Agroforestry Systems **41**: 201–211, 1998.

Cutting and resprouting of *Detarium microcarpum* and herbaceous forage availability in a semiarid environment in Burkina Faso

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Key words: bush encroachment, grazing, silvopastoralism, tropical savanna, vegetation dynamics

Abstract. The tree-shrub savanna 'Forêt Classée de Nazinon' (Burkina Faso) is submitted to a management of grazing and rotational cutting of *Detarium microcarpum*. This species resprouts after cutting. In order to investigate whether this silvopastoral land use system is sustainable, aboveground herbaceous biomass was measured on subplots under uncut trees ('uncut'), next to the stubs of cut trees ('cut') and on subplots not influenced by the (former) crowns of trees ('open grassland') in four lots. These lots were cut one, three, six and seven years before the study. Vegetation composition of the lots and the composition of the diet of cattle were also determined. Comparisons were made between treatments and lots. Herbaceous biomass was lower in the open grassland subplots than in uncut or cut subplots. We speculate that soil enrichment and more efficient precipitation input in (former) tree crown zones could have resulted in this pattern. Cutting and subsequent resprouting of trees did not lead to significant differences in herbaceous biomass between cut and uncut subplots. The most simple explanation for this is that the trees could extend their roots beyond the location of their neighbouring trees. Biomass and coverage of perennial grasses, mainly *Andropogon ascinodis* and *Andropogon gayanus*, did not change in lots cut one, three or six years before the study, but decreased dramatically in lots that were cut seven years before the study. When foraging, cattle spent more than 90% of their time feeding on these species. This indicates that, as a consequence of tree cutting, forage availability may be reduced to the point where local herdsmen are forced to take their cattle to another region.

Introduction

Trees and shrubs in tropical savannas have often been found to improve their understorey environment (Kellman, 1979; Belsky et al., 1989). This common finding is important for the field of silvopastoralism, a land management system in which trees and shrubs are retained in or introduced into pastoral land (Le Houérou, 1987). But the effect of trees and shrubs on their understorey environment depends on factors such as rainfall, type and intensity of use of the different components of the silvopastoral system, and the density of the trees. As an example, Belsky et al. (1993) found that the beneficial effect of widely spaced trees on the biomass of the herbaceous layer diminishes with increased livestock utilization.

The herbaceous-woody plant ratio of savannas seems to be mainly governed by rainfall, which is low to moderate (500 to 1300 mm) and extremely variable (Whittaker, 1975). This suggests that soil water availability is a major factor limiting the growth of savanna vegetation. Fire and herbivory may also have a profound effect on this ratio (Kelly and Walker, 1976; Werger, 1983; Dublin, 1995). The general model for the competition between the woody and herbaceous vegetation component is that of a two layered soil-water system in which each vegetation component is the superior competitor in a different layer (Walker et al., 1981). Herbs are more efficient in extracting water from the upper soil layer (topsoil, 0 to 30 cm) whereas woody plants have better access to water that percolates through the topsoil and infiltrates into the subsoil (30 to 150 cm). Field evidence to support this hypothesis was obtained in dry savannas (Knoop and Walker, 1985; Sala et al., 1989; Brown and Archer, 1990).

Recent work by Le Roux et al. (1995), however, shows that in more humid environments (> 1300 mm rainfall per year) both woody and herbaceous plants obtain their water from the same soil layer. Competition between these two vegetation components for available soil water may thus be stronger than in arid areas, provided that soil water availability is still a major factor limiting plant growth. The same was found by Belsky (1994), who demonstrated that trees competed with herbaceous species for soil water and reduced their productivity at wetter sites (> 750 mm per year). Vegetation at drier sites (450 mm per year) showed less intense competition between the woody and herbaceous component, as trees at these sites extended their roots over a larger area than trees at wetter sites. In all cases herbaceous productivity was higher in the tree crown zone than in the open grassland zone. The reason for this seems to be that trees add nutrients to the understory environment in the crown zone in the form of litter and droppings of reposing animals and reduce soil and plant temperatures and evapotranspiration by the shade they cast (Belsky et al., 1993; Belsky, 1994).

Thus, in a semiarid ecosystem plants in an understory environment may benefit from tree presence by the increased nutrient input and decreased temperature in the below-crown microhabitat, but they may also suffer from the increased competition for available soil water and nutrients. Cutting of a tree eliminates these immediate effects on the herbaceous layer. The accumulated amount of nutrients in the former crown zone, which is a long term effect of tree presence, is now exclusively available to the herbaceous component of the vegetation. As the benefit of increased levels of available nutrients is expected to outweigh the possible disadvantage of increased radiation, it seems plausible to expect an increase in herbaceous biomass in the former tree crown zone after cutting (Breman and Kessler, 1995). A higher biomass yield for grasses in areas recently cleared of woody vegetation has been found by Ben-Shahar (1992). He argues that for this reason bush clearance may be of some benefit to herbivores.

The aims of this study were to determine the effects of cutting and resprouting of *Detarium microcarpum* on herbaceous biomass over several years, including the subsequent implications for biomass availability for grazing cattle.

Material and methods

Study site and plot choice

The fieldwork of this study was performed in the rainy season of 1996 in the 'Forêt Classée de Nazinon', with an area of 23.699 ha, situated in the province of Ziro, district of Sapouy, Burkina Faso (11°30′–11°51′ N, 1°27′–1°50′ W). Around the woodland 24 villages are situated, with a total population of 15.511 in 1985 (estimated yearly increase of 4.9%). The main ethnic groups are Mossi, Gourounsi and Peulh. The vegetation in this woodland can be characterised as a tree-shrub savanna. Dominant woody species (low trees and shrubs) are *Detarium microcarpum*, *Burkea africana* and *Strychnos spinosa*, with a highly variable total aerial coverage of 3 to 75%. Precipitation is 850 mm per year (1961 to 1990) which classifies the region as North Sudanian ecoclimatic zone; the rainy season lasts from May to September. Physiographically the area can be classified as a slightly undulating plateau. Soils were classified as Haplic Luvisols (Lvh) and Haplic Alisols (Alh) (FAO, 1988). Both natural and man-induced fires occur with an estimated frequency of one fire per year. The woodland is divided into 140 lots, of which seven are selected every year for harvesting part of the woody vegetation (about 50% of the trees in a 20-year rotation) for fuel wood. The woodland is grazed mainly by cattle with an estimated density of 0.5 to 1.0 tropical livestock unit (TLU) per ha. (Coulibaly, 1993; Diarra and Selmi, 1994; Ouedraogo, 1997).

In order to determine the effect of cutting and resprouting of *Detarium microcarpum* over several years, four neighbouring lots were selected, from which part of the woody vegetation was cut in 1989, 1990, 1993 and 1995 respectively (seven, six, three and one years before this study). The area of each of these lots is 100 to 140 ha. Within these lots, subplots of 1 m^2 were selected through stratified random sampling under uncut trees ('uncut'), next to the stubs of cut trees ('cut') and on subplots not influenced by the (former) crowns of trees ('open grassland'). The three types of subplots are refered to as 'treatments' and there were five replications per treatment. All 60 subplots were selected in areas with similar tree densities. Large irregularities in the terrain (rocks, eroded areas, local depressions, etc.) other than local soil differences were avoided. In view of the large areas of the lots, we assumed that all relevant soil variation was included within each lot representing a certain year of cutting. Therefore, biomass differences could could not be atrributed to local soil differences, which were not measured. It was further assumed that the lots had a similar vegetation before cutting. All selected trees were of the species *Detarium microcarpum* (Caesalpiniaceae), which is abundant in the woodland and is used as firewood. This species resprouts after cutting. The density of this species in this area is two to four trees per 100 m^2, crown diameter is 3.69 ± 0.12 m (mean ± SE) (Ouedraogo, 1997)

Herbaceous biomass

Herbaceous biomass, excluding litter, and including tree seedlings and small shrubs with a stem diameter of less than 0.5 cm, was harvested from the subplots by hand- clipping. Biomass was sorted into functional groups (annual grasses, perennial grasses, and forbs) and fresh weight was determined per functional group using a spring balance (Weighmaster).

Vegetation composition

In order to determine any long term effect of cutting on vegetation composition, five transects were laid out according to the point-quadrate method in each of the four lots studied. Along two lines of 10 m, which crossed each other in the middle at a right angle, each plant species and functional group (trees, shrubs, annual and perennial grasses, annual and perennial forbs) touching an imaginary vertical line were noted at 20 cm intervals. Resprouting Detarium microcarpum were noted as trees. Thus for each transect information was collected at 100 points in an area of 50 m^2 (a square area from which the lines are the diagonals) rendering a species-specific coverage as a percentage of surface area.

Herbivory

In order to determine the effect of cutting of the woody vegetation component on forage availability for grazers, the dependence of these grazers on the different species of gramineous herbs occurring in the area was determined. To this purpose herds of cattle were followed when foraging in the woodland, and the forage-species eaten by a randomly picked animal was noted every minute. Thus the amount of time spent foraging on any species was obtained as a percentage of total foraging time. The term foraging here includes the action of biting only, as further ingestion and digestion of food is not directly related to forage availability.

Data analysis

Two-way ANOVA tests were used to determine the main and interaction effects of treatments and year of cutting. If effects were found one-way ANOVA tests and Student-Newman-Keuls tests were used to determine significant differences ($P < 0.05$) between means. Before testing, biomass and percentual data were log and arcsine transformed respectively.

Results

Herbaceous biomass

Total herbaceous biomass and forb biomass was lower in the open grassland subplots than in uncut and cut subplots, no significant differences were found between cut and uncut subplots and no interaction effects with year of cutting were found (Table 1 and Figure 1). Total herbaceous biomass and biomass of all of the functional groups showed significant differences for the time passed after cutting (Table 1 and Figure 2). In general, biomass changed little in recently cut lots (one to three years before the study), but decreased significantly in lots that were cut longer ago (six and seven years before the study), except for annual grasses. The herbaceous layer in the four lots was characterised by an almost complete absence of annuals.

Vegetation composition

The woody component was dominated by *Detarium microcarpum* and the herbaceous layer consisted mainly of *Andropogon* spp. Tree coverage became higher with increasing time passed after cutting (Table 2). The coverage of *Andropogon* spp. did not change significantly in lots cut one, three or six years before the study, but decreased dramatically in lots that were cut seven years before the study. Coverage of perennial forbs decreased continuously with increasing time after cutting. Mean coverage of annual grasses was higher in the lot that was cut seven years earlier, as compared to the other lots.

Herbivory

Cattle spent more than 90% of their grazing time on *Andropogon ascinodis* and *Andropogon gayanus* (Table 3). The percentage of foraging time spent by the herbivore feeding on a certain species is not correlated with the coverage of forage species (Spearman correlation coefficients not shown, $P > 0.05$). Further, the animals followed were not observed to switch to other forage species in areas where *Andropogon* spp. did not occur at all.

Discussion and conclusion

In all the lots investigated, herbaceous biomass was lower in the open grassland plots than in the uncut or cut subplots (Table 1 and Figure 1). This could be attributed to the commonly found long term effect that soils under tree crowns are generally enriched and have more efficient precipitation input as compared to neighbouring grassland (Kellman, 1979; Belsky et al., 1993; Belsky, 1994). More surprising is that cutting and subsequent resprouting of *Detarium microcarpum* did not lead to differences in herbaceous biomass

Table 1. Herbaceous biomass in open grassland and under uncut and cut tree cover at Sapouy, Ziro, Burkina Faso, and ANOVA test results.

Year	Treat	Total biomass (g/m^2)	Forbs (g/m^2)	Grass (g/m^2)	Annual grass (g/m^2)	Perennial grass (g/m^2)
(1)	u	230.0	152.0	78.0	3.0	75.0
1995		(± 131.6)	(± 149.8)	(± 28.3)	(± 3.3)	(± 27.2)
	o	232.0	117.0	115.0	0.5	114.5
		(± 102.3)	(± 101.3)	(± 23.7)	(± 1.1)	(± 24.0)
	c	300.5	161.0	139.5	9.5	130.0
		(± 60.6)	(± 113.3)	(± 60.0)	(± 13.5)	(± 54.2)
(3)	u	225.0	164.0	61.0	2.5	58.5
1993		(± 237.7)	(± 239.6)	(± 24.1)	(± 1.8)	(± 23.4)
	o	217.0	154.0	63.0	3.0	60.0
		(± 253.5)	(± 275.8)	(± 40.5)	(± 2.7)	(± 42.4)
	c	342.0	246.0	96.0	2.5	93.5
		(± 303.6)	(± 276.2)	(± 62.3)	(± 0.0)	(± 62.3)
(6)	u	125.0	14.0	111.0	4.0	107.0
1990		(± 20.5)	(± 11.9)	(± 20.9)	(± 2.1)	(± 22.0)
	o	99.5	2.0	97.5	2.5	95.0
		(± 64.7)	(± 2.1)	(± 64.9)	(± 1.8)	(± 65.2)
	c	214.0	118.5	95.5	2.0	93.5
		(± 187.5)	(± 220.7)	(± 51.0)	(± 2.1)	(± 50.7)
(7)	u	194.5	146.0	48.5	6.5	42.0
1989		(± 155.0)	(± 156.3)	(± 22.1)	(± 3.4)	(± 19.6)
	o	38.0	3.0	35.0	10.0	25.0
		(± 26.8)	(± 2.1)	(± 25.0)	(± 5.0)	(± 27.2)
	c	77.0	28.0	49.0	6.0	43.0
		(± 35.0)	(± 44.0)	(± 23.1)	(± 2.9)	(± 24.6)

Year indicates the year of cutting. Treat indicates treatment, where u = uncut; o = open grassland and c = cut. Values in parentheses indicate s.d.

ANOVA	Total biomass	Forbs	Grass	Annual grass	Perennial grass
Year	$F = 8.132$	$F = 8.462$	$F = 8.991$	$F = 6.305$	$F = 9.656$
$n = 60$; df = 3	$P = 0.000$***	$P = 0.000$***	$P = 0.000$***	$P = 0.001$**	$P = 0.000$***
Treat	$F = 4.683$	$F = 5.674$	$F = 0.913$	$F = 0.399$	$F = 1.863$
$n = 60$; df = 2	$P = 0.014$*	$P = 0.006$**	$P = 0.408$	$P = 0.673$	$P = 0.166$
year * treat	$F = 1.652$	$F = 1.416$	$F = 0.750$	$F = 1.680$	$F = 1.372$
$n = 60$; df = 6	$P = 0.154$	$P = 0.228$	$P = 0.612$	$P = 0.146$	$P = 0.245$

* $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$.

between cut and uncut subplots. If only tree cutting was considered, an explanation could be that the possible disadvantage of increased radiation for the herbaceous layer is balanced by increased levels of available nutri-

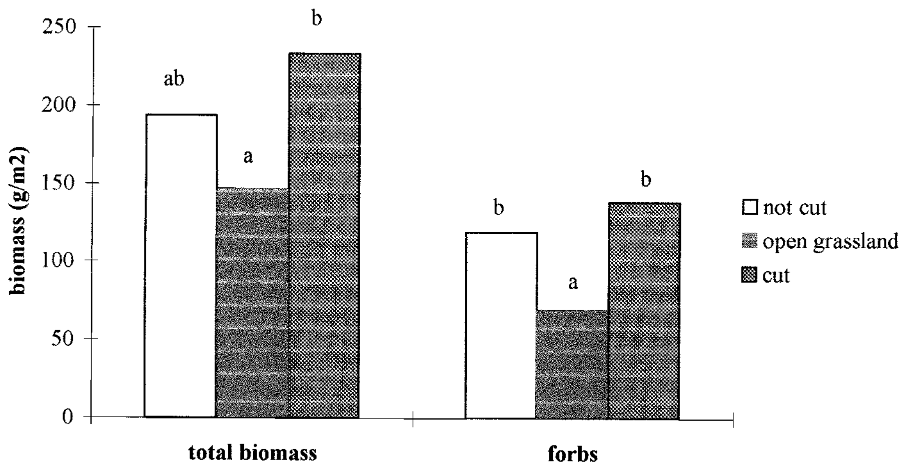

Figure 1. Biomass of different functional plant groups in relation to treatment at Sapouy, Ziro, Burkina Faso. Different letters indicate significant differences between means ($P < 0.05$) of each selected dataset.

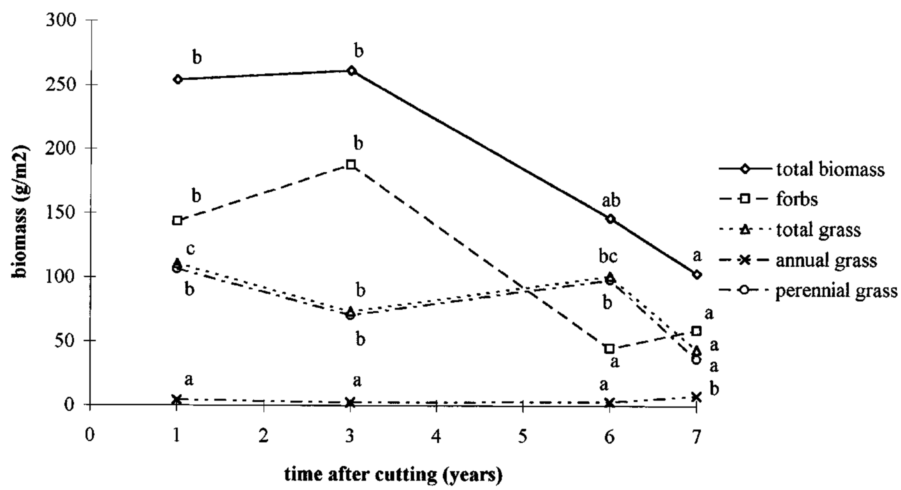

Figure 2. Biomass of different functional plant groups in relation to time passed after cutting at Sapouy, Ziro, Burkina Faso. Different letters indicate significant differences between means ($P < 0.05$) of each selected dataset.

ents (Breman and Kessler, 1995). The subsequent resprouting of the trees and the fact that no differences were found between cut and uncut subplots, independent of year of cutting, points to the possibility that there could be a continuous balance between decreased radiation and decreased nutrient availability for the herbaceous layer. However, this would only be a satisfactory explanation if, additional to the absence of interaction, no differences in herba-

Table 2. Ground cover of different functional plant groups and species in lots cut in different years at Sapouy, Ziro, Burkina Faso, and ANOVA test results.

Coverage (%)	1 (1995)	3 (1993)	6 (1990)	7 (1989)	ANOVA $n = 20$; df = 3
Total	52.60 (± 18.98)	56.80 (± 12.52)	61.20 (± 14.87)	63.00 (± 11.90)	$F = 0.4600$ $P = 0.7141$
Trees	15.60 **a** (± 13.18)	27.60 **ab** (± 16.83)	36.80 **ab** (± 24.43)	50.80 **b** (± 13.54)	$F = 3.3062$ $P = 0.0472$*
Shrubs	8.80 (± 11.92)	2.80 (± 2.77)	0.80 (± 0.84)	5.60 (± 4.88)	$F = 1.3865$ $P = 0.2830$
Annual forbs	0.20 (± 0.45)	0 (± 0)	0 (± 0)	0 (± 0)	$F = 1.0000$ $P = 0.4182$
Perennial forbs	11.20 **b** (± 5.36)	8.00 **ab** (± 3.81)	4.80 **ab** (± 3.96)	1.60 **a** (± 2.19)	$F = 5.2392$ $P = 0.0104$**
Annual grasses	0.60 (± 0.89)	2.00 (± 2.83)	0.40 (± 0.55)	9.60 (± 11.67)	$F = 2.5924$ $P = 0.0887$
Perennial grasses	28.20 **b** (± 10.69)	29.60 **b** (± 3.85)	38.00 **b** (± 11.68)	8.80 **a** (± 4.71)	$F = 10.1989$ $P = 0.0005$***
Detarium microcarpum	5.20 (± 4.32)	20.20 (± 19.75)	15.60 (± 10.50)	24.40 (± 16.88)	$F = 1.6617$ $P = 0.2151$
Andropogon spp.	27.80 **b** (± 10.26)	29.40 **b** (± 3.78)	38.00 **b** (± 11.68)	8.20 **a** (± 4.21)	$F = 11.1103$ $P = 0.0003$***

Different letters in bold type indicate significant differences between means when comparing different years of cutting for trees, perennial forbs, perennial grasses and *Andropogon* spp., respectively. Values in parentheses indicate s.d. * $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$.

Table 3. Time spent by cattle in different lots for foraging all species expressed as percentage of the time they were followed, and the time spent for foraging *Andropogon* spp. expressed as percentage of total foraging time in relation to their coverage in the Nazinon woodland at Sapouy, Ziro, Burkina Faso.

	(1) 1995	(3) 1993	(6) 1990	(7) 1989
Foraging time				
(% following time)	68.52	57.89	51.85	47.83
Andropogon gayanus				
(% foraging time)	54.05	81.82	64.29	54.55
(% coverage)	4.4	6.6	2.0	1.8
Andropogon ascinodis				
(% foraging time)	40.54	18.18	35.71	40.91
(% coverage)	23.4	22.8	36.0	6.4

ceous biomass were found between years of cutting. The fact that these differences were found (Table 1 and Figure 2) points to a different and more simple explanation: in this system trees may extend their roots over a distance larger than crown diameter and intracrown distance. It has been documented that *Detarium microcarpum* often forms lateral roots within the root zone of the herbaceous layer (Thies, 1995). A density of two to four trees per 100 m^2 also indicates that these trees can not been seen as isolated. Crown size of *Detarium microcarpum* is relatively small when compared to the size of trees used in other studies (e.g. *Adansonia digitata* and *Acacia tortilis* in Belsky et al., 1993; *Acacia tortilis* in Belsky, 1994).

Generally, herbaceous biomass changed little in recently cut lots (one to three years before the study), but decreased dramatically in lots that were cut longer ago (six and seven years before the study), except for annual grasses (Table 1 and Figure 2). These results are corroborated by the results on vegetation composition, which indicate that the occurrence of the dominant perennial herbaceous species (*Andropogon* spp.) decreases dramatically as tree coverage surpasses about 40 % in the lot cut seven years ago (Table 2). These results could be explained by the following hypothetical scenario. As transpiration and the uptake of soil nutrients is initially arrested after cutting, the situation may resemble that of non-resprouting trees. It could then be expected that the competition for soil resources between trees and herbaceous biomass may decrease and herbaceous biomass may increase, as put forward by Breman and Kessler (1995). In our study, however, herbaceous biomass did not increase significantly, probably because neighbouring trees continued to compete with the herbaceous vegetation near the stubs of the cut trees. Subsequently, the cut trees resprouted from stored nutrients in root reserves. Gradually, transpiration and the uptake of soil nutrients by the resprouting trees could have increased according to the amount of newly produced foliage, and root reserves may have become restored. As a consequence, competition for soil resources between trees and herbaceous biomass could have become stronger for all subplots, as the roots from the resprouting tree may cover a distance larger than crown diameter and intracrown distance. Continued grazing may have accelerated the process of encroaching tree coverage by causing a decline in herbaceous biomass and thus reducing soil resource competition in favour of the woody vegetation component. Increase in size and density of woody plants or less palatable herbaceous plants may have further intensified the grazing pressure on remaining palatable herbaceous plants. This positive feedback could have driven the system into a state mainly dominated by trees making a return to the original vegetation unlikely, even when livestock are removed (Archer, 1996). This hypothetical scenario will be tested in future research in this area.

Competition for light was not considered as a major factor diminishing plant growth in understorey layers. Earlier investigations (e.g. Belsky, 1994) showed that improved environmental conditions in understorey layers provided by savanna trees outweighed the negative aspects of competition, which is confirmed by our study.

Domestic herbivores in 'Forêt Classée de Nazinon' showed a strong dependence on perennial grasses, especially *Andropogon* spp. It is especially this species which is reduced drastically as a consequence of cutting and subsequent resprouting of *Detarium microcarpum*. If these results concerning the dynamics of the forage species in this woodland indicate a general pattern, grazing possibilities for cattle could be limited to uncut or recently cut areas, whereas forage availability could decrease with increasing time after cutting. Ultimately forage availability may be reduced to the point where local herdsmen are forced to take their cattle to another region.

Acknowledgements

This study was made possible through the co-operation and financial support of Wageningen Agricultural University, the program 'Recherche sur l'Amélioration et la Gestion de la Jachère en Afrique de l'Ouest' (7ACP RPR 269, 7e FED), Utrecht University and a scholarship from the FSO-programme. We thank Han Olff for his advice on the statistical analyses. For useful discussions and comments on earlier manuscripts we thank Arend Brunsting, Pieter Ketner, Moumini Savadogo and Freerk Wiersum. Hamidou Barry and Adama Ouedraogo are acknowledged for their field assistence.

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