Impact of human activities and livestock on the African environment: an attempt to partition the pressure

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Introduction

The impact of human endeavours to eke out a living through crop and animal agriculture is examined in a holistic context in this paper. It is argued that the direct and indirect impact of livestock production on the natural resource base can only be assessed as an integral part of the overall pressures that human activities exert on the environment.

Removal of plant cover by livestock is usually identified as the major cause of impact. The analyses therefore focus on the main sources of pressure which continue to modify the vegetation cover of rural Africa. These sources include effects of fires and burning of biomass, fuel wood extraction and deforestation and land clearing.

Land degradation

Assessment of land degradation is usually confined to the drylands of the world, as other degrading human activities such as deforestation and biomass burning are assessed separately. Degradation is regularly reported for rangelands, soils and crop lands (Table 1). The severity of degradation for each is grouped into four classes, ascending from none/slight to very severe. In general, these classes refer to the percentage loss of expected productivity with moderate being less than 25 per cent, severe in the range 25-50 per cent and very severe more than 50 per cent.

Table 1 Degradation rates in African drylands

Total area (million km^2)	Amount of degradation					
	None/slight		Moderate		Severe	
	km^2	%	km^2	%	km^2	%
Rangeland						
13.42[a)]	3.48	15	2.68	12	7.25	31
Soil						
12.9						

Arid	-	66	-	30	-	4
Semiarid	-	78	-	14	-	8
Subhumid	-	87	-	9	-	4
Rainfed crop land[b)]						
0.8	0.31	39	0.43	54	0.05	7

Notes:
[a)] Excludes hyperarid desert
[b)] Rainfed crop land is 55 per cent of all tropical African crop land

Source: Dregne *et al,* 1991

Rangeland degradation

Rangeland degradation is mainly related to the state of the vegetation cover of the woody and herbaceous strata. In Africa, rangelands are estimated to cover about 13.4 million km^2 or 60 per cent of the continent. This is close to the combined extent of the arid and semiarid zones and the drier parts of the subhumid zone (Dregne *et al,* 1991). Reductions in perennial grasses and woody biomass appear to be the main criteria to assess class values but the "yardstick to measure the potential" has not been clearly stated.

There is little doubt that woody cover in African drylands has decreased at a rapid rate in particular in the arid zone and in the drier parts of the semiarid zone. Needs for fuel wood and crop land has unavoidable impact on woody cover but how changes in herbaceous cover cause degradation is less clear. In the drier part of West Africa (< 800 mm annual rainfall) grasses are mostly annuals except on sites benefiting from run-on soil moisture. Their productivity is almost entirely determined by rainfall (Box 1). Perennial grasses dominate in East Africa at lower rainfall (up to 400 mm) because it is bimodal but in dry years the proportion of ephemeral annuals increases (Njoka, 1984; Herlocker *et al,* 1993).

Box 1
The resilience of Sahel Rangeland grasses

Annual grasses that dominate the various land units in the Sahel have an outstanding ability to produce large stocks of seed under many constraining circumstances

Traits that contribute to reseeding ability include:

• seed dormancy is restricted and is broken before the next growing season;

• date of flowering is governed by day length and therefore the period of seed setting is short and fixed;

• growth cycles adapt to the rainfall distribution pattern allowing at least some seed production even when rains are poorly distributed;

• plants develop protective devices against grazing when flowering and setting seed and possess efficient seed dispersal mechanisms;

• most species produce large numbers of tillers, depending on plant density and available soil moisture and nutrients;

• defoliation by livestock tends to increase tiller numbers although few tillers may reach the flowering stage; and

• under extreme continuous grazing pressure shorter cycle and lower yielding annuals replace longer cycle species and although these are palatable they are very resistant to grazing due to their short growing period.

Source: Hiernaux, 1994

As the herbaceous stratum provides most of the livestock feed, secondary productivity rises and falls with rainfall but is mostly controlled by heavy drought induced mortality. If the rangelands dominated by annual grasses are considered resilient rather than degraded, about 8-9 million km^2 move up into the none/slight class of degradation (Table 1).

Soil and crop land degradation

Soil degradation is less serious on crop than on rangelands, with 75 per cent of the drylands being unaffected (Table 1). Soil erosion, shifting sand and surface crust formation impeding infiltration and promoting run-off are among the major causes of degradation in upland soils. The same causes play a role in the degradation of rainfed crop land. It is probable, however that depletion of soil organic matter and nutrients is the most common cause of degradation (Smaling 1992). There is no substantial evidence that the major causes of soil degradation in drylands are grazing (34.5 per cent), deforestation (29.5 per cent) and agriculture (28.1 per cent) as asserted in a recent UNEP publication (Greijn, 1994).

Livestock distribution and stocking rates

It may seem odd to revert to livestock distribution patterns based on livestock statistics compiled during the late 1970s (Jahnke, 1982). Unfortunately, that analysis is the only available baseline linking livestock distributions to ecological zones within countries. Numbers have recently been updated but the older distribution patterns between zones and regions were maintained (Winrock, 1992).

About 76 per cent of the 154 million Tropical Livestock Units (TLU) in 1986-1988 were in lowland tropical Africa with 40 per cent of these being in the arid, 34 per cent in the semiarid and 26 per cent in the subhumid zones (Table 2). The other 24 per cent were mainly in the highlands (18 per cent) and the humid zone (6 per cent). East and West Africa accounted for 56 and 26 per cent of the total livestock wealth whilst Southern (12 per cent) and Central Africa (6 per cent) had fewer numbers (Winrock, 1992).

Ratios between people and livestock are indicative of their importance in rural production systems. The highest ratios are found in pastoral East Africa. More sedentary systems average 0.5 TLU/person (Table 2) except in the subhumid and humid zones where livestock wealth is very low (Table 3) and where the proportion of small ruminants is high.

Table 2 Densities of rural people and livestock in the arid, semiarid and subhumid ecological zones and corresponding geographical regions

Zone	Region	Number/km^2		TLU/caput	Percentage of	
		TLU	People		TLU	People
Arid	West	6.3	4.1	1.56	11	5
	East	11.9	6.1	1.93	24	9
	South	7.4	4.2	1.76	4	1
	mean/total	9.1	5.1	1.78	39	15
Semiarid	West	11.1	24.0	0.46	17	25
	East	13.1	21.2	0.62	14	15
	South	3.1	7.1	0.44	4	6
	mean/total	9.0	17.7	0.51	35	46
	West	6.1	22.3	0.27	7	19

Subhumid	East	16.3	14.5	1.12	15	9
	South	2.0	6.8	0.30	3	8
	Central	0.5	6.3	0.08	1	3
	mean/total	5.8	12.4	0.46	26	39

Source: adapted from Jahnke, 1992

Table 3 Density of rural people and livestock in the eastern highlands and in the humid zone

Item	Ecological zone and region			
	Highlands		Humid	
	East/Central[a)]	Ethiopia	West[b)]	Central[c)]
People/km^2	149.2	36.6	49.2	7.1
TLU/km^2	58.3	27.5	6.1	0.4
TLU/caput	0.39	0.75	0.12	0.06

Notes:
[a)] Kenya, Uganda, Burundi, Rwanda
[b)] Nigeria, Ghana, Guinea, Sierra Leone
[c)] Zaïre, Gabon, CAR, Congo, Cameroon

Source: adapted from Jahnke, 1992

In the Ethiopian highlands, population and livestock pressures are high (up to 120 people and 130 TLU/km^2) due to a near universal reliance on cattle and equines for soil tillage and transport. Intensive small holder dairying has transformed the livestock industry in the Kenya highlands where highly productive pastures, cut and carry forage production and supplementary concentrate feeding allow stocking rates as high as 100 TLU/km^2. Extremely high population pressure in the highlands of Rwanda and Burundi explain why stocking rates are lower (50 TLU/km^2) due to continuous conversion of pastures to cropped land. Feed resources are thus scarce here. They include banana stems and leaves, spent grain from beer brewing and forages grown on erosion bunds.

From 1979 to 1988, cattle increased by 18 million (12 per cent), small ruminants by 48 million (22 per cent) and camels by two million (18 per cent). Increases in numbers have not been uniform across zones and regions. In the arid zone, due to droughts in the early 1980s, cattle numbers stagnated or declined due to high mortality and permanent migration into better rainfall areas. This, combined with rapid expansion of ox traction cropping of cotton, boosted cattle populations in subhumid West Africa.

Biomass removal

Livestock

Consumption of plant cover by livestock has a major impact and overgrazing is believed to contribute substantially to desertification and land degradation (Dregne *et al,* 1991). Plant removal reduces protective plant cover, vigour and regrowth capacity, the effects of which increase exponentially with removal rates (Belsky, 1988; Hiernaux *et al,* 1994). Indirect effects include trampling which leads to soil compaction and, when excessive (as along cattle trails and around homesteads and water points), may cause run-off and gully erosion. Grazing implies removal of nutrients (NPK and trace elements) and organic matter, part of which is returned as faeces and urine. Depending on the recycling processes, a substantial portion is retained in the ecosystem (de Leeuw *et al,* 1994; Fernandez-Rivera *et al,* 1994).

To assess impact on a continental scale overall biomass removal can be derived from the expected intake of the entire population of grazing ruminants. The parameters included in this computation (Table 4) are based on meta-analyses of a large set of data (Fernandez-Rivera *et al,* 1994) on intake and faecal output providing gross and net removal rates, and the fraction of herbaceous forage and browse in the intake. Gross removal amounts to 460 million tonnes of dry matter (DM), over 80 per cent of which is from the herbaceous layer. Cattle account for 70 per cent of the total removal. Small ruminants and camels consume the remainder, including almost 90 per cent of the browse totalling 83 million tonnes of DM. Net consumption averages 55 per cent of gross intake so that over 200 million tonnes are potentially recycled back to the ecosystem.

Table 4 Gross and net annual feed intake of domestic ruminants in tropical Africa

Item	Livestock species			
	Cattle	Sheep	Goat	Camel
Number (million)	163	124	145	13
Average weight (kg)	175	25	20	250
Feed intake (t DM/year)	2.00	0.40	0.33	2.86
Faecal output (t DM/year)	0.90	0.18	0.14	1.23
Net removal (t DM/year)	1.10	0.22	0.19	1.63
Proportion browse in diet	0.05	0.20	0.50	0.90

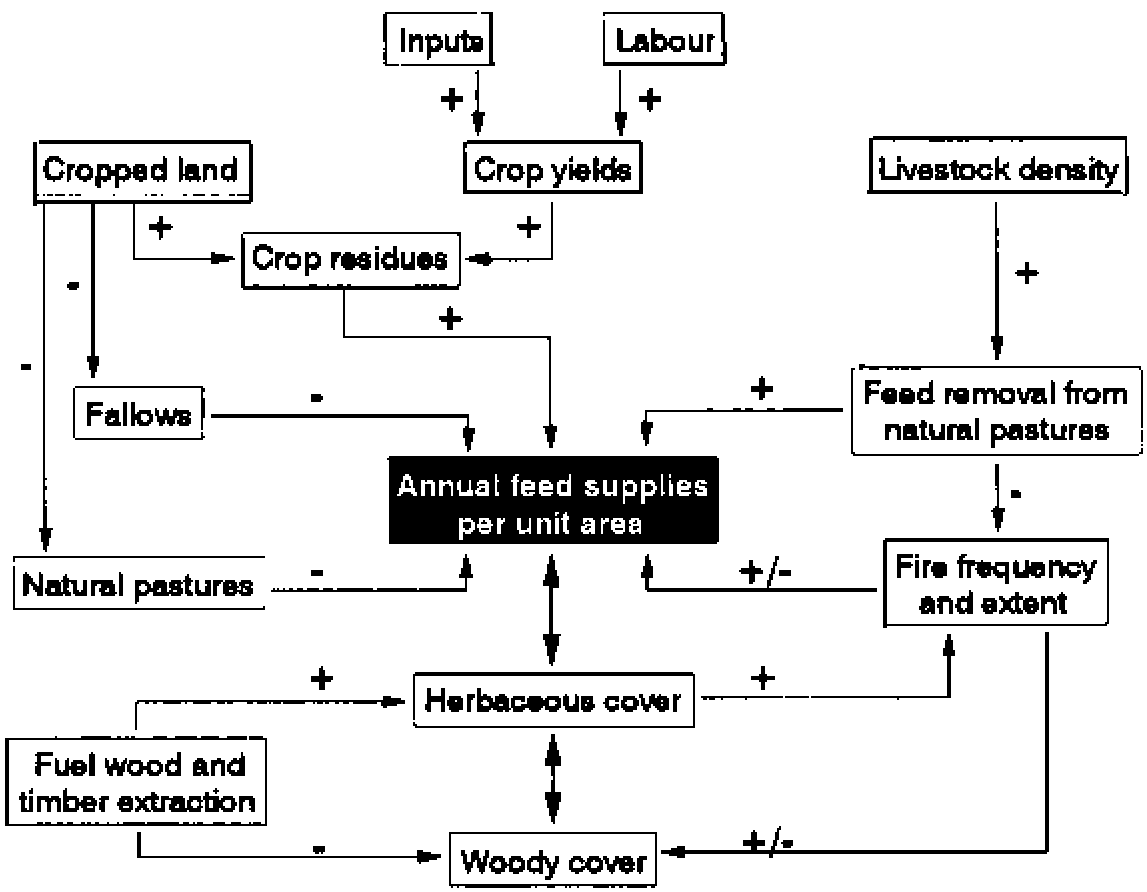
Source: adapted from Fernandez-Rivera *et al,* 1994 except livestock numbers which are from Winrock, 1992

Comparing these gross removal rates with actual stocking rates provides an index of impact per unit area of land. At 10 and 20 TLU/km^2 of stocking, roughly 0.3 and 0.6 tonnes DM of biomass are eaten. Hence, given average end of season yields of forage in the arid and semiarid zone of 0.5 and 1.5 tonnes DM/ha, the consumed fraction would be 60 per cent and 40 per cent in the two zones. These use rates may seem dangerously close to the recommended "proper use" factors of 0.3 to 0.5 (de Leeuw and Tothill, 1993). The presumed impact is much less, however, because 60-75 per cent is grazed during the dry season without impairing the subsequent regrowth potential of the grass cover. In the arid zone, impact on the herbaceous cover is further mitigated by browse consumption of camels and small ruminants. The relative proportion of perennial and annual species further modifies herbivore impact as annuals are generally the most resilient.

Highly aggregated feed demand: supply ratios ignore local factors limiting access such as flooding and cropping during the growing season, dense woodland and thickets often combined with tsetse infestation, steeply sloping terrain and areas without water. Use of grazing is also affected by site selection for pastoral settlement and by the livestock wealth of sedentary farmers. It is often believed that remote areas attract pastoralists but a strong correlation ($p < 0.001$) has been shown (Bourn and Wint, 1994) between livestock densities and the percentage of cultivated land and human habitation in West Africa and that "there is little room for doubt that livestock tend to congregate where land is cultivated". Settled farming communities attract herders and herds because they are close to water supplies, markets and other infrastructure. More importantly, livestock ownership by farmers increases with intensification of land use (Mortimore, 1989; de Leeuw *et al,* 1994).

Encroachment onto grazing land, including creation of national parks and game reserves and by squatter farmers, is usually listed high as a cause of increasing grazing pressure. It can be argued, however, that converting land from grazing to crops increases overall feed supplies, in particular in subhumid areas with high fire frequencies. Intensification reduces the fraction of grazable biomass removed by fires and raises output of crop residues (Figure 1). Fire hazards are lessened by greater herbage and woody biomass removal and a greater heterogeneity and patchiness of the vegetation.

Figure 1 Multiple effects of land use intensification on livestock feed supply per unit area



Burning

Fire in tropical Africa has received renewed attention since it was realized that biomass burning contributes 42 per cent of the gross atmospheric emissions of CO_2 (Cachier, 1992). Africa contributes 43 per cent of the total which exceeds the combined emissions of South America and Asia (39 per cent) (Williams and Balling, n.d.). The area of tropical forests is much greater (15 million km^2) than that of humid savannas (9 million km^2) but it is estimated that only 90000 km^2 of forest are burned every year compared to 5.4 million km^2 of savanna (Cachier, 1992). The total amount of burnt biomass in Africa is 2820 million tonnes DM to which savanna fires contribute 2500 million tonnes (Table 5).

Table 5 Estimated annual burnt biomass in tropical African savannas by zone

Item	Zone and subzone				Total/mean
	Semiarid		Subhumid		
	Dry	Wet	Dry	Wet	

Total area (million km^2)	2.75	3.41	3.04	0.89	10.10
Proportion burnt	0.3	0.4	0.7	0.7	0.5
Area burnt (million km^2)	0.82	1.36	2.12	0.62	4.92
Burnt biomass (m.t. DM ha/yr)	2.9	5.3	5.9	4.6	5.1
Trees and shrubs	1.4	2.3	3.4	2.9	2.7
Herbaceous layer	1.5	2.0	2.5	3.0	2.4
Burnt biomass (million m.t.)	238	721	1250	285	2494
Trees and shrubs	115	313	721	180	1329
Herbaceous layer	123	408	529	105	1165

Source: recalculated from Delmas *et al,* 1991

Savanna fires in tropical Africa extend roughly from 15° N to 25° S latitudes. The area potentially subject to fire hazard is of the order of 10 million km^2 encompassing savannas in the semiarid, the subhumid and the drier part of the humid zones (Table 5). Almost all savanna fires occur during the dry season, from December to March in the northern hemisphere with the peak in January. Night-time low-light satellite imagery shows the highest frequencies of fires in a broad belt between 3° N and 10° N, coinciding with the subhumid zone and secondary vegetation in the humid zone (Cahoon *et al,* 1992). Farther north, fires are more patchy and extend into southern Mali, Burkina Faso and Sudan.

South of the equator frequent fires reach peak occurrence in southern Zaïre in June and then sweep eastward to reach maximum values in Mozambique in September. Fires are widely spread over the entire dry season between 0° and 18° S in Congo, most of Angola, the southern third of Zaïre, most of Zambia and eastern Tanzania (Cahoon *et al,* 1992).

Interpretation of AVHRR/NOAA and LANDSAT imagery combined with field observations indicates that about half the fire prone zones are burned each year (Table 5). Annual fire frequency decreases from 0.7 to 0.4 with diminishing rainfall, mainly because of reduced fuel loads. Along the rainfall gradient, combustible biomass, comprising mainly standing grass and tree and shrub foliage, falls from 7.5 to 3.5 m.t. DM/ha. Because most fires are wind-driven, they pass through rapidly and thus the amount of woody biomass destroyed is negligible (Delmas *et al,* 1991).

Woody foliage and herbaceous biomass were partitioned by difference. As fire initiation needs a combustible ground mass greater than 1 m.t. DM/ha it seems likely that fires in the drier areas burn off about 1.5 m.t. DM/ha on average. With increasing rainfall, standing dry herbage and litter increase to median values of 3.0 m.t. DM/ha although in West Africa much higher herbage yields are recorded (Boudet, 1975; ILCA, 1979; Cesar, 1991).

These computed foliage yields are in agreement with literature sources (Walker, 1980) but may be overestimated where combustion rates are lower than the 80 per cent that has been adopted elsewhere (Delmas *et al,* 1991). This may partly explain some lower estimates (de Leeuw 1992) on a total area of 3.3 million km^2 with a biomass loss of 800 million tonnes DM, this being only about 30 per cent of the 2500 million tonnes shown in Table 5. The two estimates produced respective average burned mass amounts of 5.1 m.t. DM/ha and 2.7 m.t. DM/ha. The major conclusion arising from these analyses, however, is that fires remove about half the dry season herbaceous biomass or 1000 million tonnes DM per year, about 45 per cent of which is from the semiarid savanna. Assuming lower combustible fuel loads and reduced proportions of burnt land with rising rural population density a revised estimate of the contribution of the semiarid zone would be lower and amount to 32 per cent (de Leeuw 1992).

Fuel wood extraction

The impact of fuel wood use by local rural populations and the more distant urban centres on wood resources and vegetation structure is a major pressure on the environment. In rural Africa, 80-90 per cent of the energy demand is derived directly from woody vegetation and wood-derived charcoal is an important source for food preparation and heating in the urban sector.

Total demand in tropical Africa of the rural population of 350 million people in 1994 would convert to 170 million tonnes of wood at average annual use rates of 0.5 t/person. The urban population of 150 million would require 60 million tonnes at a use rate of 0.4 t/head. Other sources of organic fuel include crop residues and animal dung. In areas such as the Ethiopian highlands where wood is scarce these sources supply 45 per cent of total demand.

Given the high transport cost, fuel supplies in rural areas are mostly from nearby sources, either from a farmer's own land or communal areas. The impact of wood cutting is therefore localized and directly related to site-specific population densities. At a density of 20 people/km - a common figure in many parts of the semiarid and subhumid zones - wood extraction would amount to 10 t/km^2/annum. In these zones, standing woody biomass in farm and fallow shrub lands varies from 3-8 m.t. DM/ha but rises to 20 m.t. DM/ha in well developed *Acacia* woodlands (Franklin and Hiernaux, 1991).

Similar estimates of woody cover were made in an assessment of wood volume and vegetation cover over 320000 km^2 in northern Nigeria. Woody biomass in farmed and shrub lands was in the range 3-7 m.t. DM/ha whereas in woodland it was in the range 15-30 m.t. DM/ha. Fuel wood biomass of the entire area averaged 7.5 m.t. DM/ha (RIM, 1991). At annual increments of 0.2 m.t. DM/ha (Groten; 1991) fuel wood support capacity would be about 40 people/km^2. Standing woody biomass gradually diminishes in excess of this density unless wood from distant surplus areas is available. The most critical part of the survey area was the dry semiarid zone (< 700 mm rainfall) where rural population density was high (> 150 person/km^2), cropped land exceeded 60 per cent and there was more pressure from livestock at densities of more than 50 TLU/km^2 (Mortimore, 1989, RIM, 1991; Bourn and Wint 1994).

Deforestation and land clearing

Discussion on deforestation in Africa usually emphasises the closed forests of the humid zone. Estimates combine exploitation for commercial timber, removal of woody cover related to slash and burn agriculture and conversion to small holder or plantation tree crop production. African closed forests covered 2.0 million km^2 in 1985, or half the area designated as the humid zone. Annual projected deforestation rates for 1981-1985 averaged 0.6 per cent or 12000 km^2 (World Resources, 1989). The rate for open woodlands was estimated at 0.5 per cent representing an annual area of 23400 km^2

Statistics on clearing of new land and of old fallows are difficult to interpret as there is overlap with data on deforestation. In contrast to Latin America, clear felling of woody cover to open land for cropping is still rare in rural Africa. In most cases land clearing is a gradual process and useful trees are retained, this explaining the wide occurrence of parklands in tropical Africa (Nair, 1989; RIM, 1991).

About 1.5 million km^2 of land was classified as crop land in 1985-1987 (World Resources, 1989), representing 6.4 per cent of total land. If it is assumed, however, that lack of rainfall precludes cropping in areas with less than 350 mm in West Africa and less than 500 mm in East and Southern Africa (Ellis and Calvin, 1993), the cropped area would rise to 8.7 per cent and this would increase further if expressed as a ratio of the total of potentially arable areas if land with shallow stony soils and very steep slopes were excluded.

Cropped areas expanded rapidly in 1965-1975 but possibly decelerated thereafter. In 1965-1985, 15 of 36 major countries in tropical Africa had growth rates exceeding 20 per cent, and 11 countries had rates of over 50 per cent. In contrast, 21 countries showed less than 5 per cent expansion in 1976-1986, whilst crop land areas contracted in several more. Expansion greater than 10 per cent continued into the 1980s in only six countries (World Resources, 1991). Total crop output seems to corroborate these trends with rapid growth during 1965-1973, a drastic slowing down in 1973-1980 and then an upturn in 1980-1987. To what extent these swings in output can be attributed to the effects of rainfall fluctuation on crop yield per unit area is not clear.

An increase of only five per cent expansion of crop land over 1976-1986 - equivalent to 7.3 million ha -seems incompatible with a rise in the rural population averaging 7.5 million/yr as this would indicate that each additional person adds less than 0.1 ha to the pool of cultivated land (Winrock 1992).

Biomass addition

It is usually accepted that savanna vegetation becomes more dense and reverts to woodland when protected, especially when fires are effectively excluded. A series of burning experiments was established during the 1950s across the savanna regions of English-speaking Africa (see bibliography by Wein and Edroma, 1986). The major purpose was to assess the use of fire as a rangeland management tool, mainly to promote the grass component and suppress woody regrowth, especially of vigorously coppicing species.

Woody regrowth in savanna systems is environmentally desirable to control erosion, supply fuel wood and sequester carbon but farmers dislike regrowth in their fields as it reduces the grazing potential for cattle. Bush encroachment thus reduces the feed supply: demand ratios if demand is not reduced through destocking. This positive feedback between overgrazing and invasion of woody species is described for the Borana region in Ethiopia (Coppock, 1993) and shows that woody growth reduces herbage yield and limits access by stock, thus exacerbating grazing pressure on land with less bush (Box 2). Overstocking on Zimbabwe ranches was linearly related to financial loss due to reduced beef output from bush infested grazing land, losses being less severe on ranches with browsing wild herbivores (Kreuter and Workman, 1994). Similar interactions between fire frequency and herbivory by grazers and browsers (especially elephants) were highlighted in models developed to predict long term trends in woody and herbaceous biomass and its effects on the productivity of land stocked with mixed domestic and wild herbivores (van Wijngaarden, 1986).

Box 2 **Bush encroachment: the case of Sidamo in Ethiopia**
Climate Semiarid to subhumid with 600 mm annual rainfall in two seasons: droughts occur one year in five and multiyear droughts one year in twenty
Cyclic herd performance drought losses ® recovery ® overgrazing (with 50 per cent drought loss and 6-8 year recovery cycle) resulting in grassland (perennial grasses) ® woodland (mainly *Acacia*) due to increased grazing pressure

repeated defoliation ® nutrient removal ® nutrient removal in topsoil ® reduced vigour ® less reseeding ® reduced or no fire
Effects shift from herbaceous to semipermanent dense woody cover access to grazing stock reduced increasing pressure on remaining more open land leading to lower animal output lower income and impaired food security of cattle owners
Remedies prescribed burning during recovery phase planned woody cover reduction through fuel wood and charcoal sales hay making and *Acacia* pod collection for supplementary feeding opportunistic crop production in favourable areas in good years greater livestock offtake when density dependent phase approaches

The complexity of these interactions is also shown by the potential effects of increasing population and livestock density on fire frequency and extent and the potential consequences for the overall feed supply at the community level (c.f. Figure 1).

Further additions to woody biomass arise from fallow regrowth after cropping. Recovery is particularly rapid where fire tolerant species that coppice vigorously from extensive root systems are dominant. The destruction of primary forests due to slash and burn agriculture in the humid zone is similarly countered by increases in secondary forest cover and conversion to tree crop agriculture. In Côte d'Ivoire between 1965 and 1985, for example, one third of the forests were converted to other land use. Some 28 per cent of the 6 million ha was converted to tree crops, seven per cent was used for food crops and 65 per cent reverted to secondary woody formations. Thus over 90 per cent of the land retained some form of woody cover (Spears 1986 quoted in Ehui and Hertel, 1989).

If, during the 1980s, the annual rate of land clearing was restricted to about 1 million ha, the removal of biomass would be very small in comparison to that removed by livestock, fire and by use for fuel wood. Herbaceous cover and woody foliage are usually burned after clearing whereas woody stems and trunks are removed for fuel or for building material.

Discussion and conclusions

Partitioning of annual biomass removal between the three major sources of impact shows that livestock grazing is responsible 24 per cent of the herbaceous biomass loss and for 14 per cent of the combined woody and herbaceous loss in a total of 3200 million tonnes DM (Table 6). These fractions would diminish substantially if only net ruminant intake were considered. Given the inverse relationship between the extent and frequency of fires and livestock density, it is postulated that greater livestock pressure reduces biomass removal by fires, thus increasing the available herbage and reducing the relative removal rates by livestock.

The impact of fuel wood removal depends on whether dead or live biomass is taken. Where fires are frequent and woody cover is adequate (as in most of the subhumid zone) cutting of live vegetation is rare and loss to the ecosystem is therefore minimal. Charcoal production which accounts for a quarter of the total has greater impact as valuable hardwood species, including *Acacia,* are selected and overall savanna biodiversity is reduced.

The partitioning of biomass removal throws light on the relative importance of the pressures exerted by human activities. It has, however, been argued that these impacts should be aggregated (de Leeuw, 1992) rather than partitioned as is done by UNEP (Greijn, 1994). By assessing support capacities for crops, livestock and fuel wood an aggregate index could thus emerge that would measure overall impact on the environment. Depending on ecosystem resilience -emanating from climate, landscape and characteristics of the soil and vegetation cover - risks of degrading processes and their resulting impact could then be identified. Rather than partitioning sources of impact, causes of degradation such as wind and water erosion and nutrient depletion in soils due to crop and biomass removal could be given importance rankings and then aggregated.

Impact assessment could easily be incorporated into the procedures that have been developed by FAO to estimate the human support capacity from assessment of potential yields and outputs of crops (Higgins *et al,* 1987). Actual crop yields are derived from the suitability of land by assessing climatic and edaphic attributes at given levels of inputs. Conversion of yields of appropriate crop mixes into quantities of calories and protein enables the computation of potential population densities that the food output can support. Comparison with present and future anticipated population densities allows the calculation of critical areas where food output is or will become insufficient to meet minimum human requirements.

Livestock and fuel wood productivity models have recently been added by FAO to the estimation of potential productivity of land resources (Kassam *et al,* 1991). These models are designed to operate on a digitalized land resource data base and include provisions for quantifying soil erosion hazards and resulting estimates of "tolerable" soil losses. Since the three models are interphased with each other, land productivity can be optimized for any given set of development constraints and demand. A contextual framework thus exists that incorporates the essential building blocks for assessing whether current land use is sustainable and could accommodate location specific data sets to estimate the impact on the environment.

Table 6 Annual gross removal of biomass by livestock fires and fuel wood extraction in tropical Africa (million tonnes DM)

Source of removal	Herbaceous stratum	Woody stratum		Total
		Foliage	Wood	
Livestock	378	83	-	461
Fire	1165	1320	-	2494
Fuel	-	-	230	230
Total	1543	1403	230	3185

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