The Fate of Nutrients during Fires in West African Savanna

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Abstract

Prescribed fire is a common site preparation method in many country of the world. The nutrient loads contained in the grassy fuel before fires, and after in ash, were compared to determine the fluxes of some macronutrients (C, P, K, Ca and Mg) during fires in Lamto reserve (Ivory Coast, West Africa). Theses fluxes were estimated during three different fire regimes: early, mid-season and late fires. Generally, 98-20 % of all measured nutrients in the fuel were transferred to the atmosphere during fire. The general tendency was the greatest magnitude of fluxes during the early fire. Indeed, the fuel load was highest during this period (about 1553 ± 186 g/m^2 vs. 1475 ± 145 and 1415 ± 39, respectively for mid season and late fires). For each nutrient, the proportion transferred to the atmosphere as entrained ash was calculated. For this early fire regime, 83-98 % of all nutrients were loss vs. 64-98 for the mid season fire and 20-98 % for the late fire. The nutrient most losses were C irrespective of fire regime. The loss rate of most of nutrient (K, Ca and P) showed the tendency of decreasing when fuel load decrease. This tendency was more clear for P, its loss rate seems dependant of fire regime. It decrease when fire intensity increase or fuel load decrease. For the all nutrient apart from C, the tendency was the low rate of loss during the late fire.

Introduction

Prescribed fire is a common site preparation method in many country of the world. It has been used for centuries by many populations, particularly in Africa, to manage savannas and fallows (Trollope 1984; Menaut et al., 1991). Fires have a profound and long-term impact on nutrients cycles in ecosystems where there are used, depending on the severity and duration of fire (Gill 1990). In Africa particularly, because of rapidly rising human population, the shifting cultivation that is practiced in many regions to create fields is leading to a reduction in the duration of the fallows, which would not allow the reconstitution of soil fertility. In tropical ecosystems, most nutrients are not stored in the soil, whose holding capacity is structurally low, but in the vegetation. Clearing and burning for crops means destroying the stock of nutrients in live vegetation to transform it into ashes. These ashes constitute a source of nutrients quickly usable by plants but a significant fraction are lost by wind and water erosion or transferred to the atmosphere in smoke. The cumulative effect of small but persistent losses of nutrients from an already low edaphic capital under very frequent fire regimes in area like Lamto, may decrease site productivity and cause degradation in the long term. Despite the importance of fire as a land management tool by West African farmers, there has been little research into its effects on nutrients cycling. The aim of this study is to quantify the loss of nutrients from the fuel during different fire regimes (earlier fire, mid-season fire and late fire: the last one correspond to crops period) since the magnitude of nutrient losses due to fire is determined mainly by biomass of understorey and fire intensity. The fate of nutrients during fires was studied in Lamto Reserve (Ivory Coast, West Africa).

Methods

The fate of nutrients during single fires was studied in Lamto reserve (6◦13’N, 5◦02’W) in savannas growing at the margin of the rain forest (Menaut & C´esar 1979). Nine compartments (each 100/50 m^2) have been delimitated in shrubby savanna. Three of each have been submitted to different fire regimes: (1) early fire compartments were burnt in November 2013, (2) mid season fire compartments were burnt in January 2014 and those of late fire were burnt in Mars 2014.

The concentrations of nutrients were determined in 50 g (composite sample) of grasses, leaves and twigs from different compartments' according to the treatment. P, K, S, Ca and Mg contents were determined using an inductively coupled plasma mass spectrometer following digestion with nitric acid. Nutrients yield were calculated by multiplying the mean concentrations by the biomass of each component in each plot.

The losses of nutrient by volatilization at the time of each fire regime were quantify for each elements (C, P, K, Ca, Mg) by the difference between the quantities before fire (mineral mass of grasses or herbaceous layer) and after the fire (mineral mass of ashes).

The rates of losses have also been evaluated according the following formula:

LR (loss rate) = mineral mass losses/ grasses mineral mass

Results and discussion

The biomass of herbaceous layer was more important during the early season (1553 ± 186 g/m^2 vs. 1475 ± 145 and 1415 ± 39, respectively for mid season and late fires, Table 1). The greatest magnitude of fluxes has been observed during this early fire (Table 2). The mineral mass was more import respectively for C, Ca, K, Mg and P for all fire regimes (Table 1). During the mid season, whereas the biomass of herbaceous layer decreases, the mineral mass of K increases, Table 1).

Almost all C was lost during fire; the rate of loss was about 0.98 for all fire regimes. The loss of Ca was also very important during each fire regime (0.72-0.93, Table 2). The loss rate of most of nutrient (K, Ca and P) showed the tendency of decreasing when fuel load decrease (Table 1 and 2). The loss rate of P seems dependant of fire regime (Table 2). It decrease when fire intensity increase (The mean fire intensities (KW/m) of different fire regimes were 1666±636, 2663±2919, 4269±2425 respectively for early, mid-season and late fires) or fuel load decrease. For the all nutrient apart from C, the tendency was the low rate of loss during the late fire.

Nevertheless, the loss rate of different nutrients did not significantly change with fire regimes (Kruskall-Wallis test, $P= 0.956$; $P= 0.732$; $P=0.491$; $P= 0.561$ and $P=0.252$ respectively for C, P, K, Ca and Mg).

Table 1. Fuel and ash quantity and different nutrient content and mineral mass

		C			P		K		Ca		Mg	
		Fuel phytomass (g/m2)	Content (%)	mineral mass (g/m2)	Content (%)	mineral mass (g/m2)	Content (%)	mineral mass (g/m2)	Content (%)	mineral mass (g/m2)	Content (%)	mineral mass (g/m2)
EF	Grass	1552.70	54.33	843.63	0.02	0.27	1.07	16.64	4.30	66.81	0.50	7.69
	Ash	188.30	10.00	18.83	0.02	0.05	1.37	2.58	2.40	4.51	0.43	0.81
MSF	Grass	1474.80	50.33	742.32	0.01	0.20	1.40	20.57	3.67	54.06	0.50	7.38
	Ash	200,10	8.93	17.88	0.05	0.11	1,96	3.91	3.05	6.11	0.39	0.78
LF	Grass	1415.31	52,67	745.40	0.02	0.24	1.41	19.95	2.82	39.87	0.46	6.46
	Ash	206.50	10.57	21.82	0.08	0.16	2.39	4.94	4.12	8.51	1.07	2.20

Table 2. Loss rate of different nutrient in Lamto savanna

	C		P		K		Ca		Mg	
	loss rate	g/m2	loss rate	g/m2	loss rate	g/m2	loss rate	g/m2	loss rate	g/m2
EF	0.98 ± 0,01	823.71 ± 196.8	0.83 ± 0.03	0.22 ± 0.04	0.83 ± 0.07	13.97 ± 3.74	0.93 ± 0.02	62.47 ± 15.05	0.89 ± 0.04	6.91 ± 2.10
MSF	0.98 ± 0,002	720.8 ± 122,52	0.64 ± 0.383	0.10 ± 0.03	0.82 ± 0.04	17.20 ± 6.58	0.85 ± 0.16	51.60 ± 28.29	0.89 ± 0.01	6.60 ± 1.15
LF	0.98±0,022	728.71 ± 51.07	0.20 ± 0.63	0.07 ± 0.18	0.75 ± 0.13	14.69 ± 1.90	0.72 ± 0.21	31.50 ± 23.92	0.62 ± 0.24	4.26 ± 2.56

EF: Early fire; MFS: Mid season fire and LF: Late fire. g/m^2 or 10 Kg/ha.

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