shabeelle Swamps will protect some of the species dependent on riverine and wetland habitats. Smaller species of dry bushlands are presumably not threatened unless these environments become seriously degraded by increases in livestock populations. The proposed reserves will help to protect the only known endemic riverine plants.

Rare species, internationally. The much-publicized campaigns to protect elephant and rhinoceros are of limited interest to Somalia. Rhinoceros is close to extinction in the country and only remnant elephant populations remain. Conservation efforts directed at these species will be far more effective in other countries. Two rare bat species (Table 27) will have at least part of their range protected in the Jubba forest reserves. Crocodiles are listed as "vulnerable" by the IUCN. However, Jubba populations are extremely high, and will increase after construction of Baardheere Dam. A controlled cropping program is recommended.

Rare species, or species of restricted distribution in Somalia. Several mammals, birds, and plants are restricted to riverine habitats on the Jubba. Some of these will probably be lost as a result of agricultural development. It is hoped that as the conservation areas recommended here are more effectively managed, they will become refuges for some of these species.

Diverse, unusual, and diminishing communities. Most of the study area is dry bushland supporting a high diversity of plant life. These areas are not presently threatened, except in small localized areas around settlements and watering points. Conservation areas proposed here will protect the last remnants of riverine communities. In addition, Bushbush contains dryland bushed and wooded thickets which are underrepresented in conservation areas in East Africa.

IX. FLOODPLAIN ENVIRONMENTS

Throughout preceding sections of this report the distinctive nature of the Jubba floodplain has been emphasized. This section brings together some of that information to suggest why floodplain ecology is different to surrounding areas and to suggest what changes may occur after closure of Baardheere Dam.

Several observations made earlier in the report show floodplain vegetation is different than that of the river-dependent zone. They include:

- the floodplain supports closed evergreen forest which would not normally occur unless rainfall was twice that of the Jubba Valley;
- floodplain grasslands are much more productive than is normal in the Jubba Valley rainfall regime;
- phenological activities of floodplain plants indicate a more prolonged growing season than outside the floodplain; and
- vegetation on old levees which are now far from the river and no longer flood are more like the river-dependent zone in biomass and phenology.

These features indicate that the floodplain is a more productive environment that the river-dependent zone. High production of floodplain vegetation is not an abstract ecological phenomenon since it results in greater wood and forage production for human use. This higher production could result from several factors:

- surface flooding enhances soil moisture;
- lateral infiltration of riverine water enhances soil moisture;
- sediments deposited from flood water increase soil nutrients; and/or
- flood water is rich in dissolved nutrients.

It is likely that these features combine to produce fertile floodplains. However, the relative contribution made by each factor is unknown. The role of surface flooding is obvious, but cannot account for enhanced production in non-flood years. For example, forage yield of monitoring site grasses in 1986, a non-flood year, was similar to that in 1987 when monitoring sites were flooded.

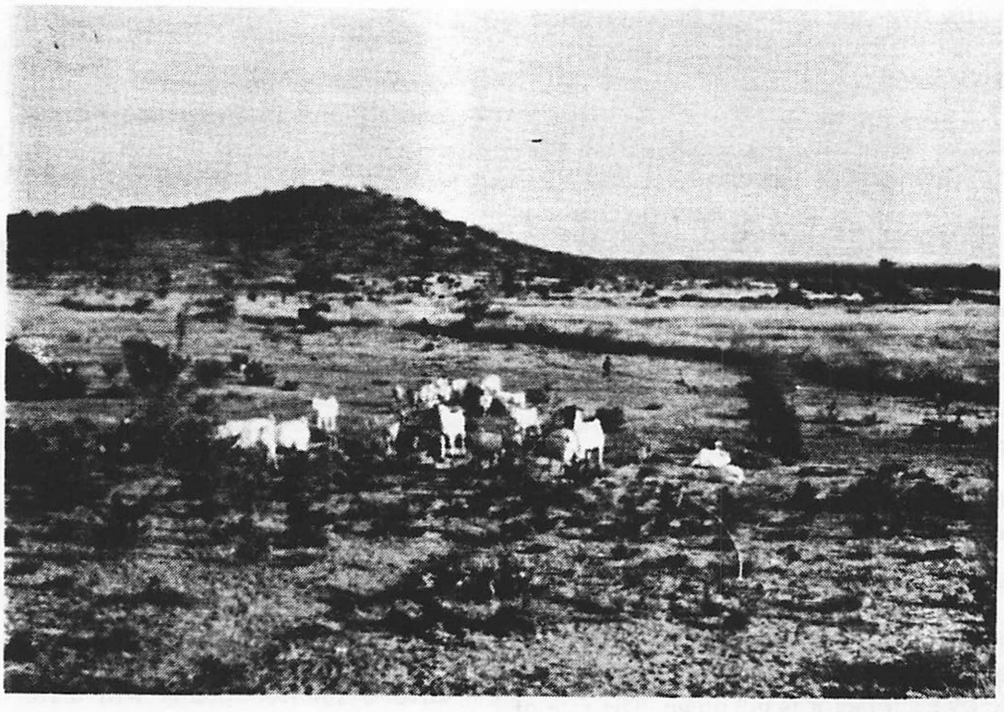
Lateral penetration of water from the river is more difficult to demonstrate, but is significant. Jubba farmers state that levee crops obtain water by infiltration from the river and subsequent capillary rise (Besteman and Roth 1988). Aerial observation of flooded dhesheegs in June 1987 showed that many contained rather clear water in contrast to the highly turbid water of the river and surface flooded areas (JESS field notes). It is likely that clear water entered dhesheegs by lateral infiltration from the river. Some clear water may have been from rainfall runoff, but rainfall in gu' 1987 was less than in 1986 when the same dhesheegs remained dry. Direct evidence of lateral infiltration is available for the Tana River in eastern Kenya. Hughes (1985) shows that the riverine water table penetrates laterally under levees and beyond for considerable distances even during low river flows. She estimates that three to seven percent of river volume is lost due to evapotranspiration and seepage to the floodplain.

JESS studies show that flood water is rich in plant nutrients. Jobin (1988) demonstrated high concentrations of important plant nutrients. Dissolved phosphorus and nitrogen were 4 mg l^{-1} and 5 mg l^{-1}, respectively, during the 1987 flood compared with less than 1 mg l^{-1} during other seasons. Suspended sediment during the flood contained almost 4 mg kg^{-1} of phosphorus and 1 mg kg^{-1} of nitrogen compared with negligible amounts at other times.

Crop production reflects the fact that herbaceous wild plants in the floodplain are more productive than would be the case in a purely rainfed area. It is for this reason that floodplain agriculture has been distinguished from rainfed areas in the river-dependent zone throughout this report. This approach contrasts with that of AHT (1988) and Watson and Nimmo (1988) who refer to all areas not irrigated or undergoing flood recession agriculture as being rainfed.

Implications Resulting from Baardheere Dam

Effects on floodplains will differ in stretches upstream and downstream of the dam site. While some immediate results are obvious, such as inundation of reservoir area floodplains and reduced downstream flooding, others are difficult to predict.



Baardheere Dam will prevent devastating floods,
but will also eliminate current floodplain grazing from the reservoir area.

Downstream of the dam it appears that occasional flooding of limited extent will continue (AHT 1988). Much of this flooding will be in Lower Jubba, but the highest frequency of flood-recession agriculture, particularly in dhesheegs, is in Middle Jubba (Section V). In other words, the projected flood regime remains damaging to areas where floods are economically most severe, but eliminates floods where the water is used mostly for farming. It is not known if any of these Middle Jubba dhesheegs will fill with floodwater from the river in post-dam floods if the dam is operated to maximize electricity generation. Soil nutrient enhancement from floodwater will also be reduced. Sediment will be deposited in the upper reservoir and dissolved nutrients will be diluted by mixing with reservoir water. Some dhesheegs may fill partially with rain water, but this water has fewer nutrients.

Lateral infiltration of river water will also be reduced. Projections for the Tana River suggest a deepening of the river channel and a lower floodplain water table which spreads less far from the river (Hughes 1985). Erosion of river channels results from clear water released from a dam picking up new sediments from the riverbed. The likely extent of this downcutting in the Jubba is unknown. Opinions of hydrologists vary from negligible effects (Alford 1987) to noticeable, but unquantified effects (AHT personal communication). If the Jubba behaves similarly to Tana projections, several consequences are likely:

- distinctive floodplain vegetation will narrow in extent to more closely follow the river channel;
- deeper rooting trees close to the river may continue to tap seepage of river water; and
- shallow rooting species such as wild grasses and field crops will probably decline in extent and productivity.

Reduced floodplain crop production downstream of dams is documented from other African river systems. Scudder (1988) quotes a 60-percent reduction in yam production within a few years of closure of Kainji Dam on the Niger River. This period coincided with a drought which must account for part of the reduced production. Also in Nigeria, Bakolori Dam caused reduced flooding leading to an approximate one-third reduction of area under dry season vegetable crops (Adams and Hughes 1986). These reductions in crop production are of a similar magnitude to the likely reduction in forage yield of wild grasses that can be inferred from Figure 14 when the "floodplain" and "prediction" lines are compared.

One of the aims of Baardheere Dam is to provide reliable irrigation to replace the unpredictable supplies of rain and often damaging flood water. However, the switch to controlled irrigation will not take place immediately or spontaneously when the dam is closed. Many floodplain farmers will suffer reduced crop production unless mitigatory measures are implemented.

One possibility is provided by the AHT (1986) dhesheeg-conversion project proposal. In this project, selected dhesheegs will be connected to the river by a canal with appropriate headworks to regulate flow to the dhesheeg, thereby allowing flood recession agriculture to continue. An alternative is to pump water from the river to dhesheegs. Another suggestion advocated by Scudder (1980; 1988) is to release a controlled flood from the dam. Such a flood would be of an appropriate magnitude to partially flood dhesheegs. Controlled releases also enable a predictable exposure and potential use of the drawdown zone around the reservoir (Scudder 1980). Both the dhesheeg conversion and controlled flood schemes would enhance floodplain agriculture to the extent of allowing predictable flooding of floodplain areas. However, soil nutrient inputs would still be lower than in the pre-dam situation, and addition of fertilizers or appropriate crop rotations may need to be employed.

Controlled floods reduce the amount of electricity that Baardheere Dam can produce. However, optimal power generation will supply more electricity initially than can be used in Somalia. Therefore, the possibility of controlled floods should be considered by MNPJVD. It will be necessary to determine riverbed and floodplain morphology in order to model the extent of flooding related to volume of water released from the dam. Such studies need not delay dam construction since several years remain before dam closure. Controlled flooding may be a temporary expedient to allow conversion from current floodplain agriculture to pumped irrigation. As this conversion is completed and demand for electricity increases, it may be desirable to phase out controlled floods.

Recommendation: *The feasibility of controlled floods to maintain floodplain production systems should be assessed.*

Upstream of the dam, new "floodplains" will be created in the drawdown zone of the reservoir. Suggestions about the potential of this zone for agricultural or range production indicate that it should be included in planning of Jubba Valley development (see Sections V to VII). Scudder (1988) cites tens of thousands of cattle using the Kafue flats in the Zambian drawdown behind Kariba Dam and drawdown agriculture being practiced around Lakes Kariba, Volta, Aswan, and Kainji. However, such potential is not always realized. For example, Roggeri (1985) points to crop failures around Masinga reservoir on the Tana River.

The situation around Baardheere reservoir needs further study. Much of the drawdown zone is stony or rocky and will only be productive of wild grasses or crops if finer sediments are deposited in this zone. Some TEBS monitoring sites in the drawdown zone have gypseous soils and would not be suitable for agriculture (Appendix I). The current floodplain of the reservoir stretch immediately south of Luuq town will be the first area to be exposed by reservoir drawdown and is the most likely area to have deposition of new sediments. This narrow reservoir section will surely have potential for drawdown agriculture, or development of grasslands for livestock. Since drawdown will occur during dry seasons, the potential for increasing livestock and crop production should be significant. Seasonal grass production in floodplains in this area exceeds 1 t ha^{-1}. Exposure of 2,000 to 3,000 ha of riverine sediment south of Luuq could produce enough forage to feed more than 10,000 cattle for six weeks each drawdown season. This potential compares with the estimated loss of forage of more than 20 million kilograms as a result of inundation, assuming no drawdown forage (Section VII.E). Reservoir area livestock populations currently have a forage demand equivalent to more than 40,000 cattle. Such drawdown zone forage production should not be assumed, but the development of drawdown zone vegetation and its use should be monitored (Section X).

The largest drawdown area will be in the wide part of the reservoir in the vicinity of Buurdhuubo. This area should be delineated on the ground and surveyed so that its potential for agriculture or livestock forage production can be assessed. If potential exists, water releases from the dam should be programmed to optimize drawdown production at the lowest cost in lost power generation and downstream irrigation. Initially, drawdown of the reservoir could be coordinated with controlled floods to maintain floodplain agriculture during its transition to pumped irrigation (see above).

Recommendation: *Potential of the reservoir drawdown zone as a productive resource should be assessed and incorporated into land-use planning and dam operating schedules.*

X. MONITORING OF TERRESTRIAL ECOLOGY

An objective of JESS is to propose monitoring schemes to track important changes during development of the Jubba Valley. TEBS proposals for monitoring should be read in conjunction with those developed by SEBS (Craven, Merryman, and Merryman 1989) and Tillman (1989). Important considerations include building on TEBS baseline data; emphasizing important indicators of change; and determining monitoring frequency, methods to be utilized, and appropriate implementing agencies. Some TEBS monitoring proposals do not involve MNPJVD in data collection or analysis, but the Ministry (or an eventual "Jubba River Authority" is envisaged as the central authority involved in assessing changes and coordinating appropriate responses to adverse developments. It should be noted that monitoring is also useful in demonstrating successful planning and projects.

Effective use of TEBS monitoring data by MNPJVD will require a trained and motivated group of environmental scientists who can communicate with planners and policymakers. It is not enough to develop technical expertise to collect data, unless those data can be analyzed and interpreted in ways useful to planners and policymakers (see Tillman 1989).

Many of the monitoring activities specified below do not give direct information concerning land use, forestry, range management, and biological conservation sectors considered in this volume. Similar analyses to those of TEBS will be required to link, for example, livestock populations to range resources, or woody cover to forestry resources. Nevertheless, these monitoring methods are the best approach to overall environmental monitoring, provided a skilled monitoring unit can be assembled.

Simpler monitoring methods could be devised, but would not be reliable. For example, changes in availability of fuelwood or construction wood might be reflected in changes in market prices. But how would a sudden rise in the price of wood be interpreted in the ecological context? How could environmental interventions be devised on this basis? Such information may be useful in pointing to features requiring further analysis of the environmental monitoring data, but it cannot replace those data.

Most monitoring activities should begin before the dam is closed. Such a schedule enables a partial separation of trends begun before dam closure from those resulting from dam closure.

A. Rainfall

Rainfall records in the Jubba Valley have poor coverage and are unreliable. Yet rainfall is perhaps the most important variable determining ecosystem processes in semi-arid areas such as TEBS study area (Deshmukh 1986a). Range vegetation production and livestock stocking rates are usually closely correlated with amount of rainfall received. Optimizing water use for irrigation is also dependent on knowledge of local rainfall. However, problems exist in setting up a rain gauge network. Much of the river-dependent zone has no permanent settlements and, therefore, no one to take daily rainfall readings. Monthly storage gauges could be used in more remote areas, but these may be inaccessible during the rains. It is also probable that local people would find materials in a rain gauge useful, leading to destruction or removal of gauges. Even deeply buried sections of topographic benchmarks have been removed for the metal they contain. A rain gauge is much simpler to dismantle. Where settlements exist, rain gauges are often read sporadically or data are lost or left uncollected.

The Food Early Warning System of the Ministry of Agriculture has increased the number of rain gauges in the study area and improved data collection and analysis. This agency is appropriate to develop an enhanced rainfall data collection and analysis capability for the study area. Information would then be passed to MNPJVD.

Ideally, a grid of rain gauges would be established throughout the river-dependent zone with perhaps one gauge per 500 km^2, requiring 60 gauges. In the floodplain, one gauge per 25 km of river length (a total of 20 gauges) would be useful for agricultural planning given the gradient of rainfall north to south in the study area. However, reliable records are unlikely to be kept with such an evenly spaced network, since settlements are not located in such a regular manner. A better approach may be to set up daily-read gauges located at all new or existing project sites with permanent staff. Locations could include forest nurseries, health posts, agricultural projects, livestock stations, and conservation projects. Such a system will produce duplication in some areas and leave other areas unmonitored. Duplication is not disadvantageous since it enables cross-checking of nearby sites and an assessment of local variability. In areas with no projects, it may be possible to employ village leaders or enterprising farmers to keep records.

In all cases, effective record keeping requires motivation. People need to see that rainfall data are being used and are useful in their own lives. Every few months an agent from the Food Early Warning System or MNPJVD should visit rain gauge sites to show how accumulating records are used and to illustrate features of local interest which correlate with rainfall. For example, a farmer could be shown differences in crop growth in nearby areas with somewhat different rainfall.

This scheme will not produce adequate rainfall data for the river-dependent zone. An alternative to rain gauges for extensive areas is the African Real-Time Environmental Monitoring using Imaging Satellites (ARTEMIS) program established by FAO. Cloud cover, cloud-cover duration, and cloud-top temperatures are monitored to give estimates of precipitation and days with rainfall. The system is calibrated for West Africa, but East African calibration is under way. ARTEMIS information is available through the Regional Remote Sensing Center in Kenya, of which Somalia is a member. This program is probably the most appropriate means of obtaining rainfall data for the river-dependent zone.

Recommendation: *A system of rain gauges should be established in the Jubba floodplain with gauges located at all project sites and other appropriate locations.*

Recommendation: *Rainfall in the river-dependent zone should be monitored using the ARTEMIS system coordinated by FAO.*

Recommendation: *Collection and processing of rainfall data for the Jubba Valley should be performed by the Food Early Warning System (Ministry of Agriculture) who would routinely pass on appropriate information to MNPJVD.*

B. Vegetation

The monitoring site approach to TEBS vegetation studies was established with a view to continued monitoring after JESS. Of the three sets of monitoring sites (TEBS ground; TEBS aerial photographic; SRS ground) described in Section VI.B, it is suggested that the two sets of TEBS sites should continue to be monitored under the guidance of MNPJVD. The SRS sites are more appropriate for a national rangeland monitoring system for which they were designed. In the absence of such a national system, the SRS sites may be usefully reassessed if other developments indicate that information on rangeland resources distant from the river is important to MNPJVD (see Watson and Nimmo 1985 for details of SRS sites).

1. Aerial Photographic Monitoring Sites

Repetition of these photographs at appropriate time intervals is a relatively rapid method of objectively assessing changes in vegetation structure over the TEBS study area (see Section VI.B.2; Appendix B). Analysis of the photographs would be repeated as before for cover and size structure of woody vegetation. Effectiveness of this method depends on accurately photographing the same areas on each occasion. Should this precision not be possible, gross changes in vegetation structure should be detectable by taking a new random sample using the same stratification and making statistical comparisons between old and new photographs. However, re-photographing original sites is preferred since specific changes will be apparent. The original photographs are black and white. Color (or color infrared) photography should be used in the future to make analysis easier and to provide information about extent of herbaceous cover (see Appendix B).

This monitoring activity provides information on changes in distribution of structural vegetation types. Since forestry and range resources are closely related to relative proportions of vegetation types, human use of vegetation is also monitored (Section VII). Gross changes in land use, for example, loss of native vegetation to agriculture, would also be tracked by this method. Simple visual comparison of old and new photographs is an effective way of disseminating information about vegetation change requiring action from planners and policymakers.

A monitoring unit established in MNPJVD is the appropriate body to carry out this monitoring (see Tillman 1989). Photography should be repeated in June to August (when trees and bushes are in full leaf and herbaceous layer is green) at five-year intervals. The first repetition should be carried out before closure of Baardheere Dam. Besides flying time, which would be contracted out, analysis and interpretation should take two to three person-months (see Appendix B).

Recommendation: *Aerial photography vegetation monitoring sites should be re-photographed and analyzed at five-year intervals. Commissioning and analysis of aerial photography vegetation monitoring sites should be carried out by a monitoring unit in MNPJVD.*

2. Ground Monitoring Sites

The aerial photography monitoring sites provide a quantitative view of changing patterns of vegetation structure. However, they cannot be used to show changes in species composition and diversity unless these changes are very large. Since vegetation in and close to the Jubba floodplain is expected to change markedly due to hydrological changes and increasing human use, monitoring of species composition is important. Changes in relative abundance of species indicates availability of plants which have specific human uses (see Section VII.B). Reduction and possible loss of species, particularly those confined to the Jubba floodplain, are of importance to biological conservation. From a scientific viewpoint, changes in vegetation composition as a result of changes in floodplain hydrology are valuable in predicting impacts of future dams in similar environments.

For these reasons, monitoring of TEBS ground monitoring sites should be continued in the future. The first reassessment should be conducted before closure of Baardheere Dam with subsequent repetition at 10-year intervals. Monitoring procedures are given in Appendix A. The work should be undertaken in June to August, the season when most sites were established. Two to three months would be required for a team of four to five. Since the work is specialized and intermittent, it is not appropriate for MNPJVD to maintain such a team, although they should provide assistance in the field. This monitoring team could be led by appropriate personnel from the National University of Somalia, the NRA, or an expatriate specialist. Funding should come from an appropriate international agency or scientific research body, rather than being part of the MNPJVD recurrent budget. The data is primarily of scientific interest, or of interest to development planners in other countries, rather than being directly of use to MNPJVD.

Monitoring should be an important component of conservation projects such as the Shoonto and Barako Madow Forest Reserves and Shabeelle Swamps (see Section VIII). If properly protected from human destruction, the forests could provide information on effects of hydrological changes due to dam construction on riverine forest. Wildlife monitoring in conservation areas should also be conducted. The nature of such monitoring is properly defined in a management plan for each conservation area rather than in this overview of monitoring activities for the whole TEBS study area. Since NRA is responsible for conservation activities, it should oversee monitoring at these sites. SRP outlines a research program for the riverine forests which includes monitoring activities (Madgwick and Wood 1988). This program includes establishment of permanent vegetation plots to monitor growth rates and changes in species composition. Such changes will yield useful information for both forestry and conservation purposes. Effects of changed hydrology caused by Baardheere Dam would also be evident. Wildlife populations would also be monitored.

Recommendation: *TEBS ground monitoring sites should continue to be monitored to provide information on changes in vegetation species composition. These sites should be assessed again before closure of Baardheere Dam, then at 10-year intervals.Monitoring of ground sites should be coordinated by MNPJVD in collaboration with NRA and/or the National University of Somalia with expatriate technical assistance as required.*

Recommendation: *All designated conservation areas should have a monitoring system included in management plans.*

The Reservoir Drawdown Zone

Several TEBS ground and aerial photograph monitoring sites are in the drawdown zone of the future reservoir behind Baardheere Dam. These sites should continue to be monitored as outlined above; however, changes in landscape and position of tracks and other markers following inundation may prevent accurate relocation. Clearance of reservoir vegetation, as recommended in Section VII, should exclude these sites and a buffer zone around them, if possible. However, even if these sites are cleared before inundation, known prior vegetation and soil conditions may help to explain subsequent development of drawdown vegetation.

An additional monitoring system should be established to follow development of vegetation and surface soil in the drawdown zone. Techniques would be the same as those used at TEBS ground monitoring sites (see Appendix A). If soil changes are marked, more detailed soil analyses than those used in TEBS surface soil descriptions will be desirable. Parameters of interest include soil depth, texture, and chemical composition. Laboratory measurements should be possible at the Ministry of Agriculture soil laboratory, established as part of JuDAS project, with possible collaboration from the Faculty of Chemistry, National University of Somalia.

Paired vegetation monitoring sites would be established. One would be surrounded by a fence to exclude livestock and human removal of vegetation, while its partner would be open to these influences. In this way natural vegetation development and its modification by human use could be assessed. Twenty paired sites should be established at various levels in the drawdown zone and on various substrates such as current floodplain, togga, and different substrates of the current river-dependent zone (stony, rocky, gypseous, other fine soil types; see Appendix I).

Sites should be established before reservoir filling to determine conditions prior to inundation. For the first five to 10 years after dam closure, the sites should be assessed annually during the jiilaal drawdown. Frequency of subsequent monitoring would depend on results from the initial years. This work should be a collaborative effort between MNPJVD, NRA, and the National University of Somalia. Annual monitoring activities may be useful field training for students in the Botany and Range Science Department at the University, or the NRA Forestry, Range and Wildlife School.

Recommendation: *A vegetation monitoring system for the Baardheere Reservoir drawdown zone should be established as a collaborative project between MNPJVD and NRA and/or the National University of Somalia.*

C. Aerial Censuses and Aerial Photography

Aerial census provides a rapid view of the whole TEBS study area. Repetition of aerial censuses conducted for JESS will provide the most efficient view of changes in land use, rural human settlement patterns, and livestock and wildlife populations. Techniques, stratification, and baseline data are given in Watson and Nimmo (1988). Baseline data sets are also included in JESS data repositories.

1. Complete Enumeration of the River

A simple system that can flag undesirable developments is the most important aspect of monitoring from the point of view of development planning. Complete enumeration of riverine features provides the basis of such a system. Areas close to the river will change most rapidly due to development both before and after closure of the dam. Therefore, it is these areas that need most frequent monitoring. The enumeration method is rapid and, if repeated frequently enough, will give information that can be followed up by more detailed or quantitative aerial or ground monitoring. Features enumerated and mapped include counts of irrigation pumps, livestock watering points, boats and ferries, crocodiles and hippopotamuses, fishing activities, and assessments of riverside land use (Watson and Nimmo 1988). Important indicators likely to undergo rapid changes include the number of pumps and crocodiles and extent of riverbank agriculture. The technique would need to be modified slightly after closure of the dam to include the reservoir perimeter.

Because of rapid land-use changes described in Section V, these riverine enumerations should be repeated at two-year intervals, beginning in 1990. Jiilaal is the appropriate season since activities in the drawdown zone will be exposed and use of the river by livestock will be high. Analysis and interpretation of data should be rapid so that interventions to mitigate undesirable developments can be undertaken before these changes become too great. This work requires an experienced aerial resource assessment team who should be contracted by MNPJVD.

Recommendation: *Aerial enumerations of riverine features (including the reservoir perimeter) should be conducted at two-year intervals beginning in 1990.*

2. Sample Censuses of Floodplain and River-Dependent Zone

Riverine enumeration as described in the previous section cannot give a complete view of the Jubba floodplain and gives no information about the river-dependent zone. Monitoring of these larger areas is equally important, but need not be as frequent. The aerial strip sample censuses conducted for JESS should be repeated to assess changes in these areas (see Sections V and VII.B; Watson and Nimmo 1988). Quantitative information collected includes livestock and wildlife populations, livestock activities, land use, rural settlements, wood extraction features, and water sources.

Ten-percent censuses of the floodplain should be repeated at five-year intervals, with the first census before closure of Baardheere Dam. Three-percent censuses of the river-dependent zone should be repeated at 10-year intervals. Two censuses should be completed in each sampling year; one in late jiilaal and one in early to mid-xagaa. These timings are comparable with those of JESS censuses and should illustrate patterns of seasonal livestock occupancy. As with the riverine enumeration, an experienced aerial resource assessment team should be contracted by MNPJVD.

By using the same flight lines and sampling framework as JESS, these monitoring censuses will allow detailed comparisons of spatially fixed features such as land use and some rural structures. However, mobile features, notably livestock and other features associated with pastoralists, are subject to spatial fluctuations which make temporal trends difficult to detect. Nevertheless, as the length of time of monitoring increases, it will be possible to determine trends in these features since the river will remain the major dry season water source. Monitoring of livestock activities will enable developments in integration of crop and livestock production to be followed. Changes in the numbers of livestock feeding on crop residues will be an important indicator of this change.

Recommendation: *Sample aerial censuses should be conducted at five-year intervals in the Jubba floodplain and 10-year intervals in the river-dependent zone.*

3. Stereoscopic Aerial Photography

JESS commissioned stereoscopic aerial photography at 1:10,000 scale of a strip of land stretching approximately 2 km either side of the Jubba River. It is not recommended that this photography be repeated routinely. Such photography and its interpretation are expensive. However, many of the monitoring activities described above may highlight "hotspots" where land-use changes needing detailed analysis are located.

Recommendation: *In some instances it may be desirable to repeat stereoscopic aerial photography of selected areas for comparison with the earlier photography.*

4. Potential of Aerial Video

Aerial video, as a partial substitute for aerial photography, is potentially valuable as a monitoring tool. Advantages include lower price, a continuous record of the area overflown and an excellent medium for demonstration to planners, policymakers, or the general public. Techniques are rapidly improving in terms of resolution, stop-frame mechanisms, and use of infrared wavelengths.

Aerial video could be used in conjunction with many of the monitoring activities described above. For example, stop-frame techniques could replace the use of photographs in aerial vegetation monitoring. A continual visual record of river enumerations and sample census strips could be analyzed more completely than someone counting from an airplane. To reduce flying time, a new set of aerial vegetation monitoring sites could be placed on the census strips and extracted from the taped record. A permanent record allows new analyses to be made if they become desirable. However, such analyses should be used as an addition to rather than a replacement for the direct aerial counts. Direct counts are available more quickly than is likely from an analysis of a videotape. There is also a danger that a tape will remain unanalyzed, since there will always be a temptation to leave it until a later date.

Pertinent issues need to be resolved before a video system is adopted. These include finding a system which has the resolution necessary to enable livestock counts, while using an adequate strip width so that extra flying time is not required. For vegetation monitoring, resolution should be adequate to distinguish shrubs of at least 2-m crown diameter. Convenience of analysis for measurements of area, use of dot grids, and other techniques should also be considered.

Recommendation: *The possibility of using aerial video to carry out a variety of environmental monitoring tasks should be investigated.*

Annotations in square brackets following a reference indicate where more obscure items may be found.

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Ninety ground monitoring sites were established on or close to the Jubba floodplain. Detailed estimates were made of vegetation characteristics. Many sites were visited in different seasons when some measurements were repeated. These quantitative data are recorded in TEBS data bases, which are retained in JESS data repositories. Data bases relevant to ground monitoring sites are listed in Table 28. In addition, surface soil, and other readily observable features such as grazing, wood cutting, and burning were noted. Additional land-use and ethnobotanical information was gathered by interviewing local people whenever possible. The details of location and site descriptions are given in TEBS Ground Monitoring Sites, available at JESS data repositories (see Section II).

Table 28. Data Bases Using Information from TEBS Ground Monitoring Sites

NAME of DATABASE	CONTENT
SITEDESC	Site descriptions: location; structural vegetation type; soil type; woody biomass.
PLANTAX	Plant taxonomy and ethnobotany: taxonomic information; vernacular names; use of plants.
WOODYFP	Enumeration of all woody plants; floodplain sites.
WOODYNFP	Enumeration of all woody plants; river-dependent zone (non-floodplain).
HERBVEG	Herbaceous vegetation: point-frame and standing crop data.
HERBSPP	Herbaceous species: species on and around sites and indices of abundance.

Procedures at Each Site

Sites downstream of Baardheere Dam site were chosen to represent the major physiographic and vegetation types identified by AHT photo interpretation (AHT 1984; see Section V.B. and Hemming 1987). Upstream sites included floodplain, future drawdown zone, and above the maximum level of the future reservoir (see Appendix I). Location of sites was subjectively chosen to be representative of the range of vegetation types by the JESS ecologist after examination of vegetation and land-use photo interpretations of AHT (1984) and Trump (1987). Tables 11 and 12 and Figure 9 record the disposition of these sites relative to the randomly distributed aerial photograph monitoring sites.

Site Layout

Each site was a 20 m x 20 m or 10 m x 10 m square using a corner tree as marker. Four-hundred square meters was used as the minimum plot size suitable for riverine forest vegetation in East Africa (see discussion in Hughes 1985). For uniform grassed, shrubbed, or bushed sites 100 m^2 was used, but the larger plot was retained for more heterogeneous sites of these types. With sites ranging from high forest, through thicket bushlands, to grasslands, it is impossible to pick an ideal plot size which optimizes sampling rigor yet keeps labor within reasonable bounds. Time taken for complete enumeration of these sites with a field team of four to six varied from two to six hours. Usually it was not possible to complete more than two sites per day except where woody vegetation was sparse.

The square plot was temporarily delineated using tapes and a sighting compass. Permanent markers for future use were added later. These comprise half-meter lengths of galvanized iron pipe pounded vertically at each corner until below the soil surface. A metal detector will be used to locate these markers should sites be visited later. As an aid to finding the "first corner" of each site, pits and mounds were dug close to the nearest track (or other appropriate semi-permanent feature). Distances were recorded linking the track and plot corner by a compass bearing.

These standard procedures were modified at a few sites due to the nature of the vegetation. Sites 40 and 50 are 4 m x 100 m belt transects laid across a major livestock route close to a watering point. Site 76 was first designated as a standard 400 m^2 plot, but modified to 20 m x 10 m due to density and uniformity of woody vegetation. Procedures at sites with no woody plants taller than the low shrub layer are described below. Individual plot size and layout and directions to the site are given in TEBS Ground Monitoring Sites.

A set of four 35 mm photographic color slides was taken of each site using a 50 mm lens. Whenever possible, they were taken after a rainy season to show the vegetation in "good" condition. Two photographs were taken of the plot from a position 10 paces outside the square. The camera was pointed horizontally towards the square at head height (TEBS ecologist; 1.75 m tall) from a point 10 paces from the mid-point of two perpendicular sides. Two further slides were taken vertically downward of the ground from bent head height at points along the point-frame transect (see "Herbaceous Plants" below). One photograph was of the inner end of the transect and the other of the mid-point. Copies of these photographs are retained by USAID/Somalia and ARD. Minor positional variants of these standard photographs were necessary at some sites. These deviations are listed in TEBS Ground Monitoring Sites.

Enumeration of Woody Plants

The following data were recorded for each tree and shrub (excluding dwarf shrubs which were treated as herbaceous plants) in each plot. These measurements were made at the first visit to each site, since changes within the study period were not expected to be detectable. However, the following measurements should be repeated for long-term monitoring (see "Future Monitoring", below, and Section X):

- basal diameter of stem of trees or length of longer axis of basal stem cluster of asymmetric shrubs;
- crown diameter in two perpendicular horizontal directions (mean crown diameter was used in computations to correct for asymmetry);
- total height measured for smaller trees and shrubs or estimated visually for taller individuals;
- height above ground at which crown begins;
- whether the plant is single- (tree) or multi- (shrub) stemmed; and
- species field identifications or herbarium specimens for later identification (see Appendix D and PLANTAX data base described in TEBS Data Guide).

Percentage cover of woody canopy at each monitoring site was computed as the sum of crown area (assuming crown is circular) of all woody plants rooted in the plot relative to ground surface area of the plot. This method assumes that any crown overhang of measured plants outside the plot is equal to overhang of plants rooted outside into the plot.

Herbaceous Plants

Species composition was not measured quantitatively because of difficulty distinguishing vegetative parts in a sward. However, approximate relative abundance and height of recognizable species was recorded at the first visit to a site and subsequent major changes noted on seasonal visits (see Section VI.D for some examples). The abundance scale scored species as abundant (5), common (4), frequent (3) occasional (2), or rare (1). Height was scored as 4 (> 100 cm), 3 (51 to 100 cm), 2 (21 to 50 cm), or 1 (0 to 20 cm). A composite index for each species at each site, the sum of abundance and height scores, was also computed. Thus, a small rare plant will score 2 and a tall dominant species 9. These indices are recorded in HERBVEG data base. The "index of abundance" referred to in Table 15 is the sum of the composite index for each species across all ground monitoring sites. As with woody plants, specimens in suitable condition were collected for herbarium identification. The following quantitative estimates were made at each visit to a site.

Proportional cover was estimated using a point-frame. Ten pins were suspended 50 mm apart from a frame 0.5 m tall. Two sets of observations were made. First, number of pins hitting each type of plant and condition class (grass, forb, dwarf shrub; green or brown condition) was noted. Then, the nature of the ground at the point of each pin (soil, rock, plant litter, dung, unseen) was recorded. This procedure was repeated at 20 positions at marked 0.5 m intervals along a rope of known orientation within each plot. The position of this rope was recorded with respect to plot boundary tapes and compass bearing. In this way approximately the same 200 points were sampled during each seasonal visit to a plot.

Figure 13 presents a summary of this data showing seasonal changes. The ordinate scale is the mean number of hits across all monitoring sites visited in each month. Thus the maximum score for any category is 200 hits. Only data from sites downstream of the dam site are given since repeated visits were not made to upstream areas.

Standing crop of herbaceous vegetation was also estimated on each visit to sites with sufficient vegetation to warrant sampling. Analysis of data from sites assessed indicates that those with "insufficient" vegetation had less than 50 to 100 kg ha^{-1} standing crop. Ten 25 cm x 25 cm square quadrats were tossed randomly within the sample plot. All vegetation within each quadrat was clipped at ground level and stored in paper bags for air-drying in the field and subsequent oven-drying in Muqdisho.

At sites with no woody plants (14, 19, 21) a square plot was not laid out. Instead, a line transect was used. Point-frame samples were taken at fixed intervals along a marker tape. For tall grass sites (14, 21) a 1.5 m tall 5-pin frame (pins 10 cm apart) was used. See TEBS Ground Monitoring Sites for details of length of transects, intervals between point frames, and other data recorded at each of these sites.

Most sites were established in early xagaa when vegetation was in good condition for field or herbarium identification (Table 29). Herbaceous vegetation was also at its peak and ungrazed or barely grazed following dispersal of livestock during gu'. A minority of sites was set up during early jiilaal. Due to poor deyr rains in 1986 and 1987, vegetation condition was relatively poor in jiilaal.

Table 29. Dates of Establishment and Number of Vegetation Plots in Different Areas of the Jubba Valley

Downstream of Baardheere Dam Site:

MONTH	Floodplain	River-Dependent Zone	TOTAL
July-August 1986	25	11	36
January 1987	9	3	12
August 1987	0	2	2
January 1988	1	3	4
Total	35	19	54

Upstream of Baardheere Dam Site:

MONTH	Floodplain	Non-Floodplain to be inundated	Non-Floodplain above Reservoir	Total
July 1987	10	11	11	32
December 1987	2	2	0	4
Total	12	13	11	36

* *Exact position relative to reservoir water level is not certain; many "inundated" plots will probably be in the drawdown zone.*

Phenology

In addition to estimates of herbaceous cover, condition, and standing crop, visual estimates of phenological condition of dominant herbaceous and woody species were made on each visit to a site. Dates of visits are recorded in TEBS Ground Monitoring Sites and data base HERBVEG. Categories recorded were leaf or flower buds; young, mature, or senescent leaves; flowers; fruit. Each category was scored:

0 = no activity/absent,
1 = slight/few,
2 = moderate,
3 = high/common, or
4 = full/abundant.

A similar system was employed to record the degree of grazing or browsing on dominant species (0 = none, 1 = slight, 2 = moderate, 3 = heavy). To maintain consistency, these visual estimates were scored by the same individual on seasonal visits.

Figure 12 was prepared using these data. "Young leaf" and "leaf bud" categories were combined; there were no records for flower buds. Scores in each category were summed for dominant species at a site, then summed over all sites visited. This grand total was expressed as a percentage of the maximum possible score (number of sites x number of species x 4) for each phenological category. Looking, for example, at the first floodplain column in Figure 12: young leaves plus buds was 7 percent of total possible activity (100 percent); mature leaves 90 percent; senescent leaves 17 percent; flowering 10 percent; fruiting 6 percent. If all categories are showing maximum activity, the ordinate scale would be 500. Data presented are from sites downstream of the dam site since repeated visits were not made to upstream areas.

Other Information Recorded

Sites were described in terms of topography, drainage, and erosion and flooding features (see Appendix I). Whether floodplain sites were subjected to flooding was initially determined by presence or absence of two snail genera, *Pila* and *Achatina*. The former indicates that surface water is present at least part of the time, while the latter occurs in dryland conditions. Although not an absolute guide, experience showed that these snails are good indicators of flood regime. Confirmation of flooding was obtained at sites by interviews with local people wherever possible. Eventually, the large flood of May-June 1987 gave direct evidence as to which sites are likely to flood.

Surface soil was examined superficially at each site. Description of the surface was first made including the presence of litter, crusts, cracks, and termite activity. A shallow pit (c. 25 cm) was dug using hand-axe or shovel to indicate whether upper horizons could be distinguished. Presence or absence and shape of peds was noted if they occurred. Texture was approximated by a combination of visual examination using a x5 magnification hand-lens and stickiness and plasticity when wetted. A USDA soil texture triangle was used to classify soils (e.g., silt, clay, loam). Soil color was determined using a Munsell color chart.

Whenever present or brought-to a site, local people were asked a series of questions about each site and the surrounding area. Questions included (but were not restricted to):

- flooding patterns—timing, frequency, depth;
- grazing/browsing patterns—timing, frequency and by whom, presence/absence of tsetse (including use of prophylaxis for trypanosomiasis), range burning;
- interactions with wildlife;
- ethnobotanical information—vernacular names of species and local uses of plants; and
- recent land use.

Future Monitoring

For future monitoring of TEBS ground monitoring sites (Section X.B.2) the same procedures should be used as given above. Some procedures may be omitted such as herbaceous standing crop estimates and visual assessment of phenology. These measurements make little sense unless seasonal visits are carried out. However, point frame measurements will be worthwhile as indicators of change in herbaceous vegetation. Repetition of site photographs should also be carried out for comparative purposes.

Monitoring of the drawdown zone (Section X.B.2) should also follow the same procedures. Paired plots would be established at the same level relative to receding water, but one would be fenced to exclude grazing and cutting. At least 10 pairs of plots should be established at different levels of the drawdown area and on different sediments (Section X.B.2). Since these plots will be monitored more frequently than others, standing crop and phenological assessments are useful, particularly for comparisons between plots in a pair.

To provide a statistically valid view of vegetation structure, which would supplement and complement ground monitoring sites, JESS commissioned sample vertical aerial photographs. These photographs, at approximately 1:1,000 scale, were taken in xagaa and early jiilaal 1987. These photographs are available at the JESS data repository at USAID/Somalia. Negatives are retained by RMR, Ltd. Due to camera malfunction, the photographs were not available until later in the project than intended. This problem limited the extent of analysis successfully completed.

A stratified random sample was taken divided between floodplain and river-dependent zone (see Section VI.B.2 and Watson and Nimmo 1988). Areas under cultivation were not photographed except where farming was so intensive that fields could not be avoided. Floodplain photography (291 prints) was stratified first by river section, then by physiographic units. For the river-dependent zone (269 prints), stratification was by river section and distance from the river east and west of the floodplain. River-dependent zone photography has also been assigned to strata used in the Southern Rangeland Survey (Watson and Nimmo 1985) in TEBS data bases. This additional stratification is provided for comparison with results of that survey. Number of prints per stratum is approximately related to total area of each stratum. Sampling intensity of the floodplain was almost 20 times that of the river-dependent zone since the former was a primary TEBS focus.

The strict random criterion was relaxed to the extent of making the photographs accurately mappable relative to landmarks. It is assumed that this process produces no discernible bias relative to vegetation types. Accurate mapping was required for two reasons. First, it was intended that TEBS would visit a proportion of photographic sites to check the accuracy of measurements made on the photographs relative to those made at ground sites. Unfortunately, late delivery of photographs and other priorities precluded this possibility. Second, if the photographs are to be used for monitoring, more or less exact replication of photographic sites is desirable.

Analysis of photographs took two forms. Percentage cover of woody plants was estimated using a dot grid with 100 dots in a stratified random pattern (Figure 18). The grid was placed over each photograph in turn, percent cover simply being the number of dots coinciding with trees and bushes. Only woody plants greater than ~ 2 mm diameter were included. This diameter corresponds approximately to plants 2 m tall (determined from ground monitoring site data) to make tree and bush assessment equivalent to that at ground sites. Other cover categories counted include grassy cover or bare ground (where discernible), fallen trees, water, vehicle tracks, human/livestock trails, and other human features (see TEBS Data Guide). These data are recorded on the VEGPHOTO data base.

Separation of "bushland" and "woodland/forest" categories (see Appendix C) was partly subjective based on the experience of the JESS ecologist. Average crown diameter of woody plants (see below) was used as a guide while viewing the photographs. A woody plant of approximately 5 m diameter is approximately 5 m tall according to data from ground monitoring sites. Use of crown diameters as the final arbiter of vegetation classification was not possible because of sampling problems described below.

An attempt was made to estimate size classes of trees and bushes with a view to biomass estimation. Size class of the random sample located by the dot grid (see above) was estimated using the device pictured in Figure 19. The clear plastic-film template was placed over each selected shrub and tree whose crown diameter was then assigned to one of the classes identified by numbers on the template. Class 1 is <2 m; Class 2 , 2 to 4 m; Class 3, 4 to 6 m; Class 4, 6 to 8 m; Class 5, 8 to 10 m; Class 6, 10 to 15 m; Class 7, >15 m. Total number of woody plants within the dot-grid frame was also counted. Proportion of plants in each size class from the sample was then related to total number of plants to estimate the total number of plants in each size class in the dot-grid frame. The intention was to apply the crown diameter/biomass relationships developed in Appendix F to the vegetation photographs.

This sampling approach did not produce reliable results. Shortage of time resulting from unavoidably late delivery of photographs precluded alternatives from being tried. Problems included small sample size in some cases. Many plants were not measured

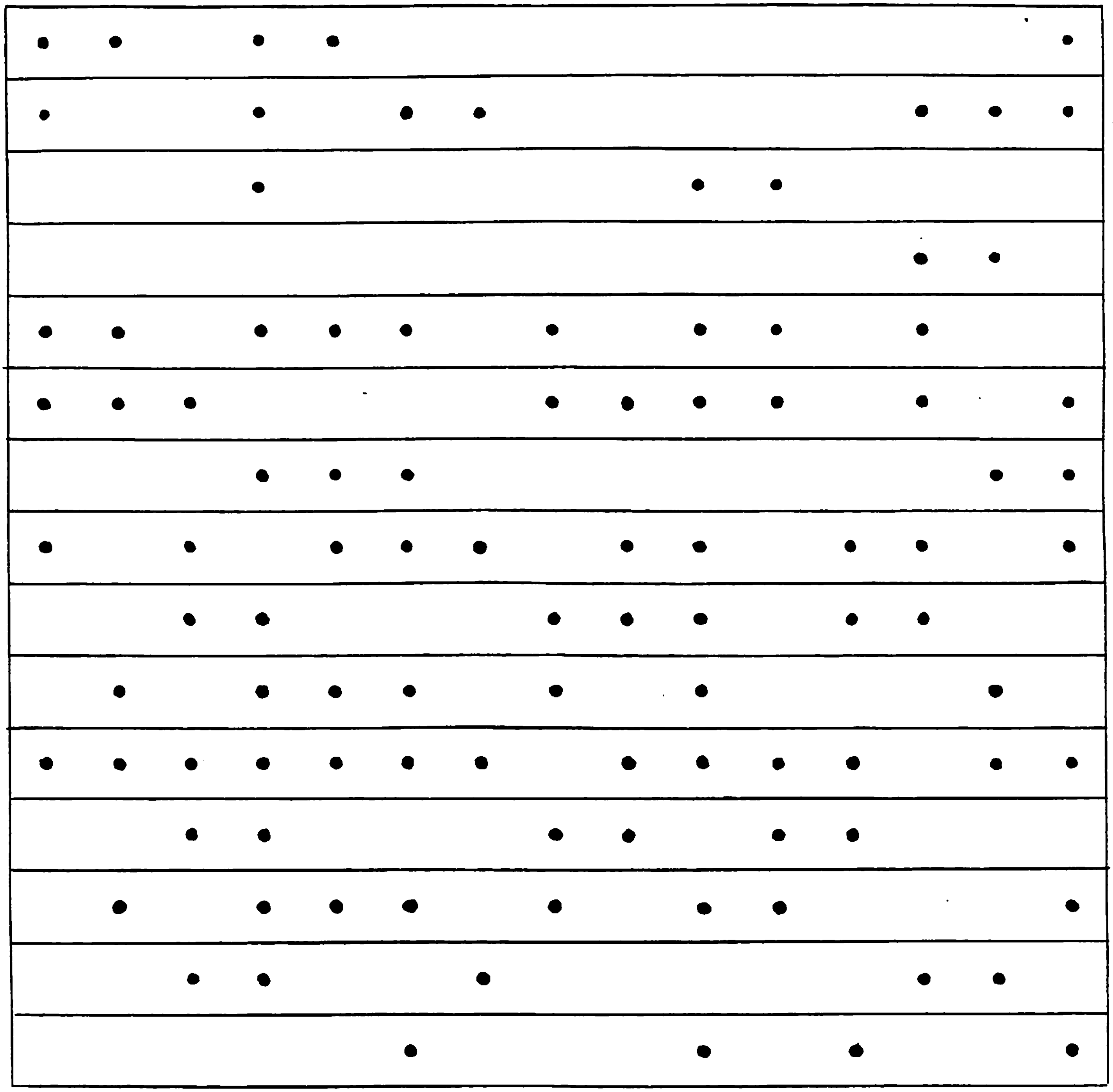

Figure 18. Dot-grid used in determining percent cover of woody vegetation and other features on aerial photographs of vegetation monitoring sites. Actual size is shown.

because of two or more crowns merging, a problem particularly evident in thickets and forests. Since these vegetation types contain a large wood biomass, accurate estimation is needed. Despite these problems, the crown size data are recorded in VEGPHOTO data base as they may be worthy of further analysis when monitoring procedures are operational (see Section X and "Monitoring", below). Because of these problems, biomass estimation was eventually done using a combination of ground monitoring sites and photographic monitoring sites as described in Appendix F.

Future Monitoring

Repetition of these photographs in the future will depend on accurate relocation and photography of sites by airplane. RMR is probably the only company that could repeat the photography as a result. Should RMR be unavailable, an alternative is to photograph another set of random locations using the same stratification and sampling technique (see Watson and Nimmo 1988). Statistical comparisons could then be made between successive sets of photographs, but specific changes at particular sites could not be observed. Given the small sample area represented by the photographs, (see Section VI.B.2), reassessing the same sites is preferred. It may be possible to locate sites on the ground using the mapped locations and set of photographs. Gross changes would be evident from ground visits.

Percentage woody cover on new photographs would be estimated as before using the dot grid in Figure 18. In the original study, the dot grid was placed centrally on the photograph with "TOP" being placed such that photographic frame references were at the bottom edge of each photograph. Color photography is recommended in Section X.B.1. This would give better definition of crowns of trees and bushes and allow a better estimate of herbaceous cover.

Improvements in assessing size structure of crowns would need a different sampling approach than using the dot grid. The crown size class template of Figure 19 could still be used, but a different sampling approach is needed. Crown diameter of a fixed number of (at least 30) randomly selected trees and bushes should be assessed rejecting plants where canopy shape suggests the crown is a mixture of several plants. Plants of size class 1 could be ignored since these contribute little usable biomass (see Appendix F). Density of plants per unit area should be assessed by counting in a sample of each photograph, rather than counting the whole frame. Color photography (see above and Section X.B.1) would help in assigning plants to size classes since the crown edge would be more clearly defined.

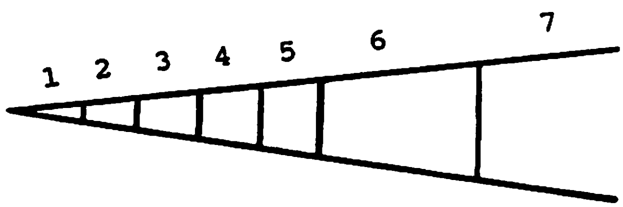

Figure 19. Template used to determine size of trees and shrubs on aerial photographs of monitoring sites. Actual size is shown.

The structural classification system builds upon that of Pratt and Gwynne (1977), but introduces greater resolution.

Woody cover (above the herbaceous layer which includes dwarf shrubs) is divided into two:

- "Canopy," height <2 m; and
- "Low shrub layer," >2 m.

It should be noted that "canopy" normally includes many shrubs (*i.e.*, multi-stemmed plants) also. The "low shrub layer" will also contain some single-stemmed woody plants, but in most situations the majority of plants are shrubs, some species of which never gain greater stature.

Sites are classified primarily by percentage canopy cover as in Pratt and Gwynne. However, extra categories are used in the 20 percent-plus range to give greater resolution. Also, allowance is made for sites with little or no herbaceous layer. "Woodland" is separated from "bushland" by mean height of trees/shrubs in the "canopy" stratum (*i.e.*, plants <2 m excluded from calculation). Thus, "woodland" has a mean height >5 m; "bushland" <5 m.

The following "canopy" cover classes are named:

• 0 to 2 percent	negligible;
• 2 to 19 percent	sparse;
• 20 to 39 percent	open;
• 40 to 59 percent	medium;
• 60 to 79 percent	dense; and
• 80+ percent	thicket (for bushland or low shrubland; forest for what would be thicket woodland).

These density classes are used for the low shrub, bush, and woodland/forest categories. The "negligible" or "sparse" categories may be replaced by "grassland," "wooded grassland," "bushed grassland," or "low-shrubbed grassland" combinations if the grass cover is sufficient. However, in situations where grass cover is negligible, then "open (woodland, etc.)" is used. Maximum seasonal herbaceous cover has been classified in the following way. The numbers refer to number of hits from a point frame giving a relative density (see Appendix A).

• 0 to 49 hits	negligible herb layer;
• 50 to 99 hits	sparse herb layer;
• 100 to 249 hits	medium herb layer; or
• 250+ hits	dense herb layer.

At least a sparse grass cover is required before such names as "grassland," "bushed grassland," "wooded grassland," are used. In other situations, different methods (including visual estimates) may be used to define herbaceous cover. Nevertheless, the same principles of classification can be used. If forbs predominate over grasses, the terms "forbland," "bushed forbland," etc., are applicable.

Normally, a site is named for its canopy/herbaceous strata as in Pratt and Gwynne, *e.g.*, "bushed grassland" if canopy cover is between 2 and 20 percent, or "open bushland" if herbaceous cover is negligible. The low shrub layer is only invoked if it is obviously important; for example, a "low shrubbed grassland" if >40 percent low shrub cover, or "sparse, open shrubland" if grass cover is negligible.

A complete structural description of a site includes all three strata. For example:

Name: *medium bushland*
low shrub: open
herb stratum: negligible

Name: *open shrubland*
low shrub: open
herb stratum: negligible
(canopy stratum negligible by implication)

Name: *wooded grassland*
low shrub: sparse
herb stratum: dense

Name: *forest*
low shrub: sparse
herb stratum: negligible

The complete classification is given for ground monitoring sites in the SITEDESC data base.

This naming system can be used in a completely quantitative way by measuring cover and height of plants, or in a semi-quantitative way using visual estimates by an experienced worker. Complete mensuration of TEBS Ground Monitoring Sites produces names which match well with subjective visual estimates.

Plants that could not be identified in the field were collected, if in suitable condition. Repeated visits to many ground monitoring sites enabled most species to be identified. Four specimens were collected whenever sufficient material was available and distributed as follows:

- Somali National Herbarium, National Range Agency;
- National University of Somalia, Faculty of Agriculture herbarium (JESS working collection);
- Royal Botanic Garden, Kew, United Kingdom; and
- East African Herbarium, National Museums of Kenya.

Grasses and sedges were identified by Miss C. Kabuye (East African Herbarium) and other plants by Mr. J. Gillett at Kew. Field identifications were initially by Mr. C. Hemming who also handled liaison with the herbarium taxonomists. JESS is indebted to these workers for rapid identifications. Mr. Cali Warsame Yusuf took excellent care of the JESS working collection.

The following plant lists are subdivided to separate species found only in the floodplain from those of the river-dependent zone and those found in both habitats. Note that absence from one of these lists does not preclude the possibility of a species occurring elsewhere. For example, many floodplain species are known to occur in non-floodplain habitats in Somalia. Nomenclature follows Kuchar (1988). Further taxonomic and distributional data are given in PLANTAX data base. Species that could not be identified are not included. These plants are listed by vernacular names or as "unidentified" in WOODYFP, WOODYNFP, and HERBSPP data bases and in TEBS Ground Monitoring Sites. A question mark (?) indicates probable identification; two question marks (??) indicate doubtful/best guess.

SPECIES OF PLANTS
FOUND DURING TEBS GROUND SURVEYS

A. Species Found Only in the Floodplain

FAMILY	SPECIES	JESS Collection Numbers
Nymphaeaceae	*Nymhaea lotus*	407
Capparidaceae	*Capparis sepiaria*	237,246,253
	Gynandropsis gynandra	300
	Maerua sp.	43
	Maerua subcordata	354
Violaceae	*Rinorea elliptica*	31,94,238,244,261,432
Polygalaceae	*Polygala senensis*	415
Amaranthaceae	*Amaranthus graecizans*	310
	Amaranthus sparganiocephalus	276
	Digera muricata	311,325
Onagraceae	*Ludwigia* sp.	117
Nyctaginaceae	*Boerhavia elegans*	290
Tamaricaceae	*Tamarix aphylla*	
Curcubitaceae	*Cucumis dipsaceus*	10,101
Ochnaceae	*Ochna ovata*	55
Combretaceae	*Combretum aculeatum*	60,116
	Combretum constrictum	60,418,438
	Combretum illairii??	93
	Terminalia polycarpa?	170
Guttiferae	*Garcinia livingstonei*	168
Tiliaceae	*Corchorus trilocularis*	126
	Grewia trichocarpa	235
Sterculiaceae	*Cola* sp. *nov*	242
	Melhania ovata	134
Malvaceae	*Abutilon anglosomaliae*	291,352
	Abutilon hirtum	9
	Gossypium benadirense	280
	Hibiscus cannabinus	153
	Hibiscus hildebrandtii	155
	Pavonia propinqua	75
	Sida alba	222
	Symphochlamys erlangeri	260
Euphorbiaceae	*Bridelia cathartica*	192
	Caperonia fistulosa	84,165
	Drypetes natalensis	113
	Euphorbia acalyphoides	102
	Phyllanthus somalensis	16,138
	Spirostachys venenifera	1
Caesalpiniaceae	*Cassia fallacina*	112

Mimosaceae	*Acacia circummarginata*	29,76
	Acacia elatior	15,115,130
	Acacia macalusoi?	431
	Acacia rovumae	98
	Adenopodia rotundifolia	154
Papilionaceae	*Baphia??*	90
	Clitoria terneata	137
	Indigofera aspersa	204
	Indigofera brachynema	58
	Indigofera microcarpa	122
	Mundulea sericea	19
	Rhynchosia minima	129,149
Papilionaceae	*Rhynchosia minima*	344
	Sesbania bispinosa	6
	Sesbania sesban	248
	Tephrosia pentaphylla	205
	Tephrosia subtriflora	8
	Tephrosia uniflora	429
	Vigna unguiculata	107
Moraceae	*Ficus sycomorus*	193
Celastraceae	*Salacia stuhlmanniana*	225
Olacaceae	*Ximenia caffra*	430
Loranthaceae	*Erianthemum dregei*	218
	Tapinanthus zanzibarensis	219
Rhamnaceae	*Ziziphus mauritania*	282
	Ziziphus mucronata	171
Vitaceae	*Ampelocissus africana*	83
	Cissus aphylla	343
Simaroubaceae	*Harrisonia abyssinica*	69
Sapindaceae	*Allophylus rubifolius*	
	Allophylus senensis	70,46
	Camptolepis ramiflora	35
	Lepisanthes senegalensis	97
Anacardiaceae	*Sorindeia madagascariensis*	
Ebenaciae	*Diospyros cornii*	88
Sapotaceae	*Mimusops fruticosa*	20,119
Oleaceae	*Olea capensis*	96
Apocynaceae	*Landolphia* sp.	239,244
	Pleiocarpa pycnantha	33,40
	Saba comorensis	32
Rubiaceae	*Coffea rhamnifolia*	50
	Feretia sp.	51
	Meyna tetraphylla	120
	Pavetta transjubensis	121
	Polysphaeria multiflora	38,42,405
Compositae	*Erlangea somalensis*	150
	Launaea cornuta	82
	Vernonia cinerea	103,133
	Vernonia hildebrandtii	67
Gentianaceae	*Enicostema axillare*	80,111,206,249
Boraginaceae	*Cordia chisimajensis*	99
	Cordia goetzei	34,95,262
Solanaceae	*Solanum coagulans*	293
	Solanum incanum	127
Convolvulaceae	*Convolvulus capituliferus*	298
	Cressa cretica	190
	Ipomoea pes-trigridis	59
	Ipomoea plebeia	110,136
	Ipomoea sepiaria	105,157
Acanthaceae	*Asystasia gangetica*	81
	Barleria sp.?	283
	Ruellia patula	388
Verbenaceae	*Clerodendrum acerbianum*	22,209
Labiatae	*Leucas deflexa*	156,203
	Leucas nubica	305
	Leucas urticifolia	355,424
	Orthosiphon sp.?	166
Palmae	*Hyphaene* sp.	
	Phoenix sp.	
Cyperaceae	*Cyperus compressus*	123
	Cyperus grandibulbosus	306,307
	Cyperus sp. *nov*	279
Gramineae	*Acrachne racemosa*	294
	Brachiaria ramosa	357
	Chloris virgata	268
	Dactyloctenium aristatum	124
	Digitaria acuminatissima	125
	Dinebra retroflexa	308
	Echinochloa colona	266,316
	Echniochloa haploclada	72,77,229
	Eragrostis aethiopica	329
	Eriochloa fatmensis	269,327
	Panicum infestum	254,419
	Panicum maximum	79
	Rottboellia cochinchinensis	100
	Saccharum spontaneum	87
	Schoenefeldia transiens	71
	Setaria verticillata	296
	Sorghum arudinaceum	3,78,202
	Sporobolus nervosus	54
	Tetrachaete elionuroides	333
	Urochloa panicoides	132,390,409

B. Species Found Only Outside the Floodplain

FAMILY	SPECIES	JESS Collection Numbers
Capparidaceae	*Boscia coriacea*	211
	Boscia minimifolia	
	Boscia tomentella	374
	Cadaba farionosa	
	Cadaba glandulosa	335,367
	Cleome brachycarpa	284,392
	Maerua crassifolia	144
	Maerua sessiliflora	337
Resedaceae	*Reseda ellenbeckii*	318
Aizoaceae	*Zaleya pentandra*	285
Portulacaceae	*Portulaca foliosa*	403
Amaranthaceae	*Psilotrichum sericeum*	165,181
	Pupalia lappacea	201,397
	Sericocomopsis pallida	369
Nyctaginaceae	*Boerhavia* sp.	287
Passifloraceae	*Adenia aculeata*	
Combretaceae	*Terminalia parvula*	231,338,363
	Terminalia prunioides	220
Tiliaceae	*Grewia* sp.	322
	Grewia villosa	
Sterculiaceae	*Hermannia exappendiculata*	26
	Sterculia rhynchocarpa	162,258
Bombacaceae	*Adansonia digitata*	
Malvaceae	*Hibiscus somalensis*	320
	Pavonia arabica	271,376
Euphorbiaceae	*Euphorbia arabica*	362
	Euphorbia cuneata	
	Eurphobia erlangeri	347
	Eurphobia scheffleri	180
	Eurphobia sp. *nov*	379
	Jatropha rivae	286
	Jatropha trifida	212
Caesalpiniaceae	*Caesalpinia erianthera*	373
	Caesalpinia trothae	62,410
Mimosaceae	*Acacia bussei*	
	Acacia etbaica	
	Acacia horrida	
	Acacia mellifera	
	Acacia ogadensis	366
	Acacia senegal	
	Acacia sp.	221
	Acacia tortilis	
Papilionaceae	*Crotalaria pycnostachya*	216
	Dalbergia commiphoroides	
	Indigofera sp.	304
	Indigofera sp. *nov?*	317
	Indigofera spinosa	365,382
	Indigofera tinctoria	402
Celastraceae	*Elaeodendrum schweinfurthianum*	437
Salvadoraceae	*Azima tetracantha*	179
Opiliaceae	*Opilia campestris*	48
Loranthaceae	*Oncocalyx kelleri*	175
Rhamnaceae	*Ziziphus hamur*	
Rutaceae	*Vepris eugeniifolia*	435
	Vepris glomerata	44
Simaroubaceae	*Kirkia tenuifolia*	425
Burseraceae	*Boswellia* sp.	
	Commiphora africana	139
	Commiphora campestris	257
	Commiphora sp.	274
	Commiphora unilobata	368
Anacardiaceae	*Lannea* sp.	
Umbelliferae	*Trachyspermum aethusifolium*	172
Apocynaceae	*Adenium obsesum*	
Asclepidaceae	*Edithcolea grandis*	387
	Gomphocarpus sp.	
Asclepidaceae	*Calotropis procera*	
Rubiaceae	*Gardenia fiorii*	
	Spermacoce filituba	183
	Tarenna graveolens	210
Compositae	*Blepharispermum fruticosum*	423
Boraginaceae	*Boureria orbicularis*	259
	Cordia somaliensis	177
Solanaceae	*Solanum hastifolium*	250
	Solanum jubae	313,339,348
Convolvulaceae	*Hildebrantia* sp.	
	Ipomoea garckeana	188
	Ipomoea sinensis	398
	Seddera bagshawei	14,27
	Seddera microphylla?	384
Scrophulariaceae	*Cycnium tubulosum*	207
Pedaliaceae	*Pedalium murex*	395
	Sesamothamnus busseanus	
Acanthaceae	*Asystasia* sp.?	185
	Barleria argentea	321
	Barleria orbicularis	375
	Barleria proxima	272
	Barleria quadrispina	270,323
	Barleria ramulosa	23,63
	Berleria sp.	350
	Blepharis persica	
	Duosperma eremophilum	361

Acanthaceae *(continued)*	*Ecbolium violaceum*	346,359
	Justicia flava	377
	Neuracanthus polyacanthus	360
	Satanocrater paradoxus	49,422
	Satanocrater sp.	341
Verbenaceae	*Vitex negundo*	176
Labiatae	*Endostemon gracilis*	182
	Ocimum canum	396
Liliaceae	*Aloe* sp.	
	Asparagus somalensis	358
	Asparagus sp.	
Cyperaceae	*Cyperus teneriffae*	404
Gramineae	*Aristida adscensionis*	215
	Aristida mutabilis	324
	Cymbopogon caesius	213
	Dactyloctenium geminatum	197
	Digitaria velutina	399
	Dignathia hirtella	412
	Enneapogon schimperanus	378,380
	Enteropogon macrostachyus	161
	Enteropogon sp.? *nov*	174,198
	Eragrostis ciliaris	173,303
	Sporobolus agrostoides	199,400
	Sporobolus ioclados	65
	Tetrapogon cenchriformis	334
	Tetrapogon villosus?	28,47
	Tragus heptaneuron	408
	Urochloa rudis	411
	Urochloa trichopus	196

C. Species Found Both In and Outside the Floodplain

FAMILY	SPECIES	JESS Collection Numbers
Annonaceae	*Monanthotaxis fornicata*	114
Cruciferae	*Farsetia robecchiana*	278,349
Amaranthaceae	*Achyranthes aspersa*	187
	Aerva lanata	64
	Aerva persica	
	Celosia polystachia	12,281,297,391
Zygophllaceae	*Tribulus terrestris*	299
	Zygophllum simplex	
Lythraceae	*Lawsonia inermis*	
Combretaceae	*Combretum contractum*	73
	Combretum hereroense	233,319
	Terminalia brevipes	5,18,217,428
Tiliaceae	*Corchorus olitorius*	104,326
	Grewia tenax	
Bombacaceae	*Ceiba pentandra*	85
Malvaceae	*Abutilion pennosum*	13
	Senra incana	345
	Thespesia danis	1
Euphorbiaceae	*Acalypha fruticosa*	92,223,236,256,353,389
	Cephalocroton cordofanus	*147,251,426*
	Flueggea virosa	68,158,169,194,227,228,234
	Tragia hildebrandtii	159
Caesalpiniaceae	*Cassia longiracemosa*	302
Mimosaceae	*Acacia drepanolobium*	146
	Acacia nilotica	
	Acacia nubica	
	Acacia reficiens	
	Acacia zanzibarica	189
	Albizia anthelmintica	148,436
	Dichrostachys cinerea	
	Newtonia erlangeri	36,57,152,195
Papilionaceae	*Indigofera coerulea*	370
	Indigofera schimperi	7,21,24,41,106,131,214
	Ormocarpum kirkii	61,108,160
Celastraceae	*Elaeodendron aquifolium*	434
Salvadoraceae	*Dobera glabra*	
	Dobera loranthifolia	255
	Salvardora persica	
Balanitaceae	*Balanites* sp.	381
Burseraceae	*Commiphora boiviniana*	45,247
Sapindaceae	*Lecaniodiscus fraxinifolius*	30,52,91,240
Boraginaceae	*Cordia sinensis*	164
	Heliotropium aegyptiacum	275
	Heliotropium zeylanicum	288,301
Convolvulaceae	*Merremia* sp.	184
Acanthaceae	*Anisotes trisulcus*	245
	Justicia sp.	312,334
Verbenaceae	*Premna resionsa*	11,44
Commelinaceae	*Commelina* spp.	17
Gramineae	*Cenchrus ciliaris*	*53,140,200,401*
	Dactyloctenium aegyptium	295
	Dactyloctenium scindicum	
	Digitaria milanjiana	141,421
	Eragrostia cilianensis	25,289
	Eriochloa meyerana	135
	Leptothrium senegalense	
	Paspalidium desertorum	267,328,414,420
	Setaria incrassata	151,427
	Sporobolus helvolus	4,13,47,109,128,191,252,31
	Sporobolus sp.	336
	Tetrapogon tenellus	226,331

The following list of names was collected during TEBS field surveys in the Jubba Valley. This list should not be used uncritically in determining scientific names when a vernacular name is given. Confirmation must be sought from someone familiar with the flora if specific names are important.

These names were collected throughout TEBS study area. However, regional variations exist such that a plant may have a different name in different areas. Even at one site, with one informant, a species may have more than one name. Some descriptive names are applied and used for many different species. For example, *geed cade* (meaning "white plant") is used for at least four species of tree in the Jubba Valley. *Balambaal* is used for many plants which are perceived as of no human use. Modern Somali orthography is used wherever possible such that "c" is a glottal stop and "x" an aspirated "h". However, local pronounciations are used as a basis for spelling rather than "official Somali." The Jubba Valley is strongly influenced by the *af Maay-maay* dialect and to a lesser extent, by Swahili.

Information in this table is also available in the PLANTAX data base housed in the JESS data repositories (see Section II).

A few names on the list are from sources other than TEBS. Those marked * are supplied by Michael Madaney, Jilib District (unpublished); # are from SOMAC/SAREC (1983) Jilib, Jamaame, and Kismaayo Districts; + are from Madgwick (1988), Bu'aale District.

VERNACULAR NAME	SCIENTIFIC NAMES
abaq*	*Acacia tortilis*
aboor makareen	*Rinorea elliptica*
adad geri	*Acacia ogadensis*
aqab*	*Acacia tortilis*
alaan/alan	*Terminalia brevipes*
aluundi	*Solanum jubae*
amaamiye	*Farsetia robecchiana*
anyah	*Boerhavia* sp(p).
awalle	*Clerodendrum acerbianum*
baar	*Hyphaene* sp./*Commelina* spp.
bakaraw+	*Kigelia africana*
bala baley	*Sorghum arudinaceum*
balambaal	see introductory notes
ballo	*Digitaria velutina*
baraari	*Cissus aphylla*
bar baraajis	*Ipomoea sepiaria*
big cade	*Melhania ovata*
bilcil	*Acacia mellifera*
bile	*Aristida adscensionis/A. mutabilis*
booc	*Calotropis procera*
bookoro	*Nymphaea lotus*
boqondhoo	*Balanites* sp(p).
buni	*Cephalocroton cordofanus*
cadaad	*Acacia senegal*
caday	*Salvadora persica*
calacheche+	*Ficus scassellatii*
caleen koris	*Ampelocissus africana*
canaaniye	*Tragia hildebrandtii*
caw	*Hyphaene* seedling
caws farqoole	*Dactyloctenium aristatum*
caws guri	*Cenchrus ciliaris*
caws jeerar	*Enteropgon* sp. nov.?
caws lagoley	*Panicum maximum*
caws shiir	*Indigofera microcarpa/I. schimperi*
caws weyn	*Eriochloa meyerana*
cismaan dooy	*Monanthotaxis fornicata/Uvaria* sp.
ciddi shabeel	*Adenopodia rotundifolia/Combretum aculeatum*
chengo+	*Afzelia quanzensis*
cilaan	*Lawsonia inermis*
daangoole	*Aerva lanata*
daba dabi	*Dactyloctenium scindicum*
dabiil/debeel	*Hyphaene* sp.
dabiriq#	*Commiphora boiviniana*
dabo	*Sporobolus nervosus*
dal	*Eriochloa meyerana*
damal/dambal	*Acacia elatior*
deegaan	*Mimusops fruticosa*
dhaanrab	*Sterculia rhynchocarpa/S. africana+*
dhalad	*Acrachne racemosa/Brachiaria ramosa/Eriochloa fatmensis*
dha(n)farrur	*Grewia tenax*
dharkayn+	*Euphorbia robecchii*
dharqe/dhirqe	*Indigofera schimperi*
dhaydhay/dheydhey#	*Newtonia erlangeri*
dhay ilmood	*Cassia fallacina*
dheg dhego	*Pupalia lappacea*
dheg dhegley	*Setaria verticillata*
dhidhiigle	*Jatropha rivae/J. trifida*
dhiigdaar/dhiigtar	*Dichrostachys cinerea*
dhiraandhir	*Euphorbia cuneata*
dhoomal	*Nymphaea lotus*

dhowey	*Bridela cathartica/Grewia trichocarpa/Grewia* sp(p).
dhugaal	*Maerua subcordata*
dhul muud	*Sporobolus helvolus*
dhumeek	*Grewia* sp(p).
dhuuji	*Dalbergia commiphoroides*
dhuundhug/dhoondhug	*Anisotes trisulcus*
dhuur	*Tamarix aphylla*
dibiriq	*Commiphora boiviniana*
digir jalow	*Vigna unguiculata*
digir jinni	*Clitoria terneata*
dooyo	*Dactloctenium aegyptium*
doraar	*Echinochloa haploclada*
dub hanraar	*Heliotropium aegyptiacum/H. zeylanicum*
dulan	*Diospyros cornii*
eesle gole	*Eriochloa meyerana*
ereeb	*Terminalia brevipes*
fargaan	*Garcinia livingstonei*
fiidey malabey	*Achyranthes aspersa/Ludwigia* sp.
food cade	*Aerva lanata/A. persica*
fulaay	*Acacia zanzibarica*
fulaay-bor	*Acacia drepanolobium*
gaduud madoone	*Ochna ovata*
galamash+	*Trichilia emetica*
galool/gològ	*Acacia bussei*
gamoor	*Phyllanthus somalensis*
gamoor cade	*Flueggea virosa*
garawle	*Cenchrus ciliaris*
garas	*Dobera glabra*
garas weynle	*Dobera loranthifolia*
garroorey	*Meyna tetraphylla*
geed beered#	*Pupalia lappacea*
geed biyood	*Pleiocarpa pycnantha/Barleria orbicularis*
geed buureed	*Mundulea sericea*
geed cade	*Cola* sp. nov./(*Baphia* ?) /*Camptolepis ramiflora/ Cordia goetzei/Pavetta transjubensis*
geed goleed	*Saba comorensis*
geed guduudka#	*Indigofera schimperi*
geed hawaaleed xagar*	*Commiphora boiviniana*
geed kaar#	*Clerodendrum acerbianum*
geed maaluugees#	*Cadaba farinosa*
geed madow	*Cordia goetzei/Hunteria zeylanica+*
gerbi	*Hyphaene* sp.
gob/geb	*Ziziphus mucronata*
goriye haaris	*Digera muricata*
gorro/gorra	*Caesalpinia trothae*
gumur	*Acacia nubica*
habantir	*Phyllanthus somalensis*
half	*Aristida mutabilis/Tetrapogon cenchriformis*
hambooyow	*Aerva persica*
hidow	*Dactyloctenium scindicum*
hareeri	*Terminalia* sp(p).
himir	*Boureria orbicularis*
hiinfaal	*Cola* sp. nov.
hiiran	*Hildebtandtia* sp(p).
hinshili	*Grewia tenax*
hohob	*Grewia* sp(p).
hubur	*Ziziphus hamur*
humbawwe/hambeewi#	*Lecaniodiscus fraxinifolius*
humbow siib	*Enteropogon* sp. *nov.?*
humur	*Ziziphus hamur*
hurbuule	*Dactyloctenium aegyptium*
idaad geri	*Acacia senegal/A. rovumae*
il magor	*Leptothrium senegalense*
jabaan jow	*Jatropha trifida*
jaade jaade	*Satanocrater* sp.
jamba jamba	*Acalypha fruticosa*
jambo	*Phyllanthus somalensis*
jarbo/jarba/jarbe	*Sporobolus helvolus*
jiilaal makreen	*Enicostema axillare*
jiir xalooli	*Eriochloa meyerana*
jir	*Paspalidium desertorum*
jumeerik/jimeerik	*Barleria proxima/B. quadrispina*
kabesh/kobish/kemush	*Grewia villosa*
kabxaan	*Thespesia danis*
kishi	*Cadaba glandulosa*
kobon	*Thespesia danis*
kukih	*Commiphora* sp(p).
kulaan/kulun	*Balanites* sp(p).
kurdo	*Sporobolus agrostoides/Urochloa trichopus*
lafaay	*Flueggea virosa*
lavueeti	*Sesbania bispinosa*
liilow	*Celosia polystachia*
liwondho	*Sporobolus helvolus*
maalige	*Maerua* sp(p).
maaliqo	*Phoenix* sp.
macaratiil	*Indigofera* sp.
maci	*Euphorbia acalyphoides*
madah dhalis	*Seddera bagshawei*
madow madi edi	*Aerva persica*
mahan buuq	*Combretum illiari?*
majabe	*Phyllanthus somalensis*
makadey	*Sorghum arudinaceum*
makadey weyn	*Rotboellia cochinchinensis*
makaruumbi waaweyn	*Solanum incanum*
makongowey	*Acacia rovumae*
malaasow	*Digitaria acuminatissima*
mandharud	*Ximenia caffra*
mardaf	*Combretum aculeatum*

mared	*Cordia sinensis*
mareer	*Cordia sinensis*
mareer delib+	*Cordia goetzei*
mareer dool	*Cordia goetzei*
mareer orgaawe	*Cordia chisimajensis*
mareer orr gab	*Coffea rhamnifolia*
mar mardool	*Gardenia fiorii*
marjis	*Premna resinosa*
maroodi masiibe	*Ormocarpum kirkii*
maroodi matagen	*Ormocarpum kirkii*
masaar jabis	*Lepisanthes senegalensis*
mataan biyood	*Polysphaeria multiflora/ Sorindeia madagascarensis#*
meygaag	*Boscia minimifolia*
mudweyneeye	*Justicia* sp(p).
mukey	*Ficus sycomorus*
mukoy*	*Ficus sycomorus*
murishi	*Grewia tenax*
qabato	*Ziziphus mucronata*
qabi yari	*Euphorbia erlangeri*
qansaax/qansah	*Acacia reficiens*
qalanqaal	*Boscia coriacea/Cadaba spinosa+*
qal foon	*Cucumis dipsaceus*
qashin	*Senra incana*
qardo	*Rhynchosia minima*
qarunjo	*Cucumis dipsaceus*
qeendhi	*Tribulus terrestris*
qonji	*Cyperus compressus*
qoor(a)qabad	*Capparis sepiaria*
qoqon/qoqoon	*Combretum hereroense*
qurac	*Acacia tortilis*
qurdhubo	*Terminalia parvula*
quujo	*Cyperus compressus*
quul	*Setaria incrassata*
raasoow	*Northosaerva brachiata*
ramay	*Eragrostis cilianensis*
ramoole	*Sesbania sesban*
reexan	*Ocimum canum*
reydab	*Albizia anthelmintica*
riig	*Acacia reficiens*
roosac	*Commiphora campestris*
rufle	*Seddera bagshawei*
saaq saaq	*Ipomoea plebeia/Rhynchosia minima*
saar saar	*Rhynchosia minima*
saar saar hajiimow	*Ipomoea pes-tigridis*
sabciin	*Harrisonia abyssinica*
sakaay	*Veronia cinerea*
salaamac	*Sesamothamnus busseanus*
salbir	*Enicostema axillare*
sanriibi	*Ecbolium violaceum*
sariibiye#	*Pupalia lappacea*
sariin	*Duosperma eremophilum*
sarman	*Acacia horrida*
saydhi	*Chloris virgata*
seef dhaley	*Saccharum spontaneum*
seer	*Sporobolus fimbriatus*
shaati weebid	*Cyperus* sp. nov.
shabkaxle	*Drypetes natalensis*
shalbir	*Echinochloa colona*
shalooley	*Uvaria* sp.
shanfar(y)ood	*Garcinia livingstonei*
shiin shi	*Barleria quadrispina*
showri+	*Diospyros cornii*
sir mokaay	*Veronia cinerea*
subagoole	*Cressa cretica*
sunbul	*Veronia cinerea*
toosi	*Boscia tomentella*
tugaar	*Acacia nilotica*
umbulisaanga#	*Salacia stuhlmanniana*
ur uriqey	*Cassia longiracemosa*
wabaayo booneed	*Olea capensis*
wan are	*Lannea* sp(p).
waraan kool	*Spirostachys venenifera*
wisil dureed	*Indigofera schimperi*
xamakow	*Edithcolea grandis*
xanyo goleed	*Rinorea elliptica*
xararaay	*Allophylus rubifolius/ Flueggea virosa*
xaye goleed	*Rinorea elliptica*
xuskul	*Sansiviera* spp.
yaaq	*Adansonia digitata/Commiphora africana*
yacay	*Sericocomopsis hildebrandtii*
yagar	*Hibiscus cannabinus/H. hildebrandtii*
yululu	*Corchorus olitorius/C. trilocularis*

Destructive sampling is needed to conduct proper forest inventory in areas where mass/dimensional relationships are unknown. Such procedures are technically exacting and time consuming. An example of the painstaking methodology is provided by Bird (1988). The JESS project was not an appropriate activity for making such detailed assessments.

Throughout JESS, published regressions were sought relating crown dimensions of East African trees and shrubs to dry weight. Concurrently with JESS, the British Forestry Project, Somalia, was conducting the most thorough bushland biomass inventory yet performed in East Africa. In addition to published information, Denis Herlocker kindly provided unpublished data from his work in Marsabit District, northern Kenya.

The following relationships were examined. Mass is given in kilograms oven-dry weight; linear or area measurements are in meters or square meters.

- Western *et al.* (1981). A 22-species regression derived from trees and shrubs from the Amboseli region of Kenya. Both crown volume and crown area were used; for comparative purposes the following relationship is used here (and in Figure 20; line A = Western). Crown area was converted to diameter assuming a circular crown.

- Epp *et al.* (1982). Eight relationships were published, four for individual *Acacia* species, one for *Commiphora* spp., and three for various combinations of species. Data are for trees and shrubs from various semi-arid sites in Kenya. For all species combined, the relationship is (Figure 20; line MED = EPP;all)

  log[mass] = 0.04 + 1.53 log[crown area]

  mass = -7.76 + 7.49[crown diameter]

- A series of regressions determined by Herlocker (unpublished) in Marsabit District, Kenya. Two of these relationships are shown in Figure 20; for a mixture of *Acacia* species (line LOW = Herlocker; ACACIA) and for *Balanites* sp (line C = Herlocker; BALANITES). These are the highest and lowest lines in Herlocker's data.

ACACIA:

mass = -8.75 + 5.64[crown diameter]

BALANITES:

mass = -13.85 + 16.08[crown diameter]

- Bird (personal communication) has related crown diameter of *Acacia bussei* in Bay region, Somalia, to total weight (Figure 20; line HIGH = BIRD; TOTAL). He has also produced a relationship between crown diameter and weight of wood suitable for charcoal (Bird 1988; line D = BIRD; (CHARCOAL)).

TOTAL:

ln[mass] = -1.00547 + 3.02246(ln[crown diameter])

CHARCOAL:

ln[mass] = -4.1640 + 4.05271(ln[crown diameter])

- Watson and Nimmo (1985) used a somewhat different relationship involving crown diameter, tree height, and volume of saw wood. Typical heights and crown diameters from TEBS monitoring sites have been substituted in the equation, converted to "charcoal usable" wood (Watson and Nimmo 1985), and expressed as dry weight assuming a specific gravity of 0.6 (Synnott 1988). The result is line B = WATSON (CHARCOAL) in Figure 20.

In comparing lines in Figure 20 it should be remembered that the only statistically rigorous and verified relationships are those of Bird. The first point to note is that some relationships are arithmetic and others allometric. There is little doubt that over a wide range of sizes, allometric relationships are to be expected. However, for relatively small plants, arithmetic equations are appropriate. The studies of Herlocker and Epp *et al.* concern trees up to 5 m crown diameter. Examination of data plots of Bird (1988) show that an arithmetic relationship is suitable for smaller *A. bussei* plants, up to a crown diameter of perhaps 10 m. After this size, a logarithmic relationship is clearly required.

The second point to note is that the lines of Western *et al.* and Watson and Nimmo are substantially higher than other plots, particularly for larger plants. The appropriate comparisons are WESTERN with BIRD; TOTAL and WATSON with BIRD; CHARCOAL. Bird (1988) questions the methods (statisti-

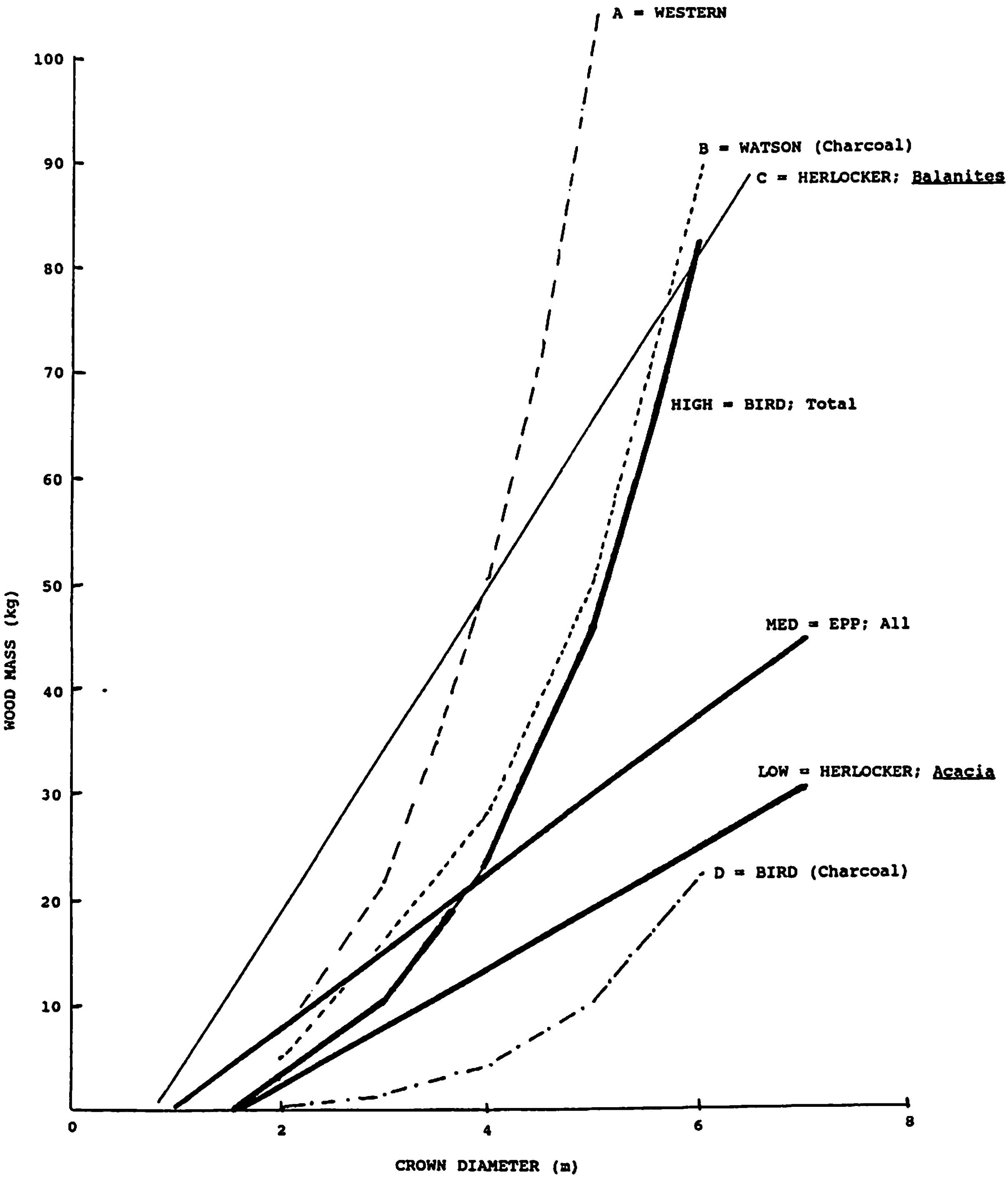

Figure 20. Comparison of several regression predictions relating dry mass of individual trees and shrubs in East Africa to their crown diameter. (See text for sources.)

cal and sampling) used in these studies. The relationships of Epp *et al.* and Herlocker are more compatible with those of Bird, albeit relating to other species. *Acacia bussei* has a particularly high specific gravity. It may, therefore, be expected that wood mass for a given crown diameter will be higher than for other *Acacia* species, as is the case in Figure 20.

For JESS purposes it is concluded that the most appropriate relationships are those of Bird, Epp *et al.*, and Herlocker.

Applying Tree Mass Regressions to JESS Data

For each JESS ground monitoring site, three regressions were used to determine the mass of each woody plant of crown diameter greater than 2 m. It was assumed that smaller plants have negligible wood mass (as indicated by Figure 20). The three regressions used are labeled HIGH, MEDIUM, and LOW in Figure 20. Plant masses were summed for each site and expressed as tonnes per hectare.

Monitoring sites were then grouped according to vegetation structure using the classification developed in Section VI and Appendix C. Results are given in Table 30. Table 17, in the body of the text, was derived from Table 30 as follows.

For "bush" dominated sites (*i.e.*, shrubs and trees <5 m high) the LOW and MEDIUM regressions were deemed applicable. These relate to *Acacia* spp. and *Commiphora* spp., which dominate the Jubba bushlands. Since *A. bussei* is uncommon, a relationship predicting lower wood mass than HIGH (*A. bussei*) is appropriate.

For woodland and forest communities (dominant woody plants >5 m tall) the MEDIUM and HIGH regressions were used. Among these bigger plants an allometric relationship becomes increasingly appropriate as in the HIGH regression.

To obtain a "best estimate" of biomass for each vegetation type, the median of LOW and MEDIUM was used for bushland sites and the median of MEDIUM and HIGH for woodland and forest sites. These estimates are presented in Table 17. It must be emphasized that this approach is "rule of thumb" and neither accuracy nor precision can be determined. However, results in Tables 30 and 17 show sensible gradations between tall and low vegetation types and open and dense vegetation types. Standard errors within vegetation types are low indicating the homogeneity of the vegetation types selected.

Table 30. Biomass predictions applied to JESS ground monitoring sites grouped by structural vegetation type. High, medium, and low refer to application of similarly labeled regression lines in Figure 20.

		BIOMASS TONNES PER HECTARE					
		HIGH		MEDIUM		LOW	
VEGETATION TYPE	N[1]	MEAN	SEM[2]	MEAN	SEM	MEAN	SEM
Forest	10	225.9	67.7	34.5	4.2	22.4	2.6
Dense woodland	2	74.8	(20.6)	12.1	(1.6)	8.3	(1.1)
Open woodland	2	12.7	(2.8)	3.0	(0.6)	2.0	(0.4)
Wooded grassland	2	2.6	(1.1)	2.0	(0.6)	1.0	(0.6)
Bushland thicket	14	55.9	7.5	33.2	4.6	18.8	2.2
Dense bushlanld	6	16.1	1.7	11.5	0.5	6.9	0.3
Medium bushland	11	13.5	1.5	6.7	0.3	4.1	0.2
Open bushland	15	7.7	0.8	4.6	0.4	2.6	0.2
Sparse bushland	4	3.7	(0.5)	2.6	(0.2)	1.6	(0.1)
Bushed grassland	10	2.7	0.8	2.2	0.4	1.3	0.3

[1] *N = number of sites*
[2] *SEM = standard error of mean; those in parentheses are dubious, since N< 5*

Another way to judge these biomass figures is to compare them with estimates for other areas. As expected, data presented by Western *et al.* (1981) and Watson and Nimmo (1985) for vegetation communities are much higher than the JESS estimates. However, other authors give figures for wood biomass closer to those in Table 17. Bird's total biomass estimate of approximately 5 t ha^{-1} for open bushlands of *A. bussei* (personal communication) is similar to the JESS estimate. Lusigi (1984) gives wood biomass estimates of 0.5 to 11 t ha^{-1} for a variety of open bushlands and woodlands in Marsabit District, Kenya. In *Acacia seyal* coppice bushland in Senegal, Gibson and Muller (1985) recorded biomass of 2 to 8 t ha^{-1}. In conclusion, the JESS estimates seem reasonable. They probably err on the side of conservatism, particularly for woodlands and forests.

Estimation of study area under each vegetation type is described in Sections VI and VII. The "mixed" vegetation type (Tables 17 and 19) is from aerial photographic monitoring sites. Most "mixed" sites are in Lower Jubba and contain a composite of large trees, degraded bush, farmland, thicket, and grassland. Biomass is arbitrarily fixed at 5 t ha^{-1} based on examination of the photographs.

Estimating Wood Production

If little data on wood biomass for East Africa exists, even less is known about growth rates. The literature gives rates of net primary production per unit of standing crop, however. Most of this data comes from other areas of the world. Western *et al.* (1981) assess this data and present a graph relating net primary production to biomass. This compilation is independent of their biomass regression which is criticized above. Watson and Nimmo (1985) used similar sources in assessing wood growth. Figure 5 in Western et al (1981) has been used to produce usable wood production estimates for JESS vegetation types (Table 19). Annual wood production is assumed to equal 50 percent of total net production (Western *et al.* 1981). Wood production as a percentage of standing biomass ranges between 1.5 percent for forests to 5 percent for bushed and wooded grasslands and open bushlands. Usable wood is defined as that greater than 2 cm in diameter. Western *et al.* (1981) estimate usable wood as averaging about 70 percent of total wood. Gibson and Muller (1985) assessed wood suitable for charcoal (5 cm diameter) as 60 percent of total biomass, while Bird (personal communication) gives a figure of 40 percent for charcoal wood on a vegetation community basis. For JESS purposes, it is assumed that 60 percent of wood production is usable as firewood. Substantially less is suitable for charcoal, but charcoal manufacture is rare in the study area. These various factors are combined to give estimates of "usable wood production" for each vegetation type in Table 19.

As with biomass, JESS wood production figures are conservative. Usable wood production ranges from 0.05 t ha^{-1} year^{-1} in bushed grasslands to 0.6 t ha^{-1} year^{-1} in forest. Lusigi (1984) reports estimates equivalent to a maximum of 0.4 t ha^{-1} year^{-1} for bushlands in Marsabit District. Annual usable coppice wood production from *Acacia seyal* bushlands was 1.1 t ha^{-1} in Senegal. However, the management system in that area probably maximizes wood production (Gibson and Muller 1985). Western *et al.* (1981) estimate usable wood mass production as 0.02 to 5 t ha^{-1} year^{-1} in Kenya's rangelands. However, they used their own estimates of wood biomass which have been judged too high (see above). Using the Marsabit and Senegal information, it may be reasonable to double the JESS estimates of usable wood production to obtain a less conservative assessment.

The only data available on increment of wood biomass in the study area comes from three JESS bushland sites in the floodplain. Each was cleared for agriculture and then abandoned a known number of years ago (Section VI.D). Using the methods outlined above it is assessed that these sites have had an average annual increment of usable biomass of between 0.6 and 2.5 t ha^{-1}. However, such data cannot be applied to other JESS sites for two reasons. First, these floodplain sites are likely to be more productive than non-floodplain sites. Most wood production and collection will inevitably occur away from the floodplain, although a proper assessment of floodplain production potential would be useful. Second, these sites began from zero biomass. The early stages of biomass increment are likely to be more rapid than when a mature community is present.

Forage Yield of Range Plants

Herbaceous Forage

Forage yield is defined as ungrazed harvestable above-ground biomass (dry matter) of herbage at the end of a growing season (Deshmukh in press). This quantity is not equivalent to net above-ground primary production, which is often double forage yield (see Deshmukh 1986b). Direct measurements of forage yield were made at TEBS ground monitoring sites after gu' rains of 1986 and 1987 and through other seasons (Appendix A; TEBS data bases).

It was expected that differences in forage yield would be apparent for different JESS vegetation types such that more heavily wooded sites would have less herbaceous vegetation. However, such differences were not clear. In the river-dependent zone, lack of such a relationship is attributed to a degraded herb layer (Section VII.D.1). In the floodplain, sites tended to be rather open with good grass cover or densely wooded with a negligible herbaceous stratum.

The approach finally adopted was to relate forage yield to estimated mean annual rainfall for each river section (rainfall is given in Section III.A.2 and Table 31). Mean annual rainfall was used rather than that received for a specific study period, because rainfall data are incomplete for 1986 when most vegetation data were collected. Peak herbaceous standing crop (post gu') for each river zone with ground monitoring sites is plotted against rainfall in Figure 16. Only sites with substantial grass growth were used in the relationships. Regression equations are:

floodplain:
$$y = 15.62x - 1020.44 \quad (r^2 = 0.95)$$
river-dependent zone:
$$y = 10.79x - 1598.66 \quad (r^2 = 0.82)$$
(y = forage yield, kg ha^{-1}, dry matter; x = gu' rainfall, mm)

Mean annual rainfall is substituted for gu' rainfall to give estimates for annual forage yield in each river section (Table 31). Figure 17 also shows a similar relationship for grasslands throughout eastern and southern Africa (Deshmukh 1984).

Table 31. Predicted herbaceous forage yield (kg ha^{-1} year^{-1}) in each river section comparing floodplain and river-dependent zone in years of average and low (drought) rainfall. Average rainfall is from Section III of this report. Low rainfall is a "typical" bad year (rather than absolutely lowest) of rainfall chosen by examination of long-term records for the study area presented by Watson and Nimmo (1985).

River Section	Mean Annual rain (mm)	Forage yield FP	Forage yield NFP	Drought rain (mm)	Forage yield FP	Forage yield NFP
I	300	3,666	1,692	200	2,104	559
II	350	4,447	2,178	200	2,104	559
III	400	5,228	2,717	300	3,666	1,692
IV	450	6,009	3,257	350	4,447	2,178
V	550	7,571	4,336	400	5,228	2,717
VI	650	9,113	5,415	450	6,009	3,257
VII/VIII	400	5,228	2,717	300	3,666	1,692

Herbaceous forage yield was extrapolated to the study area using the following assumptions:

- Land under range was estimated as the sum of "open" and "enclosed" land in Table 10.
- Rangeland under each TEBS vegetation type in each river section was calculated using the proportion of aerial photograph monitoring sites under each vegetation type for the floodplain and river-dependent zone.
- In the floodplain, forests, dense woodlands, and thicket bushlands were assumed to have negligible herbaceous forage, whereas dense bushlands had half of the forage yield predicted by the first equation above. All other vegetation types were regarded as having forage yield equal to that predicted for the relevant river section. These assumptions are derived from examination of TEBS data bases.
- In the river-dependent zone, the same assumptions about vegetation types were made, except that dense bushlands were assumed to have the full forage yield predicted by the second equation above (as the TEBS data base suggests). In addition, a multiplicative factor was introduced for

sites which were expected to have herbaceous vegetation because of low woody cover, but had a negligible amount. The factor is based on the proportion of TEBS ground monitoring sites which had negligible standing crop post gu'. In River Section II, the factor is 0.25; in River Section IV, 0.6 (i.e., 75 percent and 40 percent of sites had negligible standing crop, respectively). River Section II factor was applied to River Section I and a factor of 0.4 interpolated for River Section III. No adjustment was needed for other river sections.

Forage from Bushes and Trees

Very few estimates have been made of browsable forage in East African rangelands. Ecosystems (1985), using data gathered by the Integrated Project on Arid Lands (Marsabit District, Kenya), produced a predictive equation relating browse forage yield to rainfall and woody canopy cover:

$$y = 0.02x + 10.00A - 0.04 \; (r^2 = 0.88)$$

(y = browse dry weight, kg ha^{-1} $year^{-1}$; x = mean annual rainfall, mm; A = percent woody canopy cover).

Species composition of the Kenyan study area is similar to that of TEBS river-dependent zone, although woody cover tends to be lower in the former. It is not possible to verify the accuracy of this relationship for TEBS study area. The only other published account known to JESS of browse production in East Africa is Wijngaarden (1985). Direct comparisons with the Ecosystems (1985) relationship are difficult. Wijngaarden's equations are more strongly influenced by rainfall than Ecosystems' and also take into account browsing pressure. At 10 percent canopy cover and 200 mm rainfall (and low browsing pressure), the two relationships produce similar predictions. Under most other feasible combinations of conditions, Wijngaarden predicts higher forage yield. Species composition of Wijngaarden's study area is less similar to TEBS than Marsabit District which has a much larger data base. It was concluded that Ecosystems's equation provides the best estimate available for TEBS study area. However, it must be emphasized that predicted browse yield cannot be verified unless complex field measurements are made in TEBS study area.

The relationship was applied to JESS aerial vegetation monitoring sites in each river section. The proportion of land under each vegetation type is the same as for herbaceous vegetation except that "enclosed" areas (Table 10) were assumed to have negligible browse. Woody vegetation is usually cleared or sparse within enclosures. Predictions of browse forage yield for each vegetation type are given in Table 21. The regression model is insensitive to rainfall so that differences for different rainfall regimes are negligible. However, forage yield does respond markedly to percentage of woody cover, which is higher in wetter areas. Thus, wetter areas have higher browse yield as indicated in Figure 15 for the river-dependent zone. In computing forage yield for each section of TEBS study area, it is assumed that browse produced in forests and dense woodlands is not consumed by browsers, since many trees are too tall, most species are unpalatable, and browsing was not evident at such ground monitoring sites. It is assumed that only 50 percent of browse yield in thicket bushlands is available since livestock cannot penetrate denser clumps of bushes. When forage is scarce, however, pastoralists make some of this "unavailable" browse accessible to livestock by cutting branches from taller trees and shrubs. This additional source of forage has not been included in TEBS computations since quantitative estimates do not exist.

Figure 15 presents graze and browse forage yield for each river section comparing floodplain and river-dependent zones.

Forage Consumption by Large Herbivores

Many studies exist of daily forage intake of wild and domestic African herbivores. However, most of these relate to stall-fed animals in good condition and eating a good diet. Under semi-arid range conditions less food is consumed than by stall-fed animals, although fewer data exist. Deshmukh (in press) collected information from 10 studies on free-ranging animals (including cattle, camels, sheep, and goats) and derived the following relationship.

$$y = 0.885x - 1.445 \; (r^2 = 0.98)$$

y = log of daily food intake (kg, dry matter); x = log of live body weight of animal (kg).

Using population structure adjusted body weights (Watson and Nimmo 1988) of 304 kg for a camel, 180 kg for cattle, 150 kg for donkey, and 18 kg for sheep and goats, the equation predicts a daily forage intake of 5.65, 3.56, 3.03, and 0.46 kg, respectively. A 1,000 kg hippopotamus consumes 16.2 kg per day.

Annual forage consumption for each species and river section is then computed using density of each species in different sections from Watson and

Nimmo (1988). Number of days to which each set of aerial census densities were applied are discussed in Section VII.D.

Balance Between Forage Yield and Herbivore Consumption

Figure 15 presents total forage yield as though it is all available to large herbivores. Using such data herbivore consumption always seems to be a relatively low proportion of forage yield even in areas where herbivore density is high (Deshmukh in press). One reason that forage is not all consumable is that a proportion is unavailable or inaccessible to large herbivores. Where woody vegetation is tall or dense, parts of the crowns cannot be reached even by tall herbivores such as camels. Ecosystems (1985) suggest that 50 percent of total browse yield is available to camels and 25 percent to goats in Turkana District, northern Kenya. These proportions are assumed to be applicable to TEBS study area.

A similar situation applies to herbaceous forage. Accessibility is not a problem, except in thickets. Nevertheless, it is generally assumed that only about half of herbaceous forage is consumable by large herbivores over large areas, even though consumption locally may be higher. Herbaceous forage is lost to insects, decomposers, and by wasteful feeding methods and trampling by the large herbivores themselves (Deshmukh in press). Quantitative assumptions of proportion of herbage available include 50 percent (Watson and Nimmo 1985), 37.5 percent (Lusigi 1984), and 40 percent (Ecosystems 1985, who also quote 50 percent as the "standard practice in range science"). Measurements at ground monitoring sites in the floodplain indicate that as much as 70 to 80 percent of forage yield was consumed in some areas. An overall figure of 50 percent of herbaceous forage being available to large herbivores is considered reasonable for TEBS study area.

Balance between forage available and that consumed is given in Table 32 and summarized in Table 22. Assumptions are discussed above, or in Section VII.D . In Table 32:

- "goat browse" is 25 percent of total browse forage yield,
- "goat demand" is total annual goat food requirement,
- "camel browse" is any remaining goat browse from goat demand, plus a further 25 percent of total browse forage yield,
- "camel demand" is total annual camel food requirement,
- "browse balance" is [a) + c)] - [b) + d)],
- "total graze" is 50 percent of herbaceous forage yield,

Table 32 . Computations of available forage and demand by grazers and browsers in different river sections (kg ha^{-1} $year^{-1}$).

River Section	Goat Browse	Goat Demand	Camel Browse	Camel Demand	Browse Balance	Total Graze	Grazer Demand	Graze Balance
A. FLOODPLAIN								
I	66.3	224	66.3	996	-1,087	2,582	34	+1,648
II	52.1	280	52.1	338	-513	2,920	652	+2,268
III	77.4	60	94.8	177	-82	1,962	507	+1,455
IV	75.4	9	141.8	344	-202	2,612	532	+2,080
V	100.0	10	190.0	54	+136	2,937	612	+2,325
VI	61.2	22	100.4	15	+85	2,490	630	+1,860
VII/VIII	50.8	16	85.6	23	+63	1,513	1,961	-448
B. RIVER-DEPENDENT ZONE								
I	81.3	69	93.6	326	-232	394	115	+279
II	97.1	49	145.2	137	+12	512	190	+322
III	99.4	27	171.8	223	-51	783	168	+615
IV	135.7	16	255.4	416	-161	1,820	193	+1,627
V	145.5	4	287.0	230	+57	3,172	258	+2,914
VI	137.6	17	258.0	137	+121	4,018	146	+3,872
VII/VIII	131.5	13	250.0	155	+95	1,840	151	+1,689

- "grazer demand" is total annual food requirement of cattle, sheep and donkeys, and
- "graze balance" is [d) - e)].

As elaborated in section VII.D.3, it is realized that the livestock species all consume browse and graze, but in different proportions. The analysis presented deliberately avoids having to assign such proportions since no information is available for the study area. However, camels and goats are given "first serving" of browse and cattle, sheep and donkeys "first serving" of graze.

The analysis is repeated for a "drought year" and summarized in Table 22. Browse yield was not altered because lower rainfall had negligible effect on estimates in Table 21. Herbaceous forage was reduced according to the predictive equations above (see Table 31).

COMMON NAME	SCIENTIFIC NAME
honey bee	*Apis mellifera*
tsetse fly	*Glossina* spp.
crocodile	*Crocodylus niloticus*
ostrich	*Struthio camelus*
duiker	*Cephalophus* spp.
gerenuk	*Litocranius walleri*
waterbuck	*Kobus ellipsiptymnus*
reedbuck	*Redunca redunca*
bushbuck	*Tragelaphus scriptus*
lesser kudu	*Tragelaphus imberbis*
oryx	*Oryx beisa*
oribi	*Ourebia ourebia*
dibatag	*Ammodorcas clarkei*
Soemmering's gazelle	*Gazella soemmeringi*
Grant's gazelle	*Gazella granti*
Hunter's antelope/ hartebeest	*Damaliscus hunteri*
topi	*Damaliscus korrigum*
giraffe	*Giraffa camelopardis*
black rhinoceros	*Diceros bicornis*
plains (Burchell's) zebra	*Equus burchelli*
Grevy's zebra	*Equus grevyi*
elephant	*Loxodonta africana*
warthog	*Phacochoerus aethiopicus*
bushpig	*Potamochoerus porcus*
hippopotamus	*Hippopotamus amphibius*
baboon	*Papio anubis*
vervet monkey	*Cercopithecus aethiops*

Appendix I, "Vegetation Survey of the JubbaValley and Baardheere Reservoir Zone", which follows, combines information from *JESS Report No. 9* – "Interim Report on Vegetation Survey of the Jubba Valley," Christopher F. Hemming, October 1986 and *JESS Report No. 23* – "JESS Interim Report: Vegetation Survey of Baardheere Reservoir Zone," Christopher F. Hemming, August 1987. Associates in Rural Development, Burlington, Vermont.