AN ABSTRACT OF THE THESIS OF

Michael D. Steele for the degree of Master of Science in Fisheries Science presented on August 27, 1999. Title: Biomass and Nutrient Dynamics Associated with Deforestation, Biomass Burning and, Conversion to Pasture in a Tropical Dry Forest in Mexico.

Abstract Approved: Redacted for Privacy

J. B. Kauffman

The effects of deforestation and biomass burning in tropical dry forests (TDF) remain a little studied phenomenon. We quantified total aboveground biomass (TAGB), carbon and nutrient (N,S,Ca,P,K) loss under two separate fire severity scenarios; one early when the fuels were higher in moisture content, one later when the slash fuels were drier and then compared the loss and the regrowth of the sites. The TAGB and nutrients were measured (1993-1995) after the forest was cut, after a forest slash fire, one year after pasture establishment and, two years after the slash fire, biomass was quantified before and after a pasture fire. The treatments were based upon time from slash to burn. The low severity fires (Baja) were burned 65 days and the higher severity fires (Alta) were burned 95 days after the initial slash of TDF on $\approx$ 3.5 ha near the Chamela Biological Research Station on the Ejido San Mateo, Jalisco, Mexico.

As a result of the 1993 slash fire, TAGB declined from 118.2 to 43.6 Mg ha^{-1} (62%) in the Baja treatment and from 134.9 to 26.8 Mg ha^{-1} (80%) in the Alta treatment. Nutrients pools declined 57-88% with $\approx$10% higher combustion of the Alta pools.

In 1995, after the pasture fires, TAGB declined from 40.3 to 14.8 Mg ha^{-1} (63%) and from 29.0 to 7.6 Mg ha^{-1} (75%) in the Alta treatment and nutrient pools declined

57-88%. Total aboveground biomass loss from 1993-1995 was 103.4 Mg ha^{-1} (87%) in the Baja treatment and 127.3 Mg ha^{-1} (94%) in the Alta treatment. Carbon and nutrient losses ranged from 87-96% over the three-year study.

We found little ash retention after fire, no increase in nutrient soil concentrations and, highly volatized nutrients (i.e. Ca and P) were essentially lost due to wind and water erosion on 40 to 60% slopes. Wood decomposition between fires reduced TAGB and nutrient pools by 15% in the Baja treatment and 3% in the Alta treatment.

Biomass and Nutrient Dynamics Associated with Deforestation, Biomass Burning and, Conversion to Pasture in a Tropical Dry Forest in Mexico

by

Michael D. Steele

A THESIS

Submitted to

Oregon State University

in partial fulfillment of
the requirements for the
degree of

Master of Science

Completed August 27, 1999
Commencement June, 2000

Master of Science thesis of Michael D. Steele presented on August 27, 1999

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I understand that my thesis will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my thesis to any reader upon request.

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Michael D. Steele

Acknowledgments

I would like to thank the members of Dr. Boone Kauffman's graduate group for their constant criticism, heckling and caring that made me a more focused researcher. Specifically, I would like to thank Liane Guild for doing all of the data preparation work prior to my arrival. Her invaluable assistance saved me countless hours in the sometimes tedious, but extremely necessary, work of transferring field data to a usable computer form. I would like thank the staff of the Chamela Research Station for their assistance in field research, the local farmers for their assistance during the actual site burnings and, the National Science Foundation for their financial support of this project. To my committee members: Peter Bayley for his overwhelming knowledge of statistics and Sandra Brown for her extraordinary knowledge of tropical forest ecology. Mostly, I would like to thank my Major Professor, Dr. J. Boone Kauffman. His step by step instruction, through the maze that is Tropical Dry Forest system ecology, allowed a 'fish guy' to extend himself more than he thought was possible. My sincerest thanks to all of them.

Contribution of Authors

Liane Guild for preparing the data sets prior to my arrival. Dr. J. Boone Kauffman conducted the original research that this thesis is based upon and Dian Cummings and Lisa Ellingson for their field work.

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Dedication

To my Grandfather Earl Leonard Fitch and Jennifer Newman, two people who showed me the best in nature and the best in myself.

Chapter 1: Introduction

Deforestation and Biomass Burning continues to threaten large areas of the Tropical Dry Forests (TDF). The TDF comprises approximately 42% of all tropical and subtropical forest areas and contains the highest human population densities in the neotropics (Murphy and Lugo 1986). We were particularly concerned with the lack of long-term studies on the effects of Deforestation and Biomass Burning on the Tropical Dry Forests in Mexico. Masera et al. (1997) estimated that 1.9% (3.0×10^5 ha) of Mexican TDF is lost annually to agriculture, pasture or other land uses. We designed a three-year study (1993-1995) to be conducted near the Chamela Biological Research Station, Jalisco, Mexico. This study measured the Biomass and Nutrient Dynamics, prior to and after two separate fires in 1993 and 1995, and the respective changes in these classes are reported below. Chapter 2 reports our findings with regard to the changes in Biomass levels and Chapter 3 details the Nutrient level differences over the three-year study.

Chapter 2

Biomass Dynamics Associated with Deforestation, Biomass Burning and, Conversion to Pasture in a Tropical Dry Forest in Mexico

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Abstract

The effects of deforestation and biomass burning in tropical dry forests (TDF) remain a little studied phenomenon. Deforestation, biomass burning and, conversion of TDF to pasture is the dominant land use practice in the Jalisco region of Mexico. A 3-year study was performed to quantify biomass dynamics associated with the initial phases of land conversion. Total aboveground biomass (TAGB) was measured after the forest was cut, after a forest slash fire and, one year after pasture establishment in 1994. Two years after the slash fire, biomass was quantified before and after a single pasture fire. Each treatment was defined based upon time from slash to burn. The low severity fires (Baja) occurred when plots were burned 65 days after the initial slash of TDF. The higher severity fires (Alta) occurred on plots that were burned 95 days after slash, thus allowing for greater biomass consumption (% consumed by fire) during fire.

Prior to the initial slash fire, TAGB was 118.2 Mg ha^{-1} in the low severity Baja plots and 134.9 Mg ha^{-1} in the high severity Alta plots. Fires in 1993 resulted in biomass reduction of 74.6 Mg ha^{-1} (62%) in the Baja treatment and 108.1 Mg ha^{-1} (80%) in the Alta treatment. Fine fuels lost ~ 100% of their mass. The greatest difference in fire combustion (% biomass consumed by fire) occurred in the 1000 hour fuels (7.6-20 cm diameter). Sites in the Baja treatment lost only 31% of their 1000 hour fuel biomass due to fire, while sites in the Alta treatment lost 79%. Decomposition between fire events (postfire 1993 to prefire 1995) resulted in small TAGB losses.

In 1994, TAGB was 40.4 Mg ha^{-1} in the Baja treatment and 29.2 Mg ha^{-1} in the Alta treatment. Biomass measurements showed Baja sites had lost 12.9 Mg ha^{-1} of TAGB (11%) and Alta sites lost 2.6 Mg ha^{-1} of TAGB (2%) due to decomposition.

In 1995, prior to the TDF pasture fire, TAGB was 40.3 Mg ha^{-1} in the Baja treatment, a decrease of 3.2 Mg ha^{-1}. During this same time the Alta treatment increased in TAGB by 2.4 Mg ha^{-1} to 29.0 Mg ha^{-1}. The 1995 fires resulted in consumption of 25.5 Mg ha^{-1} (63% combustion) in the Baja treatment and 21.4 Mg ha^{-1} (75% combustion) in the Alta treatment.

During the initial land use sequence, from slashed primary forest to burned pasture (2 years), TDF losses in Baja sites were 103.4 Mg ha^{-1} (87%) and were 127.3 Mg ha^{-1} (94%) in the Alta treatment. Total wood debris losses during the study due to decomposition were 12.9 Mg ha^{-1} (15% of total wood consumption; Baja) and 2.6 Mg ha^{-1} (3%; Alta) while, the consumption by fire was 65.5 Mg ha^{-1} (76%; Baja) and 84.9 Mg ha^{-1} (93%; Alta). The 1000-hr fuels (7.6-20 cm diameter), were the only component that showed significant differences ($p = 0.04$) in combustion rates for the entire study (prefire 1993 – postfire 1995).

The Alta fuels showed higher fire combustion rates ($p<0.12$), over the three-year study, than the Baja TDF sites over the generalized methods to reconstruct actual conditions in this region of Mexico.

Introduction

Deforestation and biomass burning of tropical forest is a significant global concern due to effects on biodiversity, losses in site productivity, loss of forest biomass as a carbon sink and emissions of greenhouse gasses during fires and from decomposition (Murphy and Lugo 1995). This was evident in the high quantity of emissions that arose from fires in Mexico and Central America during the severe dry season exacerbated by the 1998 El Nino phenomenon. These losses were due to the El Nino-caused drought conditions which delayed the onset of the rainy season throughout Latin America. In 1998, Mexican forest areas were reduced by an estimated 404,686 ha (one million acres) due to natural and human-caused fires (San Diego Tribune 1998). This land area was burned from an estimated 10,000 fires that not only affected human health from emissions but also resulted in further losses of Mexico's indigenous forest ecosystems. The smoke, that covered much of the southern USA and Northern Mexico, brought an increased interest in the origins and causes of these fires.

Tropical dry forest (TDF) is the most abundant tropical forest type in Mexico covering 1.6 x 10^5 km^2 (Masera 1997). These areas are undergoing rapid rates of land conversion. Masera et al. (1997) estimated 1.9% of Mexican tropical deciduous forest, and 3.8% in the Chamela region TDF located along the South central Pacific coast of Mexico, is annually converted to agriculture, pasture or other land uses.

While deforestation rates and land conversion is high in TDF, little is known of the biomass dynamics (loss and regrowth) associated with fire and pasture establishment. Pasture establishment is most common fate of converted TDF (Maass 1995). It is important to understand the dynamics associated with land-use approaches in the TDF in order to: 1) quantify biomass and carbon (C) pools as potential sources and sinks of greenhouse gasses associated with land conversion in TDF; 2) quantify the importance of TDF in global nutrient budgets and; 3) work toward finding potential alternatives to deforestation in TDF.

Tropical Dry Forests

Information is scarce on the effects of slash-and-burn agricultural practices in the TDF. TDFs comprise 42% of all tropical and subtropical forests and contain the highest human population densities in Latin America (Murphy and Lugo 1986). Mooney et al. (1995) described TDF as occurring in the tropical regions where there are 'several months of severe, even absolute, drought', and are distinguished from savannas by the presence of tree dominated, occasionally closed canopy systems. A general overview of TDFs compared to tropical wet forests indicate they generally have less plant species diversity, lower forest canopies (Holbrook 1995), fewer epiphytes (Medina 1995), and lower total biomass (Murphy and Lugo 1995).

Site Description

This study was conducted from 1993 to 1995 on the Ejido San Mateo, Jalisco Mexico near the Chamela Biological Research Station administered by the Universidad Nacional Autonoma de Mexico (UNAM)(Figure 2.1). The research site is located on the central Mexican Pacific coast (19^{O} 35'N, 105^{O} 05'W) is classified as a Mesoamerican (Ceballos 1995), Subtropical (Holdridge 1967), seasonally dry deciduous forest (Murphy and Lugo 1995). The principal vegetation of this upland site (slopes from 40 to 60%) are deciduous trees in the Fabaceae family (Gentry 1995). Trees have a density ≈ 4325 ha^{-1}, are short (<5m) and, are relatively small-diameter (3-20 cm dbh) (Kauffman pers. comm 1998). Soils are classified as sandy loam Entisols with rhyolite parent material (Roth 1996). Mean annual temperature is 24.9^{O} C and annual rainfall is 714 ± 154mm with 80% of the precipitation occurring between July and October (Garcia-Olivia et al. 1995). Plant species richness of this area is the highest of any recorded TDF with 544 genera and 124 families (Lott 1987).

Biomass burning optimizes labor energy and capital expenditures for land clearing and the planting of agronomic crops or pasture for livestock (Bye 1995). The generalized approaches to land use/land conversion in the Chamela region are: (1) slashing existing forest with machete and chainsaw; (2) removal of usable wood (little if any wood was removed from the site during this study); (3) delay burn for 2-3 months into the dry season to allow for biomass drying; (4) burn biomass toward the end of the dry season; (5) plant crops (Corn - *Zea maiz*) and pasture grass *(Andropogon gayanus*, *Panicum maximum* and *Cenchrus ciliaris*) immediately after burning; (6) harvest crops 3-4 months after planting, graze pasture for one to two years; and, (8) burn pasture every two to three years after establishment (Figure 2.2).

The overall objective of this study was to quantify the biomass dynamics associated with the initial phases of conversion of primary TDF to cattle pasture. This was experimentally examined with two separate fire severity scenarios designed to encompass some of the variability that might be expected from slash-and-burn fires. Treatments included a low consumption fire conducted when fuels were comparatively higher in moisture compared to the other treatment, a high consumption fire. During the three-year study period, we also quantified: 1) losses due to decomposition following slash fire; 2) vegetative regrowth for the two years following slash fires; and, 3) biomass losses from a second fire in the newly formed pastures.

Methods

Experimental Design

The study site was approximately 3.5 ha in size. Three 1.0 ha replicate blocks (Figure 2.3) were established and each were subdivided into approximately three 33 x 100m (0.3 ha) treatment sub-blocks. Plot lines were set with metal posts to delineate plot boundaries. Three fire severities were included in the original design, however, due to an accidental escape of fire into one medium fire severity block (during the low severity fire), the data were excluded from the final analysis. In this study only the Alta sites (high severity) and Baja sites (low severity) are reported.

Fire Treatments

The fire severity treatments were randomly assigned to each sub-block. The differences in fire treatments were accomplished by varying the drying time between slash and burning. In 1993, Alta sites were slashed the last week of January and burned 9 May 1993 (95 days between slashing and burning). Baja sites were slashed the second week of February and burned 9 April 1993 (65 days between slashing and burning). There was no precipitation events between the slash events and biomass burning. Postfire combustion was calculated as the percent of biomass lost during a fire.

Biomass Measurements

Within each sub-block, three rhomboidal (diamond-shaped) clusters were established. Biomass in each cluster was measured along five transects established in such a way as to insure remeasurement throughout the three-year study. Thus, there were 45 biomass transects (n=45) each for the Alta and Baja treatments (15 transects per sub-block).

Total aboveground biomass (TAGB) was sampled in 1993 before and after slash burning. Towards the end of the 1994 dry season (about one year after the slash fire) biomass was again sampled in the newly established pasture. This sampling time occurred following the corn harvest and some cattle grazing. In 1995, TAGB was measured prior to, and following, the pasture fire for these experimental units.

Biomass of wood debris was quantified each year non-destructively using the planar intercept technique (Brown & Roussopoulos 1974; Kauffman et al. 1993). Wood particle sizes were partitioned into standard moisture timelag classes (Byram 1963; Table 3.1). Residual standing trees were measured within the three 225 m^2 rhomboidal plots in each plot (n = 3/treatment). The diameter at breast height (dbh) and total height was collected to estimate standing tree biomass using formulas defined by Martinez-Yrizar (1990). Biomass was determined by calculating volume and then multiplying volume by the specific gravity of large wood samples. Stumps were measured along a 20 x 1 m belt in each cluster (n = 3/sub-block, n = 9/treatment). The diameter and height of all stumps were measured to calculate volume. Each volume measurement was then multiplied by the specific gravity of the reference large wood debris (>7.6 cm diam) fuels) to calculate mass.

Litter, consisting of leaves, fruits, seeds, dead grass, old corn plant parts, wood, and bark fragments was collected in 50 x 50 cm plots established 1m away from the end of each woody biomass transect. All dicots present within the same plots were also harvested, oven dried and weighed at the station laboratory. Foliage attached to slashed wood debris was estimated by multiplying the ratio of leaves to the 1-hr fuel biomass. The ratio of attached foliage to twig and leaf biomass was calculated by collecting 50 random samples of 1-hr fuels, oven drying and then weighing the wood and leaf material, separately. Ash samples were collected immediately after burning in nine 50 x 50 cm microplots in 1993 slash fire (n=27/treatment) and six 50 x 50 cm microplots in 1995 pasture fire (n=18/treatment), within each sub-plot, using a vacuum cleaner and a portable generator.

Statistical Analysis

The experiment was established as a randomized block design. Treatments involved the two fire severities replicated in the three blocks. Statistical analysis was performed using ANOVA. Wood debris and litter at each transect, stumps and ash at each diamond and, trees and TAGB at each sub-plot was considered as an individual observation. Statistical analyses included: aboveground prefire versus postfire biomass, comparisons between treatments at each measurement stage, percent biomass consumption, biomass loss due to decomposition and regrowth. Significance was set at the $p \leq 0.10$ level.

Results

Site Description (Prefire 1993)

Prefire TAGB of the slashed TDF was 118.2 Mg ha^{-1} (Baja treatment) and 134.9 Mg ha^{-1} (Alta treatment). Total fine fuels (i.e. litter, dicots and, attached foliage) was $\approx$ 8.0 Mg ha^{-1} in both treatments and the fine fuel components comprised $\approx$ 6.9 and 5.9% of the TAGB in the Baja and Alta treatments, respectively. Total slashed wood debris was the most abundant biomass component with a mass of 86.4 and 91.3 Mg ha^{-1} in the Baja and Alta treatments. Standing tree biomass was 9.9 (Baja) and 14.8 Mg ha^{-1} (Alta) and stump biomass was 13.9 (Baja) and 20.9 Mg ha^{-1} (Alta). There was no significant difference between treatments ($p < 0.1$) in any prefire component measurement at any size. Thus, the prefire biomass composition was considered to be similar across the entire site prior to the first burn.

Fire Behavior

All fires were conducted at similar ambient air temperatures and relative humidity (Table 3.2). Flame height and length were similar for all of the slash fires. However, the mean rate of spread (fire speed in m/min) was quite different between treatments (Alta: 16.2 m/min, Baja: 1.2 m/min). The greatest difference here was attributed to the ignition pattern. The Baja sites were burned mostly by backing fires (down slope) while the Alta sites were burned with a head fire (up slope).

Postfire 1993

As expected, the high fire severity resulted in a greater consumption of TAGB (Table 2.3). Postfire TAGB for the Alta treatment sites was 26.8 Mg ha^{-1}; 80% of the biomass was consumed by the slash fires. Postfire TAGB for the Baja treatment sites was 43.6 Mg ha^{-1}; fires consumed 62% of the TAGB. The greatest consumption rates among the components were in fine fuels (i.e. litter (100%), attached foliage (89-100%) and dicots (100%)).

Baja sites had significant differences ($p<0.1$) between prefire and postfire biomass in all timelag size classes below 7.6 cm diameter wood fuels (1000-hr), trees and, all fine fuels. Biomass of all components were significantly different ($p<0.1$) in the Alta treatment except for 10,000-hr fuels ($p = 0.2$). Total wood debris declined from 86.4 to 32.7 Mg ha^{-1}, a 62.4% loss (Baja) and, from 91.3 to 15.2 Mg ha^{-1}, a 80.4% loss (Alta) ($p=0.16$). The greatest differences among treatments was in the 1000-hr fuels ($p = 0.09$). The 1000 hour fuels declined from 29.4 to 18.0 Mg ha^{-1}, a 29% loss in the Baja treatments while, the Alta treatment 1000 hour fuels declined from 31.4 to 5.5 Mg ha^{-1}, a 64% loss.

Postfire 1993 - Prefire 1995

One year after fire in 1994, TAGB was 40.4 Mg ha^{-1} in Baja plots and 29.2 Mg ha^{-1} in Alta plots (Table 2.3). The increase in TAGB from 1993 was largely due to the presence of corn residue and grass. Corn residue mass was 1.4 (Baja) and 1.9 Mg ha^{-1} (Alta). Dead grass mass was 1.1 (Baja) and 0.5 Mg ha^{-1} (Alta). The remaining increase in TAGB was due to growth in the fine fuel components. Litter added $\approx$ 3 Mg ha^{-1}

and corn and grass added ≈ 2 Mg ha^{-1} in both treatments. Total fine fuels had risen from 0.4 to 6.1 Mg ha^{-1} (Baja) and 0.02 to 5.8 Mg ha^{-1} (Alta). Total wood, after 1993 fire, was 32.7 (Baja) and 15.2 Mg ha^{-1} (Alta). 1994 wood debris declined to 26.4 (Baja) and 10.7 Mg ha^{-1} (Alta), a decomposition loss of 19 and 30%, respectively.

The TAGB in 1995 was 40.3 (Baja) and 29.0 Mg ha^{-1} (Alta). TAGB showed little change from 1994. The increase in TAGB due to pasture establishment and growth after the 1993 fire, was balanced by wood decomposition losses. Previously unmeasured biomass components in 1995 included live green grass and cattle manure. In 1995, prefire total wood biomass was 19.8 (Baja) and 12.6 Mg ha^{-1} (Alta). Thus, after two years following the initial slash fire, these sites lost 12.9 Mg ha^{-1} (39.4%; Baja) ($p = 0.4$) and 2.6 Mg ha^{-1} (17.1%; Alta) ($p = 0.15$) of their total wood biomass due to decomposition. These data indicate that greater decomposition occurred in sites with lower fire combustion rates. Lower severity sites had greater postfire biomass available for decomposition when compared to the high severity sites that had relatively little biomass remaining after fire.

Overall, between postfire 1993 and prefire 1995 (25 months), Baja sites lost 3.3 Mg ha^{-1} TAGB and Alta sites gained 2.2 Mg ha^{-1}. Losses in TAGB from postfire 1993 to prefire 1995 were due to wood debris and stump decomposition, however, a small amount of biomass was no doubt lost due to light levels of cattle grazing on the grasses between fire events. Biomass losses, in woody debris, were compensated with biomass increases in pasture and crop residue.

1995 Pasture Fire

The entire study area, now a two-year old pasture, was burned on 15 June 1995. The TAGB declined from 40.3 to 14.8 Mg ha^{-1} (63% loss, Baja) and from 29.0 to 7.6 Mg ha^{-1} (75% loss, Alta; Table 2.3). While the combustion factor was higher in the Alta treatments, these sites actually had lower absolute biomass consumed by fire due to the much higher prefire TAGB on Baja sites (p=0.2). A total of 25.5 Mg ha^{-1} of biomass was consumed in the Baja treatments and 21.4 Mg ha^{-1} was consumed in the Alta sites. Fine fuels combustion losses were similar for both sites (Alta: 88%, Baja: 86%). The greatest difference between the two fire severities occurred in percent combustion loss of the total wood debris (p=0.03). Alta sites lost 70% of its residual wood biomass, while Baja sites lost 58%. Wood debris losses by this pasture fire were: 1) Baja – 11.5 Mg ha^{-1} (19.8 to 8.3 Mg/ha) and, 2) Alta – 8.8 Mg/ha (12.6 to 3.8 Mg ha^{-1}).

Overall Changes in Biomass (Prefire 1993 to Postfire 1995)

For the three years of the study there were dramatic losses in biomass due to slash burning, decomposition and, the pasture fire. TAGB decreased over the two fire events from 118 to 15 Mg ha^{-1} in the Baja sites, a 87% decline and from 135 to 8 Mg ha^{-1}, a 94% decline in the Alta sites (p=0.12) (Table 2.3, Figure 2.4). There were significant differences ($p < 0.1$) in all classes within each treatment over this period, except in Baja stumps ($p = 0.3$). The total wood biomass in the Baja treatment declined from 86 to 8 Mg ha^{-1}, a 90% loss. Similarly, in the Alta plots, wood debris biomass declined from 91 to 4 Mg ha^{-1}, a 96% loss. Thus, total wood debris losses during the study due to decomposition were only 12.9 Mg ha^{-1} (15% of total biomass consumption; Baja) and 2.6

Mg ha^{-1} (3%; Alta) while, the losses due to fire were 65.5 Mg ha^{-1} (76%; Baja) and 84.9 Mg ha^{-1} (93%; Alta). The 1000-hr fuels, were the only component that showed significant differences between treatments ($p = 0.04$) in losses for the entire study (prefire 1993 – postfire 1995).

Discussion

Few studies have quantified the biomass dynamics associated with the conversion of Tropical Dry Forest to pasture over a two year period (Figure 2.5). We found that the majority of biomass losses occurred as a result of biomass burning, while a significantly smaller amount was lost through decomposition and cattle grazing. The initial fire resulted in biomass losses of 74.6 and 108.1 Mg ha^{-1} for the Baja and Alta sites. Masera et al. (1997) calculated that 3.0×10^5 ha of Mexican TDF is lost annually. Using these data and results from this study, we estimate that fires in this region's TDF could potentially result in annual losses from 23-33 Tg of aboveground biomass.

There are many factors that affect the quantity of biomass consumed by a fire event. These factors include: 1) relative humidity, 2) precipitation - days since last rain event, 3) temperature at the time of burning, 4) wind - speed of fire spread, 5) Moisture content - fuel moisture, 6) plant species types, 7) forest fuel composition, biomass and structure, 8) edge effects - potential drying properties, and 9) topography of site (Pyne 1984). In 1993, there was no measurable rain during the time period between initial slash and burn. Temperature, edge effect, relative humidity, wind speed and, plant species composition were similar in all blocks. Therefore, the key difference was likely the time period between slash and burn which affected the amount of moisture left in the slash.

This was particularly evident in 1993 for large woody debris (>7.6 cm) where consumption rates were quite different among treatments; 43% in the Baja sites and 74% in the Alta sites. The thirty days difference between the low and high severity fire apparently was sufficient enough to make a significant difference in the amount of large wood debris that was consumed by the fires.

Biomass Comparisons

In general, Tropical Moist forests (TMF), or evergreen forests, have greater TAGB per hectare than TDFs, and TDFs have a greater TAGB than tropical savanna, grasslands, and converted cattle pastures (Table 2.4; Kauffman et al. 1992, 1995). For example, Kauffman et al. (1992) found that TAGB of Amazonian moist forests in Brazil ranged from 290.2 - 434.6 Mg ha^{-1}. Hughes (1997) reported that standing biomass in a tropical evergreen forest in the Los Tuxtlas region of southeastern Vera Cruz, Mexico was 320-545 Mg ha^{-1}. Based upon these comparisons, TMF has 3-4 times the biomass of TDFs of the Chamela region (118.2 - 134.9 Mg ha^{-1}). It is likely that fine fuel consumption across most tropical grasslands and pastures is extremely high and that variation in total biomass consumption is largely dependent upon the quantity of residual large woody debris.

TDF/TDF Slash Fire Comparisons

Comparing this study with a similar study conducted in Brazil TDF, (Table 2.4 - Kauffman et al. 1993), we found the Brazil and Mexico TDFs to be quite different. The Brazil site was a second growth forest that had been previously burned 16 years prior to the study. The TAGB of this Brazilian dry forest (73-74 Mg ha^{-1}) or approximately a third less than that of Chamela. The site also differed in fuel composition. Woody debris comprised ~50% of the TAGB at Chamela while it comprised 76 - 86% of the fuel load in Brazil. The Brazil site had 89 - 98% of particles < 7.6 cm, while Chamela had ~65% of TAGB < 7.6 cm. Sites with greater TAGB in small woody debris (<7.6 cm) and fine fuels have greater combustion rates, 62 - 80% at Chamela versus 78 – 95% in Brazil (Kauffman, et al. 1993; Table 2.4).

TDF/TMF Slash Fire Comparison

The combustion factor (% biomass consumed) of TMF was lower than that of TDF (Table 2.4). TMF slash fires in Brazil (Kauffman et al. 1995) consumed from 125 – 228 Mg ha^{-1}, while Chamela TAGB losses ranged from 75 - 108 Mg ha^{-1}, a 62-80% loss of TAGB. These differences were likely because a greater proportion of the TDF biomass was in large woody debris (≥7.6 cm). Also, there are fewer precipitation events in TDF resulting in a lower moisture content of TDF biomass. For example, four slashed tropical evergreen forests in Brazil had much higher prefire TAGB, greater total TAGB losses, but, lower combustion factors (Kauffman et al. 1995; Guild et al. 1998) and, therefore more CO_2 releases than those of TDF (Ward 1991).

Chamela Pasture/Pasture Comparisons

The most common reason for forest conversion throughout Latin America is for cattle pasture formation (Murphy and Lugo 1995). Commonly pastures are reburned two years after the initial slash fire. Therefore, we believe our study gives a realistic approximation of the biomass dynamics of the initial phases of deforestation and pasture conversion in this region of Mexico.

The initial pasture fires in this study consumed 11 - 12 Mg ha^{-1} (86 - 88% loss) of fine fuel biomass (i.e. litter, dicots, live grass, dead grass and, manure). Higher consumption rates were measured in the natural tropical grasslands of Brazil (i.e. Campo Limpo and Campo Sujo; Kauffman et al. 1990,1993). The Brazilian grassland fires had combustion factors of 92-100% with a prefire biomass of 5.5 and 7 Mg ha^{-1}, devoid of woody debris. Pasture sites in Rondonia, Brazil lost extensively less biomass (9.4 Mg ha^{-1} fine fuel losses) with only 31% TAGB combustion (Chamela ≈ 63-75% TAGB losses) (Table 2.4; Guild et al. 1998). However, in three tropical pastures derived from TMF, Kauffman et al. (1998) found biomass consumption rates between 20-83% and losses between 25-45 Mg ha^{-1}.

Decomposition and Regrowth

With conversion of forest to pasture, there was a large TAGB reduction at the site due to burning and decomposition. Total TAGB losses were increased by decomposition losses between fire events. We estimate that 12.9 Mg ha^{-1} (Baja) and 2.6 Mg ha^{-1} (Alta) was lost between fires due to decomposition (11 and 2%, respectively of the initial forest biomass. There was relatively little wood left available for decomposition on the Alta treatment sites. Establishment and growth of pasture vegetation resulted in a shift of TAGB from large woody debris to a greater percentage in fine fuels (grasses, litter, etc.). Woody debris, trees, and stumps comprised ≈ 93% of 1993 prefire and ≈100% of 1993 postfire TAGB. The percentage of wood that composed TAGB dropped to 80-85% in 1994 and to 62-68% in 1995. The fine fuel additions after the initial slash fire added 14 Mg ha^{-1} in the Baja treatment and 11 Mg ha^{-1} in the Alta treatment.

More research should be conducted to focus on how land conversion affects the biomass dynamics and capacity to function as C sinks through time. Most conversion of tropical forests are associated with non-sustainable management practices. An increased concern is needed for the earth's dwindling natural areas in order to sustain what is remaining and to reverse the damage that we seem to have so little care or control over.

Figure 2.1

El Cielo study site located at the Ejido San Mateo de Mexico near the Chamela Biological Research Station administered by the Universidad de Nacional Autonoma in Jalisco, Mexico. Research conducted from 1993 - 1995 approximately 60 miles SSE of Puerto Vallarta.

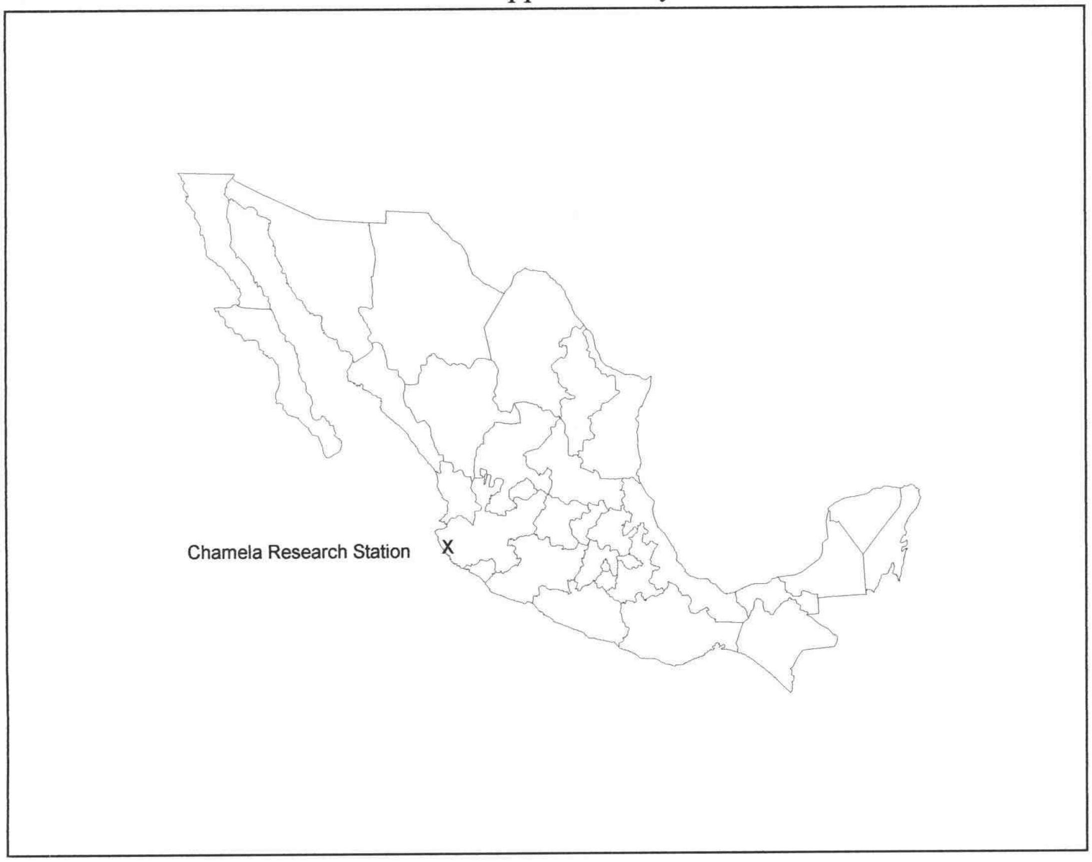

Figure 2.2

Generalized land-use sequence carried out by farmers in the dry forest region of Chamela, Mexico.

Tropical Dry Forest

Year 1 — Slash (beginning of dry season)

↓

Burn (end of dry season)
(plant corn/grasses)

↓

Year 2 — Established 1-yr old pasture/residual crop mass

↓

2-yr old pasture

↓

Year 3 — Burn (every 2 years)

↓

Postfire pasture

Figure 2.3

Experimental layout of this study. Site is 3.5 ha in size. Each block is 1 ha and each plot is 0.3 ha in size. Letters define fire severity. Lower left block is single plot (single segment of upper blocks). Right diamond defines how transects were established. Circles in plot are ash sample areas. Stumps were also measured along transect E and standing trees were measured within the entire area of the diamond. Cross section is non-measured, accidental burn area.

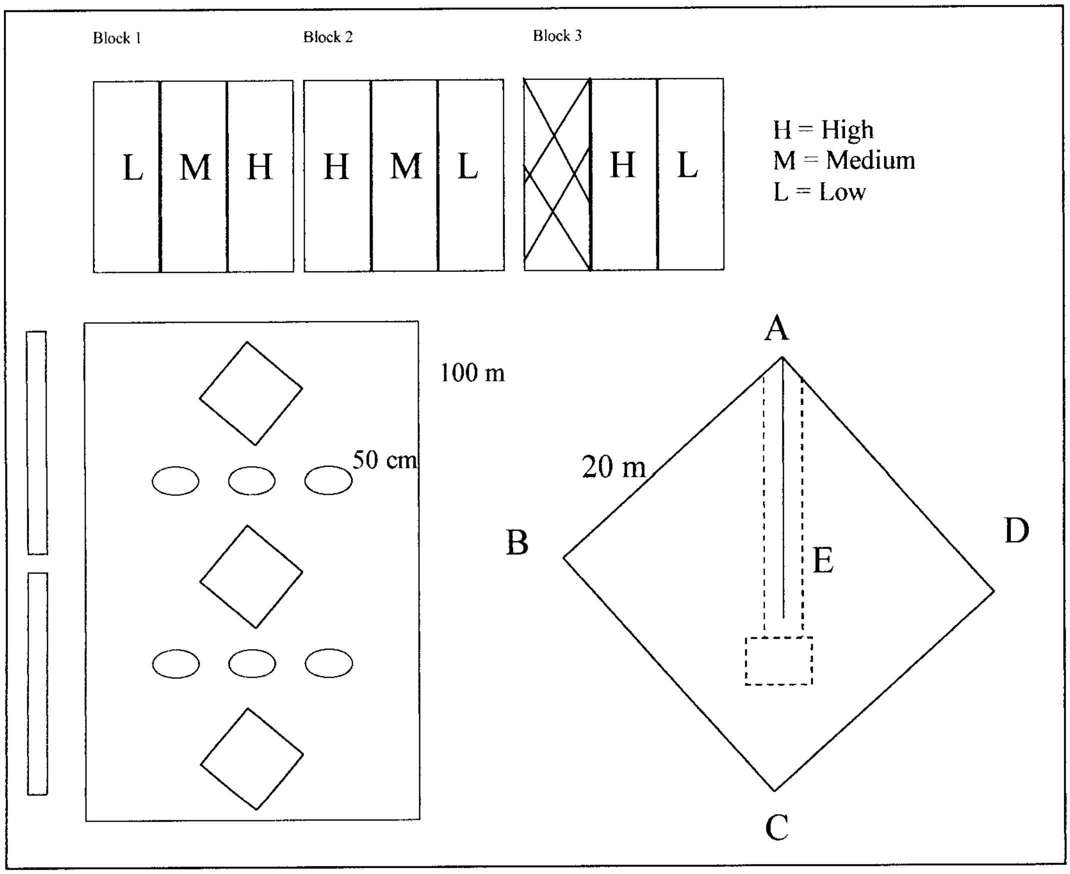

Figure 2.4

Total Aboveground Biomass (Mg ha^{-1}) graph of high (□) and low (◊) severity treatments and its change thru time at the El Cielo study site Jalisco, Mexico (1993-1995). Points correspond to time of biomass measurements (prefire 1993, postfire 1993, 1994, prefire 1995, postfire 1995). Vertical lines are SE bars.

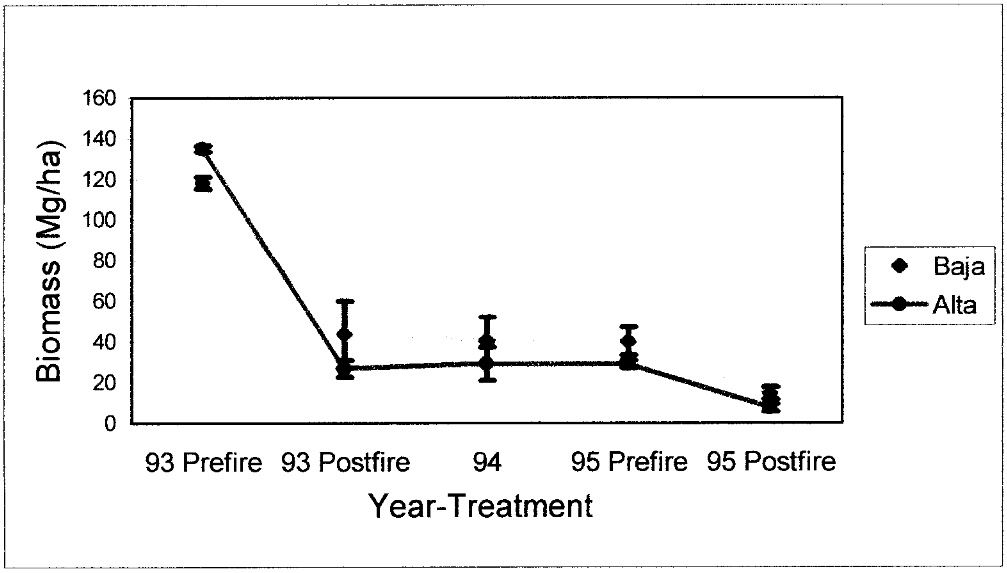

Figure 2.5

Biomass Dynamics for the El Cielo study (1993-1995) near the Chamela Research Station Jalisco, Mexico.

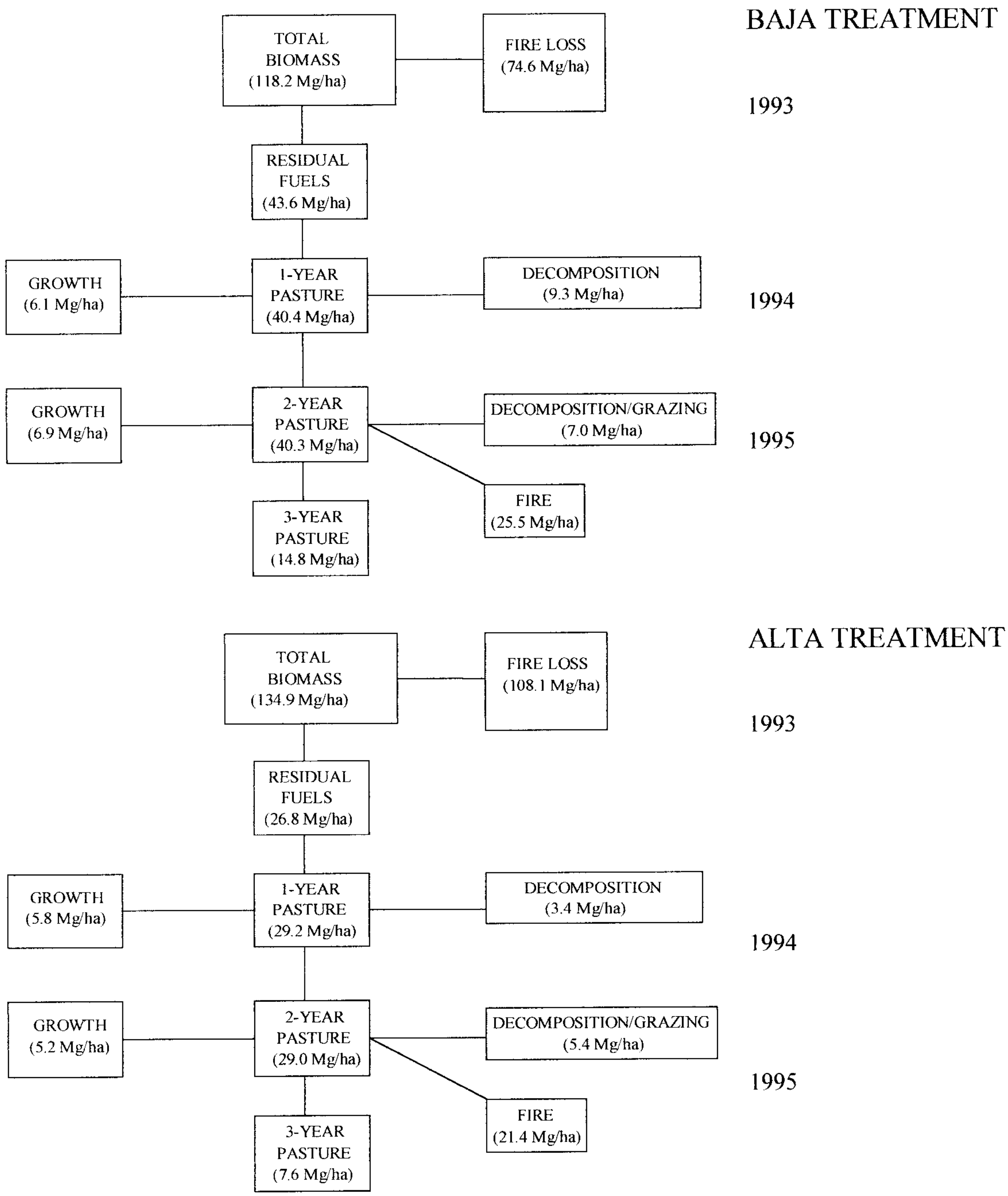

Table 2.1

Size classes in which the wood debris was partitioned to estimate biomass. Woody debris timelag classes are based upon those given by Brown & Roussopoulos (1974). Table also includes transect measurement lengths and specific gravity for each class of wood measured at the Chamela site.

Wood Debris Designation	Size (cm. Diameter)	Transect Length (m)	Specific Gravity (1995)
1-hour	0.0 - .64	1	0.71
10-hour	0.65 - 2.54	3	0.76
100-hour	2.55 - 7.6	10	0.70
1000-hour			
Sound	7.6 - 20.5	15	0.75
Rotten	7.6 - 20.5	15	0.23
10,000-hour	> 20.5	15	0.75

Table 2.2

Fire Data at El Cielo Site. Measurements include date of burn, duration (min) of flame, length, height, flame depth in meters, rate of spread of fire (m/min) and weather conditions: humidity and temperature.

Year	1993	1993	1995
Treatment	High Severity	Low Severity	Single Fire
Slash Date	Late Jan	Mid Feb	
Fire Date	3/9 May	9/10 Apr	15 June
Rainless days between fires	95 days	65 Days	
Wind speed (mph)	8	8.3	8
Flame Characteristics (Average of blocks in meters)			
Flame Length	4.6	4.8	3.5
Flame Height	3.3	3.5	4.3
Flame Depth	4.6	3.6	18
Flame Angle $(^0)$	51.6	64.6	65.8
Rate of Spread (m/min)	16.2	1.2	133
Relative Humidity (%)	47	53.3	67
Air Temperature (C^0)	27.8	26.5	30.6

Table 2.3

Total aboveground biomass (Mg ha^{-1}) before and after burning and % consumption (combustion factor) from 1993 to 1995 at the Ejido San Mateo site near the Chamela Biological Research Station, Jalisco, Mexico. N = 45 transects per severity of burn for foliage and wood debris components, N = 9 for stumps and N = 3 for trees and TAGB. No SE for 1993 or 1995 low severity stumps. 1995 Postfire biomass totals include fall measurements. %Consumption calculated from means only. Biomass was significantly different ($p \leq .10$) before and after fire within treatments in all components, except (α), and between treatments indicated (β).

	Low Severity Prefire	Postfire	Combustion Factor (%)	High Severity Prefire	Postfire	Combustion Factor (%)
Fine Fuels						
Litter	7.4 ± .61	0.0 ± .00	100 ± .00	7.4 ± .56	0.0 ± .00	100 ± .00
Att Fol	.47 ± .03	.04 ± .02	88.9 ± 3.8	.41 ± .03	0.0 ± .00	100 ± .13
Dicot	.17 ± .06	0.0 ± .00	100 ± .00	0.2 ± .04	0.0 ± .00	100 ± .00
Wood Debris (diameter, cm)						
0-0.64	2.6 ± .17	.23 ± .09	88.8 ± 3.8	2.4 ± .19	.001 ± .001	99.9 ± .13
0.65-2.54	16.8 ± 1.2	2.0 ± .78	89.1 ± 3.6	15.5 ± 1.2	.46 ± .160	96.8 ± .97
2.55-7.62	24.7 ± 1.9	6.1 ± .84	70.8 ± 4.7	28.0 ± 1.8	2.8 ± .522	87.7 ± 3.7
7.63-20.5						
Sound	29.4 ± 2.8	18.0 ± 3.2 $^{\alpha}$	31.7 ± 11.0	31.4 ± 3.5	5.5 ± 1.3	78.5 ± 5.7 $^{\beta}$
Rotten	4.4 ± .88	3.2 ± 1.1 $^{\alpha}$	85.1 ± 7.2	5.0 ± 1.2	2.0 ± .93	86.5 ± 9.9
Total	33.8 ± 2.9	21.2 ± 3.1	28.7 ± 10.0	36.4 ± 4.1	7.5 ± 1.5	62.3 ± 14.4
>20.5						
Sound	7.7 ± 2.7	3.1 ± 1.7 $^{\alpha}$	56.1 ± 22.9	7.8 ± 2.8	4.4 ± 1.9 $^{\alpha}$	71.6 ± 19.4
Rotten	.81 ± .81	0.0 ± .00	100 ± .00	1.2 ± .83	0.0 ± .00	100 ± .00
Total	8.5 ± 2.8	3.1 ± 1.7	60.9 ± 20.8	9.0 ± 2.8	4.4 ± 1.9	77.3 ± 15.7
Totals + Trees + Stumps						
Total Fine Fuels	8.1 ± .61	0.04 ± .06	99.2 ± .29	8.0 ± .56	0.02 ± .02	99.99 ± .005
Total Wood	86.4 ± 4.2	32.7 ± 4.0	62.4 ± 4.1	91.3 ± 5.9	15.2 ± 2.5	80.4 ± 4.0
Total Biomass	94.5 ± 4.3	32.7 ± 4.0	65.4 ± 3.8	99.3 ± 5.9	15.2 ± 2.5	82.8 ± 3.3
Tree	9.9 ± 4.0	.80 ± .80	78.1 ± 21.9	14.8 ± 4.6	1.0 ± 1.0	95.7 ± 4.3
Stump	13.9 ± 5.0	10.1 ± 2.6 $^{\alpha}$	27.3	20.9 ± 5.7	10.6 ± 3.1	4.43 ± 41.8
TAGB	118.2 ± 2.8	43.6 ± 16.4	62.4 ± 15.1	134.9 ± 1.4	26.8 ± 4.1	80.2 ± 2.8
Ash		3.9 ± .82			4.68 ± .42	

Table 2.3 (continued)

	Low Severity	High Severity
Fine Fuels		
Litter	3.2 ± .43	3.1 ± .44
Dicot	0.4 ± .24	0.3 ± .10
Corn	1.4 ± .22	1.9 ± .21 [β]
Dead Grass	1.1 ± .38	0.5 ± .21
Wood Debris (diameter, cm)		
0-0.64	0.2 ± .04	.07 ± .03
0.65-2.54	1.9 ± .52	.66 ± .15
2.55-7.62	9.1 ± .94	3.1 ± .57
7.63-20.5		
Sound	14.4 ± 2.4	6.5 ± 1.0
Rotten	0.3 ± .12	.23 ± .14
Total	14.7 ± 2.4	6.7 ± 1.1
>20.5		
Sound	0.6 ± .57	
Rotten		0.2 ± .20
Total	0.6 ± .57	0.2 ± .20
Totals + Trees + Stumps		
Total Fine Fuels	6.1 ± .80	5.8 ± .54
Total Wood	26.4 ± 3.2	10.7 ± 1.3
Total Biomass	32.5 ± 3.3	16.5 ± 1.3
Tree	1.0 ± .95	2.1 ± .98
Stump	6.9 ± 1.6	10.6 ± 5.6
TAGB	40.4 ± 11.5	29.2 ± 8.2

Table 2.3 (continued)

	Low Severity Prefire	Postfire	Combustion Factor (%)	High Severity Prefire	Postfire	Combustion Factor (%)
Fine Fuels						
Litter	5.0 ± .37	0.0 ± .00	100 ± .00	5.5 ± .45	0.2 ± .17	94.3 ± 5.8
Dicot	0.6 ± .24	0.6 ± .27 [α]		1.0 ± .56	0.0 ± .00	100 ± .00
Live Grass	0.4 ± .25	0.0 ± .00	100 ± .00	0.2 ± .17	0.0 ± .00	100 ± .00
Dead Grass	6.8 ± 2.1	0.1 ± .05	86.0 ± 12.3	3.3 ± .59	0.1 ± .10	42.3 ± 41.8
Manure	0.2 ± .23	0.0 ± .00	100 ± .00	1.0 ± .37	0.0 ± .00	100 ± .00
Wood Debris (diameter, cm)						
0-0.64	0.1 ± .03	.03 ± .02 [α]	72.2 ± 18	.03 ± .02	0.0 ± .00	100 ± .00
0.65-2.54	1.2 ± .43	.30 ± .16 [α]	77.7 ± 8.8	.68 ± .23	0.1 ± .05	70.2 ± 15.1
2.55-7.62						
Sound	6.9 ± .74	3.0 ± .44 [α]	50.0 ± 7.0	3.1 ± .54	2.1 ± .49	18.4 ± 16.2
Fall		0.1 ± .11			0.2 ± .12	
Total	6.9 ± .74	3.1 ± .44	50.0 ± 7.0	3.1 ± .54	2.3 ± .49	18.4 ± 16.2
7.63-20.5						
Sound	9.2 ± 1.8	3.9 ± .91	58.4 ± 8.3	8.8 ± 1.5	1.1 ± .42	81.6 ± 6.32 [β]
Fall		.98 ± .56			0.3 ± .25	
Rotten	1.1 ± .36	0.0 ± .00	100 ± .00	0.1 ± .10	0.0 ± .00	100 ± .00
Total	10.4 ± 2.0	4.9 ± .99	54.4 ± 8.8	8.9 ± 1.5	1.4 ± .48	72.2 ± 11.2
>20.5						
Sound	.63 ± .63	0.0 ± .00	100 ± .00			
Rotten	.60 ± .39	0.0 ± .00	100 ± .00			
Total	1.2 ± .73	0.0 ± .00	100 ± .00			
Totals + Trees + Stumps						
Total Fine Fuels	13.0 ± 2.2	0.6 ± .27	86.0 ± 7.0	11.0 ± 1.2	0.32 ± .20	87.5 ± 8.0
Total Wood	19.8 ± 2.4	8.3 ± 1.1 [α]	52.3 ± 6.5	12.6 ± 1.8	3.82 ± .72	67.9 ± 6.0
Total Biomass	32.7 ± 3.1	8.9 ± 1.1	71.3 ± 4.1	23.6 ± 2.2	4.13 ± .74	83.6 ± 3.6
Tree	.84 ± .73	.38 ± .34 [α]	58.9 ± 5.4	.88 ± .45	.48 ± .48 [α]	58.9 ± 5.5
Stump	6.7 ± 2.2	5.5 ± 2.1 [α]	17.9	4.6 ± 1.8	3.0 ± 2.0 [α]	49.2 ± 50.0
TAGB	40.3 ± 6.9	14.8 ± 2.9	63.1 ± 4.5	29.0 ± 2.8	7.6 ± 3.0	75.0 ± 7.9
Ash		2.1 ± .15			2.3 ± .17	

Table 2.4

Comparison between biomass and combustion factors of selected tropical forest ecosystems. Other studies were single event, single year only. Combustion is percent loss after fire.

Forest Type / Site Year	Prefire	Postfire	Combustion	Study
Tropical Dry Forest / Mexico / El Cielo				Steele, 1998
Low Severity 1993	118.2 ± 2.8	43.6 ± 16.4	62.4 ± 15.1	
High Severity 1993	134.9 ± 1.4	26.8 ± 4.1	80.2 ± 2.8	
Tropical Dry Forest / Brazil				Kauffman et al.
Serra Talhada – 1990				1993
Low	73.8 ± 2.7	16.4 ± 3.0	77.6 ± 4.8	
Medium	74.0 ± 5.0	8.3 ± 2.8	88.5 ± 4.6	
High	73.7 ± 1.9	4.0 ± 1.1	94.6 ± 1.3	
Tropical Woodland (Cerrado) / Brazil				Kauffman
Campo cerrado - 1990	8.6 ± .75	2.2 ± .60	72.0 ± 8.0	1994
Cerrado sensu stricto -1990	10.0 ± .47	1.6 ± .52	84.0 ± 5.0	
Cerrado aberto - 1993	24.8 ± 2.5	11.4 ± 1.2	54.0 ± 4.0	1998
Cerrado denso - 1993	24.9 ± 2.9	17.0 ± 2.6	33.0 ± 3.0	
Tropical Evergreen / Brazil				Kauffman 1995
Jacunda - 1992	292.4 ± 35.8	139.9 ± 24.3	52.2	
Maraba - 1992	434.6 ± 72.2	207.1 ± 53.7	52.3	
Santa Barbara - 1992	290.2 ± 20.4	165.1 ± 19.2	43.1	
Jamari - 1992	361.2 ± 36.8	155.4 ± 24.1	57.0	
Balteke - 1995	354.8 ± 47.8	187.5 ± 35.8	47.2	Guild 1998
Sergpipe - 1995	398.8 ± 44.7	185.2 ± 30.0	53.6	
Tropical Cattle Pasture / Mexico / El Cielo				Steele, 1998
Low Severity 1995	40.3 ± 6.9	14.8 ± 2.9	63.1 ± 4.5	
High Severity 1995	29.0 ± 2.8	7.6 ± 3.0	75.0 ± 7.9	
Tropical Cattle Pastures / Brazil				Kauffman 1995
Francisco - 1991	53.3 ± 4.8	8.8 ± 2.0	83.5	
Durval - 1991	119.2 ± 35.0	94.7 ± 35.2	20.5	
Joao - 1991	72.7 ± 13.1	38.2 ± 9.0	47.4	
Tropical Cattle Pasture / Brazil				Guild, 1998
Jamari – 1995	66.3 ± 13.3	45.6 ± 11.0	31.2	
Tropical Grassland / Brazil				Kauffman et al.
Campo limpo - 1990	7.1 ± .55	.002 ± 0.0	100 ± 0.0	1994
Campo limpo - 1993	5.5 ± 0.3	0.4 ± 0.2	92.0 ± 5.0	1998
Tropical Savanna / Brazil				Kauffman
Campo sujo - 1990	7.3 ± .51	.237 ± .05	97.0 ± 1.0	1994
Campo sujo - 1993	9.3 ± 0.8	1.4 ± 0.1	84.0 ± 1.0	1998

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Chapter 3

Carbon and Nutrient Dynamics Associated with Deforestation, Biomass Burning, and Conversion to Pasture in a Tropical Dry Forest in Mexico

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Abstract

Deforestation, biomass burning and, conversion to pasture has led to large scale losses of Carbon and nutrients in the Tropical Dry Forest (TDF) of Mexico. We conducted a three-year study (1993-1995) near the Chamela Research Station, Jalisco, Mexico to quantify biomass, carbon and nutrient (N,S,Ca,P,K) loss under two separate fire severity scenarios that would encompass some of the variability that might be expected from slash and burn fires. The first treatment (Baja) was a shorter time period between slash and burn (slash late-burn early) resulting in fuels of higher moisture content. The second treatment was slashed early and burned late (Alta) resulting in drier fuels. We also compared biomass and nutrient dynamics the first two years following these slash fires (including a pasture fire).

Prior to the slash fire, we found C and nutrient concentrations to be highest in litter, dicots, and grass components and decrease with increasing size of wood particles. In 1993, the total C pool of the slashed forest was 57-65 Mg ha^{-1} and declined 62% in low severity slash fires (Baja) and 80% in high severity slash fires (Alta) during the initial slash fires. The slash fire also resulted in nutrients losses ranging from 66-88% with ≈10% higher combustion of the Alta nutrient pools. We found little ash retention on-site after fire. In 1994, there was no increase in nutrient soil concentrations of nutrients found in high concentrations in ash (i.e. Ca and P). Likely the ash was lost due to wind and water erosion on the 40 to 60% slopes. In the time between the slash fire and the pasture of 1995 (2 years), we found wood decomposition losses of the postfire biomass from 17% (Alta) to 40% (Baja). In 1995 in the two-year old pasture, the C pool was 14-19 Mg ha^{-1} and declined 62% (Baja) and 73% (Alta) during pasture fires.

Nutrient pool loss for the pasture fires ranged from 57-88% of the aboveground pools. Total C loss (3 years;2 fires) was 49.4 Mg ha^{-1}, a 87% reduction in the Baja treatment and 61.1 Mg ha^{-1}, a 94 reduction in the Alta treatment. Total aboveground nutrient loss of the sampled elements were 87-96% over the three-year study.

Introduction

Deforestation, Biomass Burning and Pasture Conversion

Along with fossil fuel combustion, tropical biomass burning is a significant contributor to global greenhouse gas emissions (Crutzen and Andreae 1990). In terms of deforestation, most studies have focused on the role of tropical moist forests on global carbon cycling. Relatively little is known regarding the role of tropical dry forests (TDF) on global nutrient budgets. TDF's have the highest human population densities of any region in Latin America (Murphy and Lugo, 1986). Deforestation is continuing and rates are increasing in many TDF's of the world (Murphy and Lugo 1986). For example, Masera et al. (1997) estimated that 3.8% of the closed dry forest area in the Chamela region alone is deforested annually. These trends, as well as the lack of information on atmospheric inputs arising from site losses of carbon and nutrients, during land conversion, in the TDF of Mexico indicate a need for more study. To this end, in 1993-1995, we began experiments to quantify the effects of deforestation, biomass burning, and pasture conversion on nutrient dynamics in the Mexican tropical dry forest near the Chamela research station Jalisco, Mexico.

Deforestation and biomass burning for pasture conversion has influences that extend from local to regional and global scales. Local on-site effects include: 1) loss of biodiversity; 2) increased temperature at ground level potentially increasing drought conditions; 3) changes in hydrology due to deforestation that results in higher likelihood of erosion and landslides; 4) reduction in on-site organic carbon and nutrients thereby decreasing productivity and future reforestation attempts; 5) forest fragmentation and related effects and, 6) increased soil compaction associated with cattle grazing which reduces root growth (Maass 1995). Regionally, deforestation results in: 1) regional changes in weather patterns (Maass 1995); 2) increases in CO and O_3 result in loss of productivity (Maass 1995); 3) desertification and/or soil degradation where neither forests nor croplands will grow (Maass 1995) and, 4) human health deterioration from particulate release especially $PM_{2.5}$ (particulate matter < 2.5 μm) resulting in higher levels of respiratory disease (Ward 1991). Global effects include: 1) global loss of species and 2) increased shift of forests from carbon sinks to atmospheric carbon sources (Maass 1995).

In order to better understand the role of land conversion at local, regional and global scales, on the ground experimentation is a necessary first step. We designed a three-year study to measure biomass burning, biomass loss, nutrient composition and total carbon and nutrients (nitrogen, sulphur, calcium, potassium and, potassium) in TDF before and after the initial slash fire, the first year following crop production and pasture establishment before and after the implementation of a pasture fire.

Tropical Dry Forests

Information is scarce on the effects of slash-and-burn agricultural practices in the TDF. TDFs comprise 42% of all tropical and subtropical forests and contain the highest human population densities in Latin America (Murphy and Lugo 1986). Mooney et al. (1995) described TDF as occurring in the tropical regions where there are 'several months of severe, even absolute, drought', and are distinguished from savannas by the presence of tree dominated, occasionally closed canopy systems. A general overview of TDFs compared to tropical wet forests indicate they generally have less plant species diversity, lower forest canopies (Holbrook 1995), fewer epiphytes (Medina 1995), and lower total biomass (Murphy and Lugo 1995).

Site Description

This study was conducted from 1993 to 1995 on the Ejido San Mateo, Jalisco Mexico near the Chamela Biological Research Station administered by the Universidad de Nacional Autonoma. The research site is located on the central Mexican Pacific coast (19^{O} 35'N, 105^{O} 05'W) is classified as a Mesoamerican (Ceballos 1995), Subtropical (Holdridge 1967), Seasonally dry deciduous forest (Murphy and Lugo 1995). The principal vegetation of this upland site (slopes from 40 to 60%) are in the Fabaceae family (Gentry 1995). Density of trees (>3 cm dbh) was ≈ 4325 ha^{-1} (Kauffman pers. comm 1998). Soils are classified as sandy loam Entisols (rhyolite) (Roth 1996). Mean annual temperature is 24.9^{O} C and annual rainfall is 714 ± 154mm with 80% of the precipitation occurring between July and October (Garcia-Olivia et al. 1995). Plant species richness of this area is the highest of any recorded TDF with 544 genera and 124 families (Lott 1987).

Biomass burning is the most efficient means both in terms of labor energy and capital expenditures for land clearing and the planting of agronomic crops or pasture for livestock (Bye 1995). The generalized approaches to land use/land conversion in the Chamela region are: (1) slashing existing forest usually with machete and chainsaw at the beginning of the dry season; (2) removal of usable wood (due to remoteness little if any wood was removed from this site); (3) allow slash to dry for 2-3 months during the dry season; (4) burn biomass toward the end of the dry season; (5) plant crops (Corn - *Zea maiz*) and pasture grass (e.g., *Andropogon gayanus*, *Panicum maximum* and *Cenchrus* *ciliaris*) immediately after burning; (6) harvest crops 3-4 months after planting; 7) after corn harvest begin livestock grazing on established pasture; and (8) burn pasture every two to three years after establishment.

The overall objective of this study was to quantify the aboveground Carbon and nutrient (N, S, Ca, K, P) dynamics associated with the initial phases of conversion of primary TDF to cattle pasture. This was experimentally examined with two separate fire severity scenarios designed to encompass some of the variability that might be expected from slash and burn fires. Treatments included a low consumption fire conducted when fuels were comparatively higher in moisture and compared to the other treatment, a high consumption fire. During the three-year study period, we quantified: 1) elemental losses due to the slash fire and due to decomposition following the slash fire;
2) aboveground elemental pools in vegetative regrowth for the two years following slash fires; and, 3) elemental losses from a second fire in the newly formed pastures.

Methods

Experimental Design

The study site was approximately 3.5 ha in size. Three replicate blocks (≈ 1 ha m area) were established and each were subdivided into approximately three 33 x 100m (0.3 ha) treatment sub-blocks. Plot boundaries delineated with metals posts. Three fire severities were included in the original design, however, due to an accidental escape of fire into one medium fire severity block (during the low severity fire), the data were excluded from the final analysis. In this study only the Alta sites (high severity) and Baja sites (low severity) are reported.

Fire Treatments

The fire severity treatments were randomly assigned to each sub-block. The differences in fire treatments were accomplished by varying the drying time between slash and burning. In 1993, Alta sites were slashed the last week of January and burned 9 May 1993 (95 days between slashing and burning). Baja sites were slashed the second week of February and burned 9 April 1993 (65 days between slashing and burning). There were no precipitation events between the slash events and biomass burning. Postfire combustion (the combustion factor) was calculated as the percent of biomass lost during a fire.

Biomass Measurements

Within each sub-block, three rhomboidal (diamond-shaped) clusters were established. Biomass in each cluster was measured along five transects established in such a way as to ensure remeasurement throughout the three-year study. Thus, there were 45 biomass transects (n=45) each for the Alta and Baja treatments (15 transects per sub-block).

Total aboveground biomass (TAGB) was sampled in 1993 before and after slash burning. Towards the end of the 1994 dry season (about one year after the slash fire) biomass was again sampled in the newly established pasture. This sampling time occurred following the corn harvest and some cattle grazing. In 1995, TAGB was measured prior to, and following, the pasture fire for these experimental units.

Biomass of wood debris was quantified each year non-destructively using the planar intercept technique (Brown & Roussopoulos 1974; Kauffman et al. 1993). Wood particle sizes were partitioned into standard moisture timelag classes (Byram 1963).

Residual standing trees were measured within the three 225 m^2 rhomboidal plots in each plot (n = 3/treatment). The diameter at breast height (dbh) and total height was collected to estimate standing tree biomass using formulas developed by Martinez-Yrizar (1990). Biomass was determined by calculating volume and then multiplying volume by the specific gravity of large wood samples. Stumps were measured along a 20 x 1 m belt in each cluster (n = 3/sub-block, n = 9/treatment). The diameter and height of all stumps were measured to calculate volume. Each volume measurement was then multiplied by the specific gravity of the reference large wood debris (>7.6 cm diam) fuels) to calculate mass.

Litter, consisting of leaves, fruits, seeds, dead grass, old corn plant parts, wood, and bark fragments was collected in 50 x 50 cm plots established 1m away from the end of each woody biomass transect. All dicots present within the same plots were also harvested, oven dried and weighed at the station laboratory. Foliage attached to slashed wood debris was estimated by multiplying the ratio of leaves to the 1-hr fuel biomass. The ratio of attached foliage to twig and leaf biomass was calculated by collecting 50 random samples of 1-hr fuels, oven drying and then weighing the wood and leaf material, separately. Ash samples were collected immediately after burning in nine 50 x 50 cm microplots in 1993 slash fire (n=27/treatment) and six 50 x 50 cm microplots in 1995 pasture fire (n=18/treatment), within each sub-plot, using a vacuum cleaner and a portable generator.

Statistical Analysis

The experiment was established as a randomized block design. Treatments involved the two fire severities replicated in the three blocks. Statistical analysis was performed using ANOVA. Wood debris and litter at each transect, stumps and ash at each rhomboidal plot and, trees and TAGB at each sub-plot was considered as an individual observation. Statistical analyses included: aboveground prefire versus postfire elemental pools, comparisons between treatments at each measurement stage, percent elemental loss due to fire and elemental pool loss due to decomposition and regrowth. Significance was set at the $p \leq 0.10$ level.

Nutrient Analysis

Nutrient analysis consisted of measuring for carbon (C), nitrogen (N), sulphur (S), calcium (Ca), potassium (K) and, phosphorus (P) concentration during each year of the study (Table 3.1). Samples for nutrient analysis were collected by random grab sampling throughout each sub-plot. Ash samples were those collected for biomass determination. Nutrient analysis was completed for all the fine fuel components (litter, dicots, attached foliage, live grass, dead grass, manure and corn), for several woody debris size classes (1, 10, 100 and 1000-hour fuels) and, for postfire ash. Samples of each biomass component were taken to the Oregon State University habitat ecology lab for elemental composition analysis. Carbon, nitrogen and sulphur concentrations were determined using a Carlo Erba NA series 1500 CNS analyzer (Nelson and Sommers 1982). Potassium and calcium were determined using atomic absorption (Tabatabai and Bremner 1970). Total phosphorus was determined colorimetrically following wet digestion utilizing a Kjeldahl procedure (Watanabe and Olsen 1965). Total nutrient pools were determined through multiplication of the mean nutrient concentration and the biomass of each component (Appendix A: Table 6). Total C and nutrient prefire and postfire pools, total loss after fire and, percent loss of each nutrient was calculated for 1993 and 1995 fire data (Table 3.3; Figure 3.1).

Emission Factors

Emission factors to estimate gas releases from biomass burning were derived using data provided by Ward et. al (1991) that defined emission factors for several different forest types and several types of carbon emissions (CO_2 (carbon dioxide), CO (carbon monoxide), CH_4 (methane), NMHC (non-methyl hydrocarbons) and $PM_{2.5}$ (particulate matter <2.5µm)). We used these emission factors to estimate total emissions for TDF and pasture fires over a the three-year study period in the Chamela region. Using these data we then scaled-up to the regional scale of all Mexican TDF to provide estimates of mean annual losses arising from deforestation and slash fires.

Soil Measurements

Soils were sampled for nutrient analysis following the methods outlined in Ellingson et al. (1998). Soil measurements were taken at six time periods: 1) prefire 1993 (May), 2) postfire 1993 (May), 3) first wet season post-fire 1993 (August), 4) one year postfire (March 1994), 5) 2 years post initial slash fire and before 1995 fire (June) and, 6) postfire 1995 (June). Soil measurements were taken at two depths (0-2.5 cm and 2.5-10 cm) along biomass transects in each plot (n=9/treatment, per depth) and in a nearby reference (control) forest (n=3 in 1993 and n=9 in 1995, per depth) (Table 3.2).

Results

Fire Behavior

All 1993 fires were conducted at a similar ambient air temperature, and flame height and length were similar for all of the slash fires (Chapter 1). However, the mean rate of spread (fire speed in m/min) was quite different (Alta: 16.2 m/min, Baja: 1.2 m/min). The greatest difference here was attributed to the ignition pattern. The Baja sites were burned mostly by backing fires (down slope) while the Alta sites were burned with a head fire (up slope).

In 1995 the entire study area, now a two-year old pasture, was burned on 15 June (30.6^{O} C, 67% relative humidity, 3.5 m flame length, 4.3 m flame height, 18m flame depth, and the rate of spread was a rapid 133 m/min).

Nutrient Concentrations

Nutrient concentrations tended to be highest in the fine fuels and decreased with increasing diameter of the woody debris, trees and, stumps (Table 3.1). C concentrations ranged from 41-50% of the biomass components. Nutrient concentrations ranged from: N = 0.4-3 mg g^{-1}, S = 0.03-0.3 mg g^{-1}, Ca = 0.8-3 mg g^{-1}, K = 0.1-1.7 mg g^{-1} and, P = 0.01-0.2 mg g^{-1}. Ash concentrations (0.2-15%) were highest in Ca and C with calcium dropping from 15% in 1993 to 3% in 1995 measurements.

Carbon Dynamics

The initial slash fire decreased aboveground C pools from 56 to 21 Mg C ha^{-1}, a 62% loss in the Baja treatments and from 65 to 13 Mg C ha^{-1}, a 80% loss on the Alta sites (Appendix B; Table 6). The greatest C consumption occurred in the Alta 1000-hour fuels which decreased ≈13 Mg C ha^{-1}, or 25 % of the total carbon consumption. Baja 1000-hour fuels lost 5.6 Mg C ha^{-1} or 16% of total carbon loss (p=0.09). Consumption and hence C loss was lower in the Baja treatment. Total fine fuels had the highest consumption rates ≈100%, but only contained ≈ 5 % of the aboveground carbon pool. The concentration of C in the ash was ≈10%; only 5-6% of the C loss from the prefire slash mass remained in the ash pool. Therefore, total aboveground C loss from the site was 61% and 79% of the prefire C pools for Baja and Alta treatments, respectively.

In 1994, one year following the initial slash fire, the aboveground carbon pool ranged from 13 (Baja) to 19 (Alta) Mg C ha^{-1}. The only significant difference between treatments by component was in the corn measurements (p=0.03) which ranged from 0.6 (Baja) to 0.9 Mg C ha^{-1} (Alta). Carbon nutrient concentrations were similar to 1993 except that the 1993 litter was only 33.2% carbon (forest litter was 41% in 1993). Total C pools in the Baja treatment declined as decomposition exceeded accumulation.
The first year following fire resulted in carbon losses of 2.2 Mg C ha^{-1} on the Baja plots, or 10% of 1993 postfire carbon pool. In contrast, there was a slight increase in carbon on the Alta sites, ≈ 0.5 Mg C ha^{-1}. This was largely due to the vegetative regrowth exceeding losses from decomposition.

In 1995, both sites showed a carbon decrease of ≈ 0.1 Mg C ha^{-1} due to decomposition since the 1994 measurements. Large wood (1000-hour fuels) still comprised the greatest proportion of the total C pools (23-37% or 3.1 (Alta) to 7 Mg C ha^{-1} (Baja)). However, the litter (2.1 and 2.3 Mg C ha^{-1}) and dead grass (3.0 and 1.5 Mg C ha^{-1}) combined had similar and greater carbon mass than the once larger pools in the 1000-hour prefire fuels.

The 1995 pasture fire reduced C pools from 19 to 7 Mg C ha^{-1} (a 62% loss) on the Baja sites and from 13 to 4 Mg C ha^{-1} (a 73% loss) in the Alta plots. The greatest losses of C still occurred in the 1000-hour fuels (2 and 3.6 Mg C ha^{-1}, p=0.08), but total carbon percent losses in the fine fuel components now made up 29 to 34% of the total carbon loss in the pasture fire. Carbon concentration in ash was 16% and ash made up 3-4% of the total carbon losses from the biomass.

Cumulative C pool losses, for the three-year study, ranged from 49 Mg C ha^{-1}, a 87% loss, in the Baja sites to 61 Mg C ha^{-1}, a 94% loss, on the Alta plots. The greatest differences between treatments were in the 1000-hour fuels (p=0.04). The Alta fine fuel components had the greatest percent combustion (96%), while Baja fine fuels were decreased by 91%. Cumulative loss, due to wind and/or water erosion of the ash component, would have only accounted for 1.5% of Baja and 1.4% of Alta C pool loss for the three years of this study.

Nitrogen Dynamics

Prior to the 1993 slash fire, the aboveground N pools ranged from 855-943 kg N ha^{-1} (Appendix B; Table 7). The fire reduced the pools to 253 kg N ha^{-1} (a 70% loss) in the low severity Baja plots and to 150 kg N ha^{-1} (a 85% loss) in the high severity Alta sites. Total fine fuels declined nearly 100% and, while they only constituted ≈18% of the prefire pool of nitrogen, these losses resulted in 19-26% of total N losses by the slash fire. The greatest nitrogen loss by component occurred in the 100-hour fuels (wood 2.55-7.62 cm in diameter) with fire losses of 124 and 168 kg N ha^{-1} (75-90% of the fuel component). N concentration in ash was ≈ 0.6% and ash losses accounted for ≈ 3% of total nitrogen pool losses in the 1993 fire (N.S.D. between treatments). N pools in all components were significantly lower ($p \leq .10$) after fire within treatments. However, only in the large wood components (1000-hour fuels) were N pool significantly different ($p=0.09$) between treatments after the slash fire. There was a 83% decline in the N pool of the 1000-hour fuels in the Alta sites, while Baja sites lost only 39% of this prefire nitrogen pool.

In 1994, one year after slash burning, nitrogen pools in the Baja treatment declined 60 kg N ha^{-1}, while Alta sites lost 5 kg N ha^{-1}. Decomposition in the large wood (>7.6 cm) resulted in a 45 kg N ha^{-1} decline (45%) in the Baja plots and a 6 kg N ha^{-1} decline (5%) in the Alta sites. These large wood losses made up 74% of total nitrogen loss between 1993 and 1994 in the Baja sites. The growth of fine fuels (pasture grasses) between years composed an increase of 56 kg N ha^{-1} to the Alta N pool in 1994.

Prior to the 1995 pasture fire, nitrogen pools ranged from 220 kg N ha^{-1} in the Baja plots to 179 kg N ha^{-1} in the Alta sites (Appendix B; Table 7). N pools within wood debris of the Baja treatment declined by an additional 13 kg N ha^{-1} due to decomposition from 1994 to 1995. Therefore, between postfire 1993 to 1995 there was a total decline of 98 kg N ha^{-1} in aboveground N pools of the Baja treatment. Total Alta treatment loss was ≈ 29 kg N ha^{-1} during this time period. Losses in aboveground pools occurred because decomposition exceeded pasture growth between fires.

In 1995, the pasture fires reduced N pools by 149 kg N ha^{-1}, in the Baja plots, to 71 kg N ha^{-1} (a 68% loss) and, in the Alta sites, to 35 kg ha^{-1} (a 80% loss). N pools were significantly lower ($p<0.1$) on both sites (Appendix B; Table 4). In the pasture fires, the greatest nitrogen losses occurred through the consumption of the large wood debris (22 kg N ha^{-1}, or a 58% loss due to fire in the Baja plots and 32 kg N ha^{-1}, a 87% decline in the Alta treatment. Nitrogen ash totals were 13 kg ha^{-1} in the Baja plots and 15 kg ha^{-1} in the Alta sites. These ash losses composed ≈ 10% of total N combusted in fuels during the pasture fires.

During the study (1993-1995), aboveground N pools (Appendix B; Table 7) decreased from 856 to 71 kg N ha^{-1} (a 92% loss) in the low severity Baja fires. During the same period, the Alta N pools declined from 994 to 35 kg N ha^{-1} (a 96% loss). Total ash losses accounted for ≈ 5% of total N loss during the two fires, however, there was no increase in soil N concentrations indicating little input of N into the soil.

Sulphur Dynamics

Total aboveground sulphur pools before the 1993 slash fire were 64 kg S ha^{-1} in the Baja plots and 70 kg S ha^{-1} in the Alta sites (Appendix B; Table 8). The total S pool after fire was 17 kg S ha^{-1}, a 73% loss (Baja) and 10 kg S ha^{-1}, a 85% loss (Alta). While the 1000-hour fuels had slightly higher biomass, the higher concentration of sulphur in the 10 and 100-hour fuels resulted in these fuels having greater sulphur mass than the larger wood debris (Appendix B; Table 8). The largest absolute S consumption, during the fire, occurred in the Alta 100 hour fuels. The 2.6-7.6 cm woody debris in the Alta sites lost 13 kg S ha^{-1}, a 90% reduction and, the same component lost 9 kg S ha^{-1} in the Baja plots, a 75% loss. The 1000-hour fuels, however, had the only significant difference by component between treatments ($p=0.09$). Baja sites lost 4 kg S ha^{-1} of S biomass from the 1000-hour fuels, a 38% loss, while the Alta sites lost 9 kg S ha^{-1}, a 83% loss. Ash S concentration was 0.2% and the ash composed ≈ 14% of the sulphur loss from aboveground mass due to fire.

Between the 1993 postfire and the 1994 measurements, the sulphur losses due to decomposition were small. During this one year period, there was a 32% increase in the S pool in 100-hour fuels after fire in the Baja treatment. In contrast, S pools in the 100-hour component in Alta treatments slightly decreased 7%. The total S pool in the 1994 fine fuel components was ≈ 7 kg S ha^{-1} in both treatments.

Between the 1993 fire and the 1994 measurements, the greatest decomposition losses occurred in the Baja 1000-hour fuels which lost ≈ 2 kg S ha^{-1}, a 27% loss, while S pools in the Alta 1000-hour fuels rose slightly (0.2 kg ha^{-1}). Total 1000-hour S pool loss due to decomposition were ≈ 3 kg S ha^{-1} in the Baja treatment and ≈ 2 kg S ha^{-1} in the Alta treatment. During this period, the total site S pool increased ≈ 3 kg S ha^{-1} with the addition of ≈ 7 kg S ha^{-1} from regrowth in the Baja treatment, while the S pool in the Alta increased 5 kg S ha^{-1} due to the addition of ≈ 7 kg S ha^{-1} from vegetative growth.

Prior to the 1995 pasture fire (since the 1994 measurements) the S pool in the Baja treatment increased 6 kg S ha^{-1} with 5 kg S ha^{-1}, arising from increases in the fine fuel component and the Alta treatment increased ≈ 4 kg S ha^{-1}. Prefire S pools ranged from 27 kg S ha^{-1} in the Baja plots to 19 kg S ha^{-1} in the Alta treatments.

The 1995 pasture fires resulted in a decline of 19 kg S ha^{-1}, a 74% loss in the Baja treatment S pool and a reduction of 15 kg S ha^{-1}, a 78% loss in the Alta treatment. Fine fuels were consumed in the greatest percent consumption resulting in ≈ 96% loss of S in both treatments. The largest absolute decrease in S after fire happened in the 100-hour Baja woody debris. Baja sites lost 5 kg S ha^{-1} (57%) and Alta plots lost ≈ 1 kg S ha^{-1} (31%) of the 100 hour fuels. Following fire, the S pool in ash was ≈ 4 kg S ha^{-1} and 18 to 25% of the total pool loss of S due to fire.

Total cumulative S losses during the three year study were 57 kg S ha^{-1} in the Baja treatment, a 89% loss of S and, the two fires reduced the Alta treatment S pool by 65 kg S ha^{-1}, a 94% loss of S ($p=0.12$ between treatments). The 1000-hour fuels S pools were significantly different between treatments after the two fires ($p=0.04$) as the Baja sites lost ≈ 9 kg S ha^{-1}, a 91% loss while the Alta treatment declined 11 kg S ha^{-1} (a 97% reduction of S pool). No other components were significantly different ($p<0.1$) between the treatments for S pools. All components were significantly different within the treatments (before the 1993 slash fire until after the 1995 pasture fire), except the Baja stump S pool ($p<0.3$). Ash loss during the two fires comprised ≈ 18% of the total S loss in both treatments.

Calcium Dynamics

Aboveground Ca pools prior to the 1993 slash fire were 1365 kg Ca ha^{-1} in the Baja treatment and 1535 kg Ca ha^{-1} in the Alta treatment (Appendix B: Table 9). After fire, the Ca pool declined 66% to 452 kg Ca ha^{-1} in the Baja plots and 82% to 279 kg Ca ha^{-1} in the Alta sites. Again, the fine fuels had the highest combustion with ≈ 100% loss in both treatments. The greatest Ca pool loss within a single component occurred in the 1000-hour fuels in the Baja treatment shifting from 309 kg Ca ha^{-1} (prefire) to 189 kg Ca ha^{-1} (postfire) a decline of 120 kg Ca ha^{-1} (a 39% loss) and the Alta treatment shifting from 329 to 58 kg ha^{-1} (272 kg ha^{-1}, a 82.5% loss). While the prefire Ca pools were not significantly different between treatments, both the fine fuels ($p=0.01$) and the total Ca pools in woody debris ($p<0.01$) were significantly different after fire. The high Ca concentrations in the ash was reflective of a higher temperature of volatilization resulting in a greater proportion of the ash pool remaining on site as ash following fire. Postfire ash was 584 kg Ca ha^{-1} in the Baja plots or ≈ 64% of the prefire Ca pool. Ca pools in ash within the Alta treatment comprised ≈ 55% of the prefire Ca pool (696 kg Ca ha^{-1}).

In 1994, Ca pools for the non-fire year were 360 kg Ca ha^{-1} in the Baja treatment and 260 kg Ca ha^{-1} in the Alta treatment. Including the ash, this was a loss of 1006 kg Ca ha^{-1} (Baja) and 1276 kg Ca ha^{-1} (Alta). For the one year period following fire, the Ca pool in fine fuels increased 61 (Baja) and 58 kg Ca ha^{-1} (Alta). During the same period, the Baja 1000-hour fuel Ca pool declined 66 kg Ca ha^{-1}, a 35% decrease due to decomposition, the greatest Ca loss of any component. Decomposition losses in the Alta 1000-hour Ca pool was were ≈ 3 kg Ca ha^{-1}, a 5% Ca loss. Total Ca loss due to wood decomposition, in the one year since the slash fire, was ≈ 154 kg Ca ha^{-1} in the Baja plots and ≈ 78 kg Ca ha^{-1} in the Alta treatments.

The 1995 pasture Ca pool before burning was 310 kg Ca ha^{-1} in the Baja plots and 230 kg Ca ha^{-1} in the Alta sites. Total Ca pool in aboveground biomass after fire was 134 kg Ca ha^{-1}, a 57% loss in the Baja treatment and 67 kg Ca ha^{-1}, a 71% in the Alta treatment. The fine fuels increased the aboveground Ca pool 60-70 kg Ca ha^{-1} between fires while the total wood decomposition since 1994 had reduced Baja plots by 47 kg Ca ha^{-1}. Ca pools in the Alta treatment increased by 22 kg Ca ha^{-1} mostly due to a 21 kg ha^{-1} Ca increase in 1000-hour fuel pool. During the 1995 pasture fire, Ca pools were reduced by 117 kg ha^{-1} (Baja) and and 163 kg ha^{-1} (Alta). Alta 1000-hour wood Ca pool was reduced by 87%, but the Alta 100-hour Ca pool only lost 31% of it's 1995 prefire Ca pool. Ash comprised 32% of the prefire Baja pool mass and 39% of the Alta calcium pool mass after the 1995 fire.

Cumulatively, during the three-year study, the Ca pool (excluding ash) declined 1231 kg Ca ha^{-1} in the Baja plots (a 90% reduction) and 1468 kg ha^{-1} (a 96% reduction) in the Alta treatments. Ash Ca pool comprised ≈ 52% of the Ca pool in both treatments, although, the original slash fire. There was a significant difference within treatments for the Ca pool over the entire study ($p<0.01$) and for total Ca pool in wood debris between treatments ($p=0.03$).

Potassium Dynamics

In the 1993 slash fire, K pools declined from 310 to 102 kg K ha^{-1}, a 67% loss in the Baja treatment and from 346 to 61 kg K ha^{-1}, a 82% loss in the Alta treatment (Appendix B; Table 10). Fine fuel K pools were reduced ≈100% in both treatments. The 100-hour fuel K pools had the greatest consumption rate of 75% (Baja) and 90% (Alta) of any woody debris component. The wood components (7-9% of initial K) had relatively high prefire K concentrations (1.1%) and lost ≈ 92% (20-30 kg ha^{-1}) of their K pools. The ash K pool ranged from 76 to 90 kg K ha^{-1} and made up 31-36% of K pools after the slash fire.

In 1994, one year after the slash fire, K pools increased to 115 (Baja) and 92 kg K ha^{-1} (Alta) largely due to the vegetative regrowth and high K in the fine fuel components, particularly grass and grass litter. Fine fuels comprised 47-58% of total K pools (≈ 11% in 1993 prefire pools). Decomposition, since the 1993 slash fire, reduced woody debris K pools by 28 kg K ha^{-1} in the Baja plots, a 36% loss and by 16 kg K ha^{-1} in the Alta treatments, a 45% loss. During this period, the greatest loss of any component was the Baja large wood (1000-hour fuels) K pool with a loss of 18 kg K ha^{-1}, a 45% loss and 56% of total Baja wood K pool loss due to decomposition.

Prior to the 1995 pasture fires, the K pool was 176 kg K ha^{-1} in the Baja treatment and 121 kg K ha^{-1} in the Alta treatment. The total K pool in Baja wood declined 15 kg K ha^{-1} since the 1994 measurements due to decomposition, while the Alta wood K pool was unchanged.

In 1995, prefire fine fuel K pools made up ≈ 75% of total K in both treatments. After fire, fine fuel K pool losses were ≈ 100%, made up 85% of the total K pool volatilized, released as particulate matter or, sent to the ash pool during fire. The total aboveground K pool (excluding ash) declined from 176 to 25 kg K ha^{-1}, a 86% loss in the Baja treatment and from 121 to 14 kg K ha^{-1}, a 88% loss in the Alta treatment. Dead grass made up 48 (Baja) and 33% (Alta) of the prefire K pool, lost 95-98% of the K pool in grass during fire and, made up 55% of the total K pool lost due to fire. The largest significant difference by component between treatments occurred in the 100-hour fuels ($p=0.05$). The ash pool of K was 55 kg K ha^{-1} in the Baja plots (36% of K pool loss from combusted fuels) and 60 kg K ha^{-1} in the Alta sites (56% of aboveground K consumed by fire).

During the three year study, aboveground K pools in Baja sites declined 285 kg K ha^{-1}, a 92% loss and Alta plots declined 332 kg K ha^{-1}, a 96% loss of their original K pool prior to the 1993 slash fire. Total ash K pool 130 (Baja) and 150 kg K ha^{-1} (Alta) and made up ≈ 45% of total K pool losses in both treatments.

Phosphorus Dynamics

The 1993 slash fire reduced aboveground P pools (excluding ash) from 25 to 6 kg P ha^{-1}, a 78% loss in the Baja treatment and from 27 to 3 kg P ha^{-1}, a 88% loss in the Alta treatment (Appendix B; Table 11). The total wood P pool ($p<0.01$) and the fine fuel P pool ($p=0.01$) were both significantly different between treatments after the slash fire. The 10 and 100-hour fuels had 1.5-2 times the prefire P pool compared to the 1000-hour P pool (3 vs. 5 kg ha^{-1}). This was different than other nutrient losses during the fires. All other nutrients had greater losses in the larger woody debris. The Alta 100-hour fuels were reduced by 5 kg P ha^{-1} (a 90% loss), the greatest P pool consumption in any wood debris component. Fine fuel P pools were reduced by ≈ 100% in both treatments and the greatest difference between treatments was in the 1000-hour P pool ($p=0.09$). Ash mass was 9 and 11 kg ha^{-1} and made up 47-59% of the total P pool after the initial slash fire.

In 1994, one year after the slash fire, P pools increased to 11 kg P ha^{-1} in the Baja sites and 9 kg P ha^{-1} in the Alta sites largely due to increases in the fine fuel P pool. The fine fuel P pool was ≈ 4 kg P ha^{-1} in both treatments and made up 36-46% of the total P pools. Total P increased slightly (<1 kg ha^{-1}) in all woody debris components despite biomass decomposition of 19% P in Baja treatments and 30% in Alta treatments.

The 1995 P pool had increased ≈ 2 kg ha^{-1} in both treatments since the 1994 measurements. Baja sites now had 14 kg P ha^{-1} and Alta plots had 12 kg P ha^{-1} in P pools. Decomposition reduced total wood P pools ≈ 1 kg P ha^{-1} in the Baja plots and Alta total wood P pool increased ≈ 0.4 kg P ha^{-1} since the 1994 measurements.

The 1995 pasture fire reduced the fine fuel P pool by ≈ 100% and litter lost ≈ 3 kg ha^{-1} or 30% of total P pool losses due to fire. Only total wood P combustion was significantly different between treatments ($p<0.01$) as the higher residual wood levels in the Baja sites were reduced more than Alta P pool in the wood components. The total aboveground P pool declined from ≈ 14 to 3 kg P ha^{-1} in the Baja treatment, a 75% loss and from ≈ 12 to 2 kg P ha^{-1} in the Alta treatment, a 86% loss (p=0.2). Ash mass was ≈ 5 kg P ha^{-1} and made up ≈ 50% of total P pool consumed in fuels during the 1995 pasture fires.

During the three year study that included a slash and a pasture fire, the P pool (excluding ash) went from 25 to 3 kg P ha^{-1}, a 87% reduction in the Baja sites and from 27 to 2 kg P ha^{-1}, a 94% loss in the Alta plots. There was little overall P pool losses due to decomposition between the two fires. The majority of measurable losses of P occurred during fire. Ash (≈ 2% of the P pool) made up ≈ 67% of the total P pool in both treatments. Only the 1000-hour fuels were significantly different (p=0.04) with Baja P pool loss ≈ 73% and Alta P pool loss ≈ 93% with this fire regimen.

Soil Measurements

There were few changes in soil nutrient concentration during the study (Table 3.2). Only phosphorus showed a slight increase from prefire 1993 to postfire 1995 on the Baja sites at both depths (3-4 mg g^{-1}). The remaining nutrients declined or did not change at both depths and at each measurement phase. Ash erosion on the site was extremely high on these TDF sites found on steep slopes. In 1994, residual amounts of ash were extremely rare. Ash loss would likely be as high following the fires. It appears that most of the ash was lost from the site and not incorporated into soils because soil C and nutrient concentrations did not increase significantly ($p \leq .1\%$) and most decreased over the three-year period of this study.

Nutrient Pool Losses

Most fires in the Chamela region occur just prior to or at the onset of the rainy season. Nutrient concentrations tended to be higher in the fine fuels and decline with increasing wood diameter. The total aboveground carbon and nutrient percent losses, in the 1993 slash fire, ranged from 62-78% of the total nutrient pools in the Baja treatment and from 80-88% in the Alta treatment with an average 14% higher combustion rate in the higher severity Alta treatments. Total aboveground C and nutrient pool reductions during the 1995 pasture fire ranged from 57-86% in the Baja plots and from 71-88% in the Alta sites with an average of 5% higher combustion in the Alta treatment. The total pool decline during both fires ranged from 87-92% in the Baja treatment, 94-96% in the Alta treatment and, averaged 6% higher combustion in the Alta sites versus the Baja plots.

Several other studies (Kauffman et al. 1993,1994, 1995 and 1998; Guild et al. 1998) have measured C and nutrient loss in tropical forests, however, these studies only looked at single event fire effects and this study looked at these effects for an extended period of time. Kauffman et al. (1993) studied the effects of fire on TDF in Northeastern Brazil. They found aboveground C and N pool losses of 73-79% (Chamela: 62-85% C and N combustion) and total aboveground P losses of 3-56% (Chamela: 78-88%). The Brazil TDF had ≈ 60% less prefire slash biomass and nutrient pools than the Chamela study. It had a much lower percentage of aboveground biomass in large woody debris (>7.6 cm) and the Brazil site had lower total C and nutrient combustion losses than this study. Comparing slash fires in both evergreen and dry forests, we found the higher the large wood:fine fuel ratio, the greater total C and nutrient loss in tropical forests.

Kauffman et al. (1994) measured the effects of fire on biomass and nutrient pools in two tropical woodland and grassland sites in the Brazilian Cerrado. The percent aboveground N loss was ≈ 95% in the grassland studies and 32-58% in the woodland sites (Chamela: 68-80% in the pasture fire). Total S loss was ≈ 88% in grasslands and ≈ 70% in the cerrado woodland (Chamela: 74-78%) and total C losses were ≈ 97% in grass and ≈ 65 in woodland (Chamela: 62-73%). However, the mass loss was much lower in the Brazilian fires burning only 6-13 Mg ha^{-1} in the relatively minor natural fuels.

Kauffman et al. (1995,1998) and Guild et al. (1998) reported nutrient losses of several tropical evergreen forests in Brazil. They found aboveground C pool losses of 40-56%, N losses of 51-66%, S losses of 34-49% and, K losses of 1-9%. The Chamela K pool loss during the 1993 slash fire ranged from 67 to 82% of the prefire K pool. The evergreen forests had 2-3 times the prefire TAGB and 70-83% of its biomass in large woody debris (>7.6 cm).

The differences between the Chamela losses of Ca and P after fire compared to the single fire event studies in other tropical forest ecosystems in Brazil TDF was particularly significant. The Chamela ash was particularly high in Ca (15% of ash in 1993 and 3% in 1995) and P (0.2% in both years) concentrations. We found no evidence of ash retention on-site. For example, there was no increase in soil pools of Ca or P after fire and the Ca pools in regenerating vegetation <30% of the forest Ca pool.

We found that as much as 80% of the aboveground Ca pool and 88% of the aboveground P was combusted and deposited as ash during the Mexican TDF slash fires. Because we could not find this in 1994 and as soil concentrations did not reflect changes, we assume most of the ash mass was lost via erosion. Kauffman et al. (1993) found P losses in TDF to range from 3-56% of prefire P pools. In several Amazonian tropical evergreen forests, Kauffman et al. (1995) found Ca losses between 3-11% and P losses between 7-32%.

We found that 57-71% of the aboveground Ca pool and 75-86% of the aboveground P pool was lost or deposited as ash during the 1995 pasture fires. Kauffman et al. (1995) found Ca losses in a Brazilian cattle pasture after fire to be as low as 15% and P loss to range from 1 to 37%. Kauffman et al. (1994) found P losses of ≈ 22% in tropical cerrado (woodland) and 67% P reductions in tropical grasslands in Brazil. The Chamela Ca and P losses are much greater than any other reviewed tropical fire study in either a TDF or pasture fire.

Discussion

Chamela Nutrient Losses

There are ≈ 16 million ha of intact TDF in Mexico and Masera et al. (1997) estimated that 1.9% (304,000 ha) is deforested annually. In the Chamela region, the annual loss is estimated to be as high as 3.8% annually (Masera et al. 1997). We used these estimates and our results from Chamela (Baja data for a low estimate and Alta data for a high estimate) to calculate nutrient losses associated with land use/land conversion in Mexican TDF (Table 3.4; Figure 3.2-3.4). If our sites are representative of land use/land conversion change throughout the region, total Mexican TDF carbon losses would range from 10.7 to 15.7 Tg yr^{-1}. Using the Masera et al. (1997) estimates of tropical dry forest area lost on an annual basis in Mexico and multiplying them by the Chamela carbon loss, total carbon pasture losses associated with Mexican annual fires would range from 3.6 to 3.0 Tg yr^{-1}. For 304,000 ha deforested in a single year (Masera et al. 1997) the cumulative carbon losses, for the initial three years of pasture establishment and use, would range from 14.3 to 18.7 Tg yr^{-1}. Nutrient loss estimates for a three-year land use sequence would result in atmospheric inputs (or ecosystem loss) of ≈ 0.3 Tg yr^{-1} N, ≈ 0.02 Tg yr^{-1} S, ≈ 0.3 Tg yr^{-1} Ca, ≈ 0.1 Tg yr^{-1} K and ≈ 9 Gg yr^{-1} P.

Chamela Emissions

We calculated that the total mean carbon losses (excluding ash) in the 1993 slash fire to be 35.3 Mg ha^{-1} (Baja) and 51.6 Mg ha^{-1} (Alta). Total carbon loss due to decomposition and grazing was 2.3 Mg ha^{-1} in the Baja treatment and carbon pools increased between fires 0.4 Mg ha^{-1} in the Alta treatment due to compensation by vegetative regrowth of the fine fuel components. Mean carbon loss after the 1995 pasture fire was 11.8 Mg ha^{-1} in the Baja sites and 9.9 Mg ha^{-1} in the Alta sites. Total aboveground carbon losses for the initial three years of deforestation and pasture conversion were 49.4 Mg ha^{-1} to 61.1 Mg ha^{-1}. Based upon the equations given by Ward et al. (1991) we estimate the CO_2 production from the 1993 slash fire to range from 117 to 170 Mg ha^{-1} and from 34 to 40 Mg ha^{-1} during the 1995 pasture fires. Total estimated losses from the initial three-year land use sequence of biomass burning and pasture establishment would result in between 157 and 204 Mg ha^{-1} of CO_2 released per hectare in Mexican TDF (Table 3.5; Figure 3.5). Using the CO emission factor (Ward et al. 1991) we estimate CO emissions would range from 2-9 Mg ha^{-1} in the 1993 slash fire, from 1.7-2.1 Mg ha^{-1} in the 1995 pasture fire and cumulative three year CO loss to be between 8-11 Mg ha^{-1} (Table 3.5; Figure 3.6). We also estimated the three-year loss estimates for CH_4 (0.5-0.7 Mg ha^{-1} in 1993, 0.1-0.2 Mg ha^{-1} in 1995 and, cumulative losses of 0.6-0.8 Mg ha^{-1}), NMHC (0.7-1.0 Mg ha^{-1} in 1993, ≈ 0.2 Mg ha^{-1} in 1995 and, 0.9-1.2 Mg ha^{-1} cumulative loss) and, $PM_{2.5}$ (Particulate Matter <2.5 μm: 0.8-1.1 Mg ha^{-1} in 1993, ≈ 0.3 Mg ha^{-1} in 1995 and, 1-1.3 Mg ha^{-1} cumulative losses) (Table 3.5; Figure 3.7).

Mexican TDF Emissions

Crutzen and Andreae (1990) estimated that 2-5 Pg carbon were released annually from global biomass burning. They estimated that this level of burning results in 1.6-4.1 Pg CO_2 yr^{-1} released globally. Combining the Ward et al. (1991) and Masera et al. (1997) data with the ground-based results of this study (Table 3.6; Figure 3.8) we estimate total annual Mexican TDF CO_2 releases ranged from 35.8 (Tg yr^{-1}) during low severity fires to 51.8 (Tg yr^{-1}) during high severity TDF fires. If we use the conservative level of 1.6 Pg yr^{-1} global CO_2 inputs, we estimate that annual Mexican TDF fires result in 2.2 to 3.2 % of the global contribution of CO_2 arising from biomass burning.

CO_2 Emission Comparisons with other Tropical Forest Ecosystems

Utilizing the Ward et al. (1991) emission factors, we calculated the CO_2 emissions for several previous fire studies in Latin America in order to compare them with the CO_2 emissions from this study (Table 3.7). Brazilian evergreen forests had biomass pools 2-4 times greater than initial Chamela biomass totals. However, the Brazil forests (Kauffman et al. 1995) had combustion rates much lower (43-57%) and their CO_2 emissions were ≈ times greater than TDF emissions. All other forest types in Latin America had CO_2 emissions less than this study. For example, a Brazilian TDF site (Kauffman et al. 1993) had similar prefire biomass and higher consumption rates, however, their CO_2 emissions were significantly lower than Chamela. The Brazil site had 4-11% of TAGB in large woody debris (>7.6 cm), while the Chamela site had ≈ 35% of prefire TAGB in large wood debris. The greater the percentage of wood, especially large wood, resulted in greater CO_2 emissions. The lowest emissions came from pasture or grassland sites that contained much smaller biomass pools and little or no woody debris prior to fire.

Global and Regional Factors

Recent efforts to understand the sources of global greenhouse gases, and possible approaches to alleviate their increase, have led the scientific community to focus research on pools and emissions arising from tropical forests (Fosberg et al. 1993). While tropical moist forests have received considerable attention, the tropical dry forests have been relatively little studied in the area of carbon and nutrient dynamics associated with land use change (Mooney et al. 1995). However, given the magnitude of deforestation rates and the large quantities of carbon and nutrients lost via land conversion focus on this region is warranted. The additional burdens on human health, biodiversity and, site productivity are also important reasons to study land cover change in Mexican tropical dry forests.

The loss of forests in Mexico may also be important for the future economic growth of the Mexican economy (Murphy and Lugo 1995). Based upon Masera's (1997) estimates of deforestation rates, very little of intact TDF will remain in ≈ 100 years. The people of the region depend upon this resource for food, money and, culture. The dominant objective of TDF deforestation in Mexico, similar to Amazonian rain forest, is for cattle pasture. Reforestation efforts are hampered because TDF wood production is only half that of tropical moist forests (Murphy and Lugo 1986) and replanting efforts are expensive in a region that does not have the resources for such an endeavor.

Figure 3.1: Total carbon and nutrient loss (%) after fire in a tropical dry forest over a 3-year period (1993-1995) near Chamela Biological Research Station Jalisco, Mexico. Carbon (C), Nitrogen (N), Sulphur (S), Calcium (Ca), Potassium (K) and, Phosphorus (P) loss measured after fire in 1993 and 1995 plus total loss over 3 years.

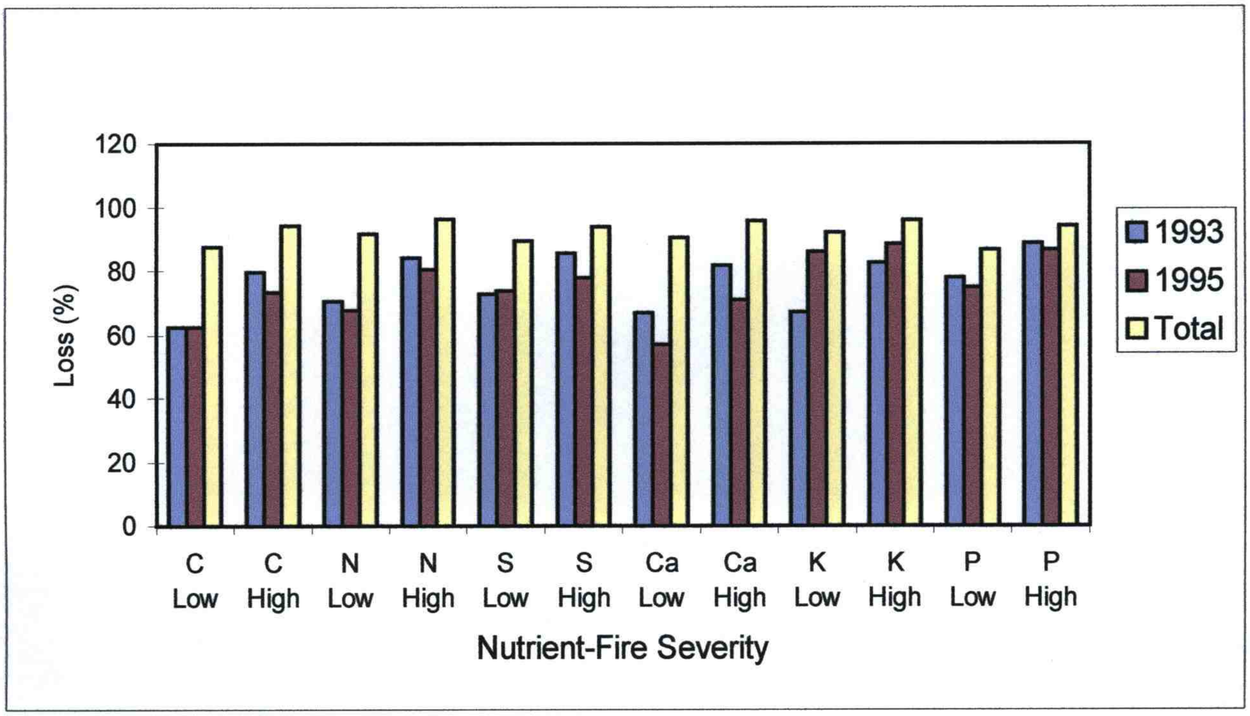

Figure 3.2: Total carbon loss (Tg yr[-1])in all Mexican TDF using estimates (Masera 1997) of total Mexican TDF annual hectare losses and multiplying by our TDF fire data. Baja is low severity and Alta is high severity fire.

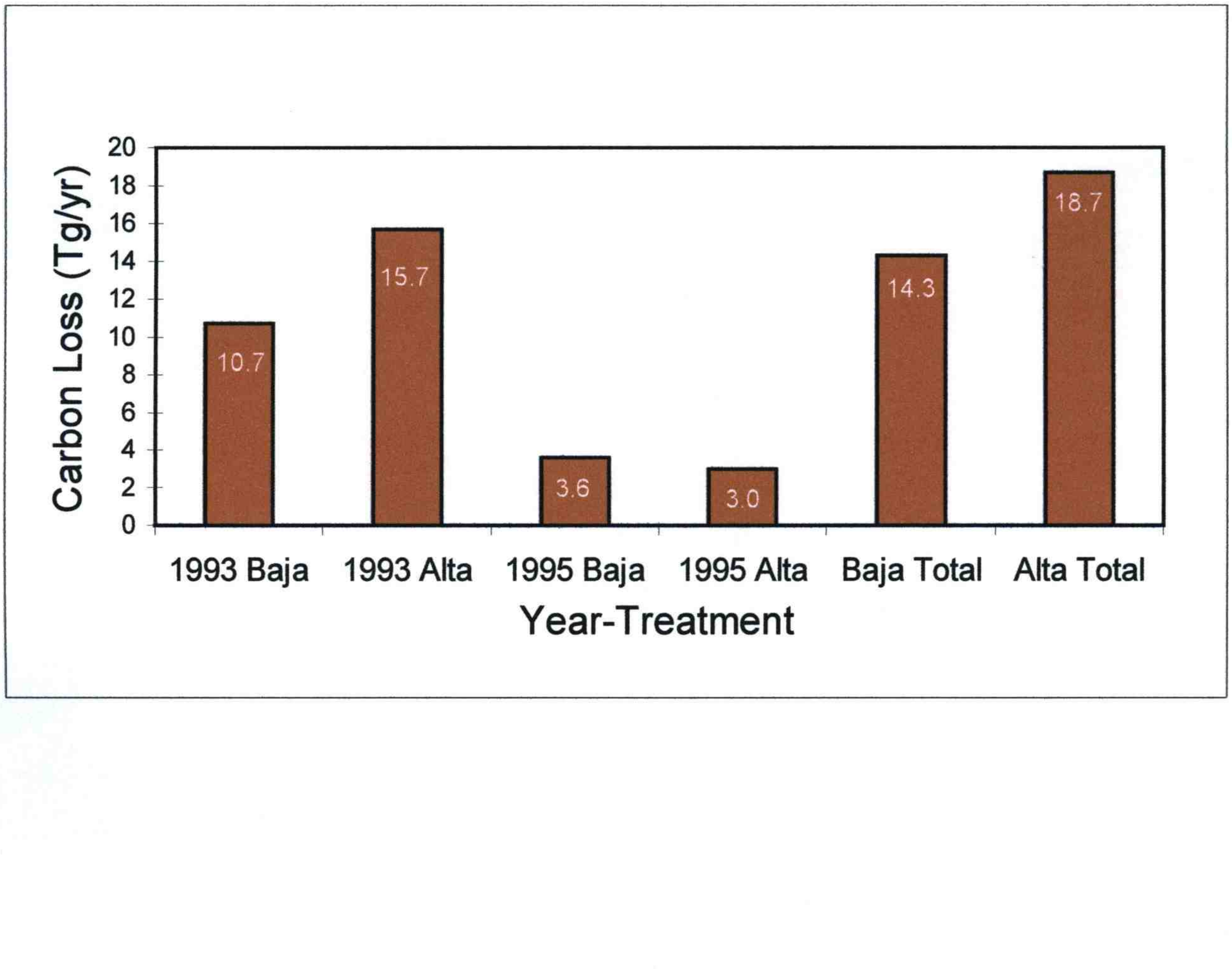

Figure 3.3: Total nutrient loss (Tg yr^{-1}) in all Mexican TDF based upon estimates of (Masera 1997) from total Mexican TDF annual hectare losses and multiplying by our TDF fire data. Baja is low severity and Alta is high severity fire. Calculations for: Nitrogen (N), Calcium (Ca) and, Potassium (K).

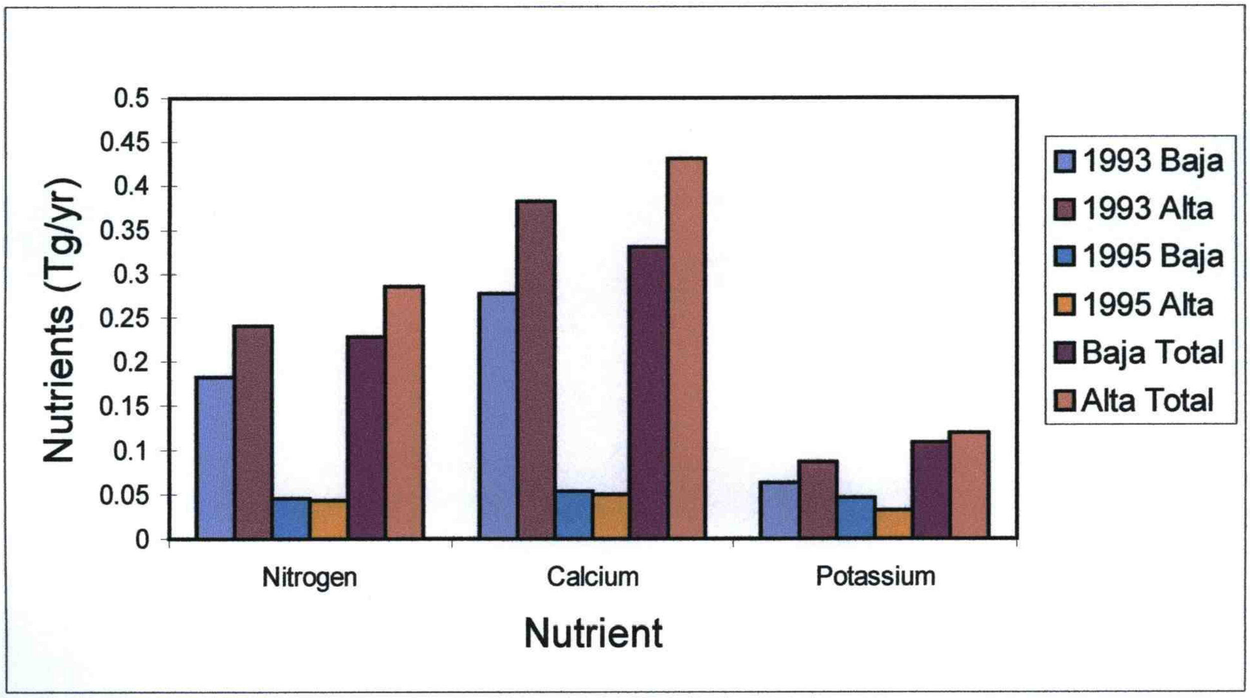

Figure 3.4: Total nutrient loss (Tg yr^{-1}) in all Mexican TDF based upon estimates (Masera 1997) from total Mexican TDF annual hectare losses and multiplying by our TDF fire data. Baja is low severity and Alta is high severity fire. Calculations for: Sulphur (S) and Phosphorus (P).

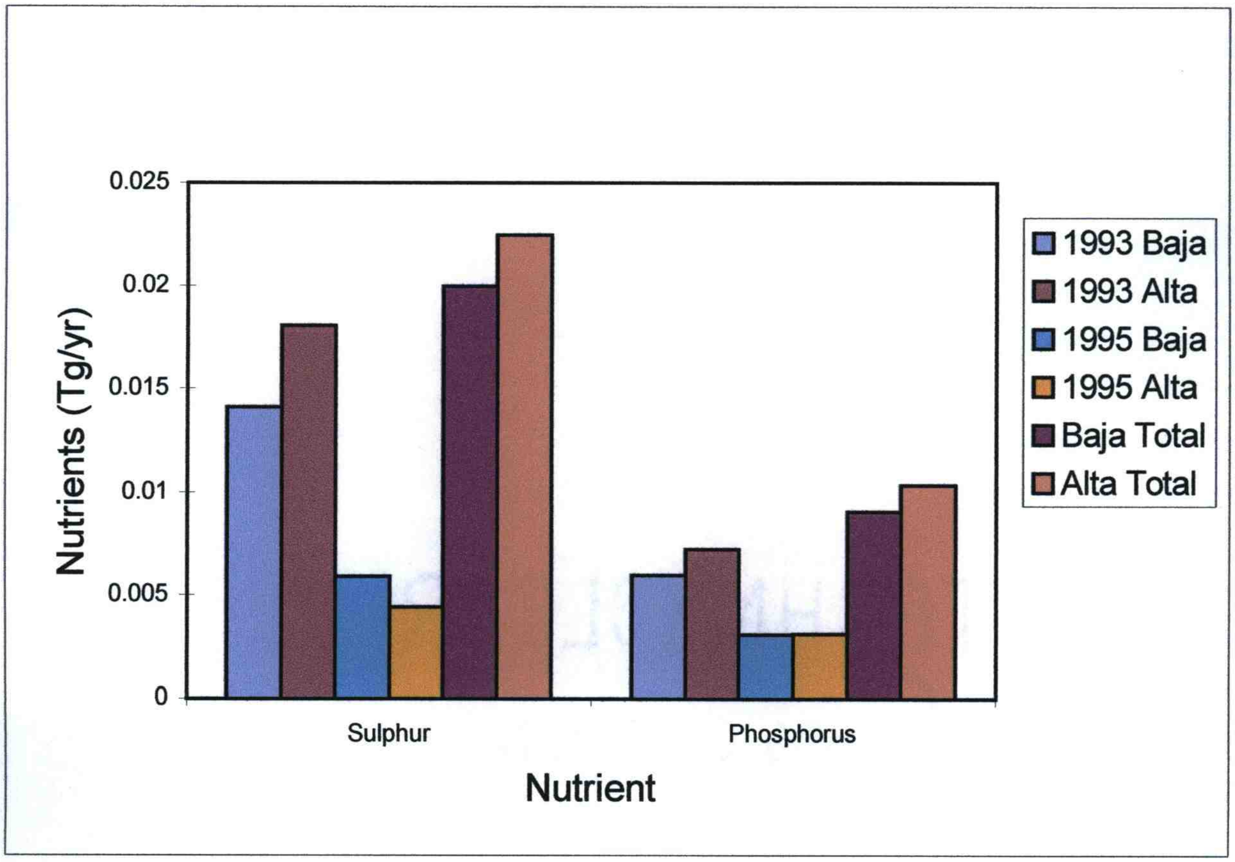

Figure 3.5: Total CO_2 emissions (Mg ha^{-1}) in Chamela TDF (1993-1995) during two fires. Baja is low severity and Alta is high severity fire. Chamela data was multiplied by emission factors (Ward 1991).

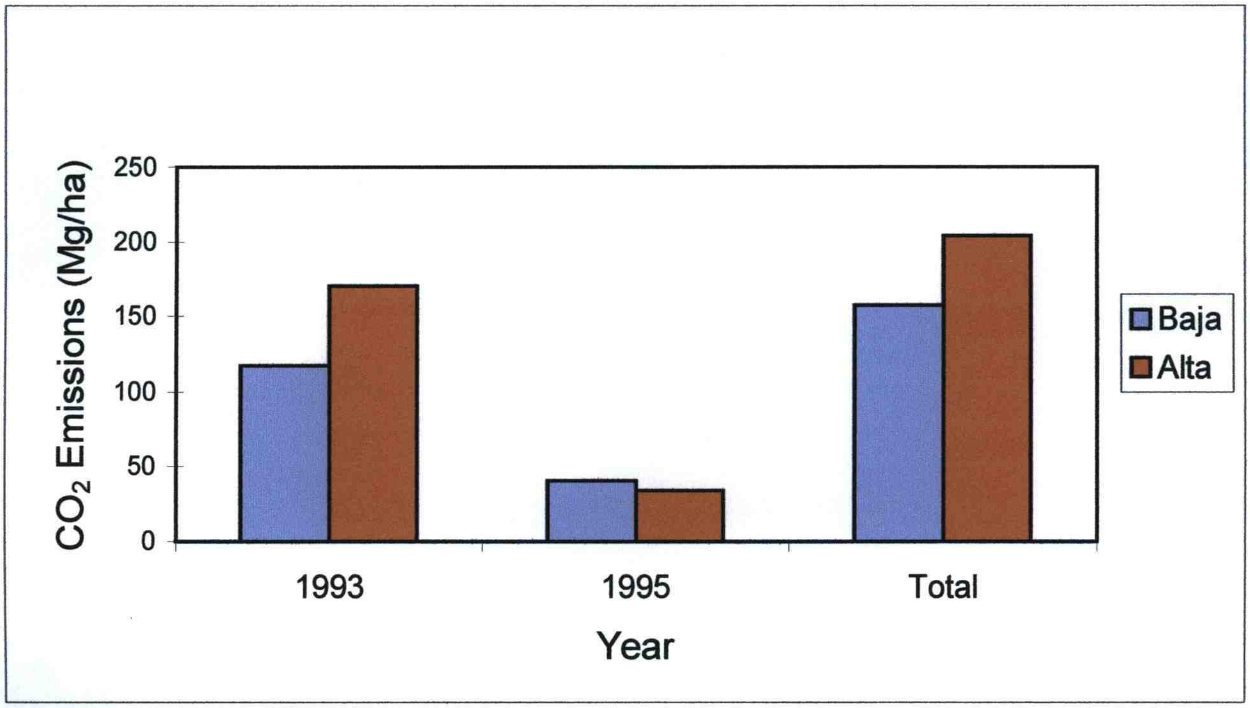

Figure 3.6: Total CO emissions (Mg ha^{-1}) in Chamela TDF (1993-1995) during two fires. Baja is low severity and Alta is high severity fire. Chamela data was multiplied by emission factors (Ward 1991).

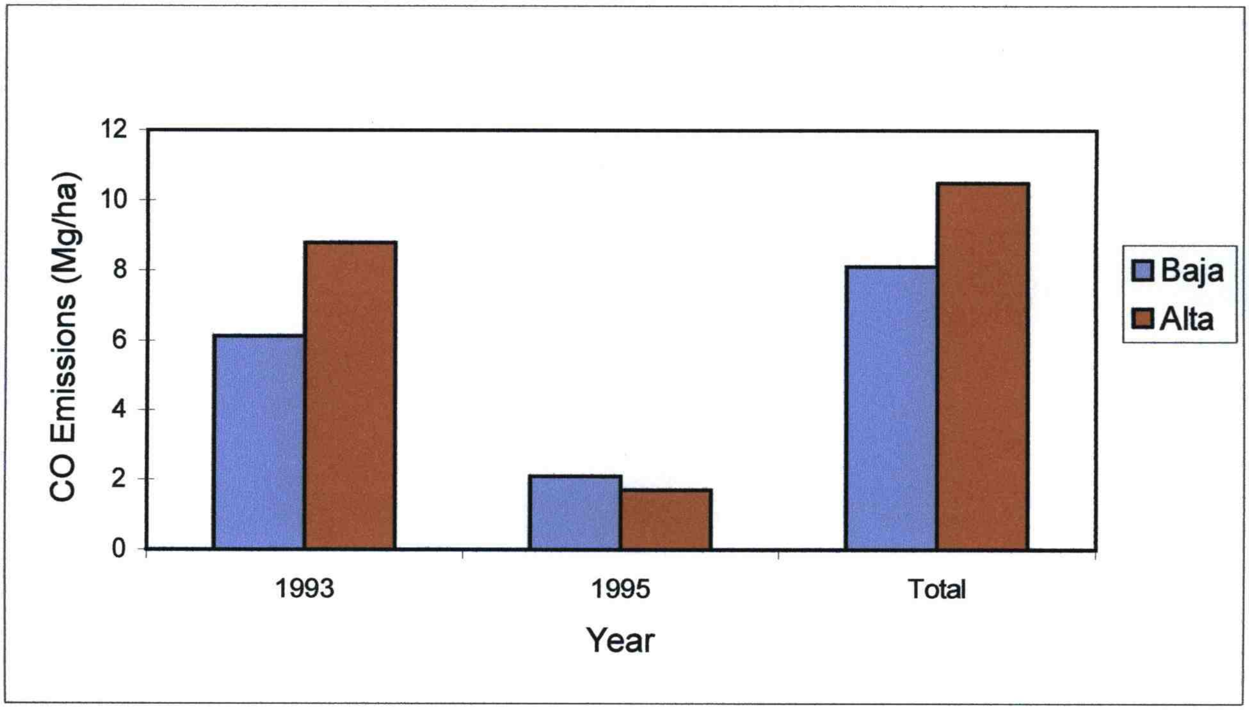

Figure 3.7: Total CH_4, NMHC, $PM_{2.5}$ emissions (Mg ha^{-1}) in Chamela TDF (1993-1995) during two fires. Baja is low severity and Alta is high severity fire. Chamela data was multiplied by emission factors (Ward 1991).

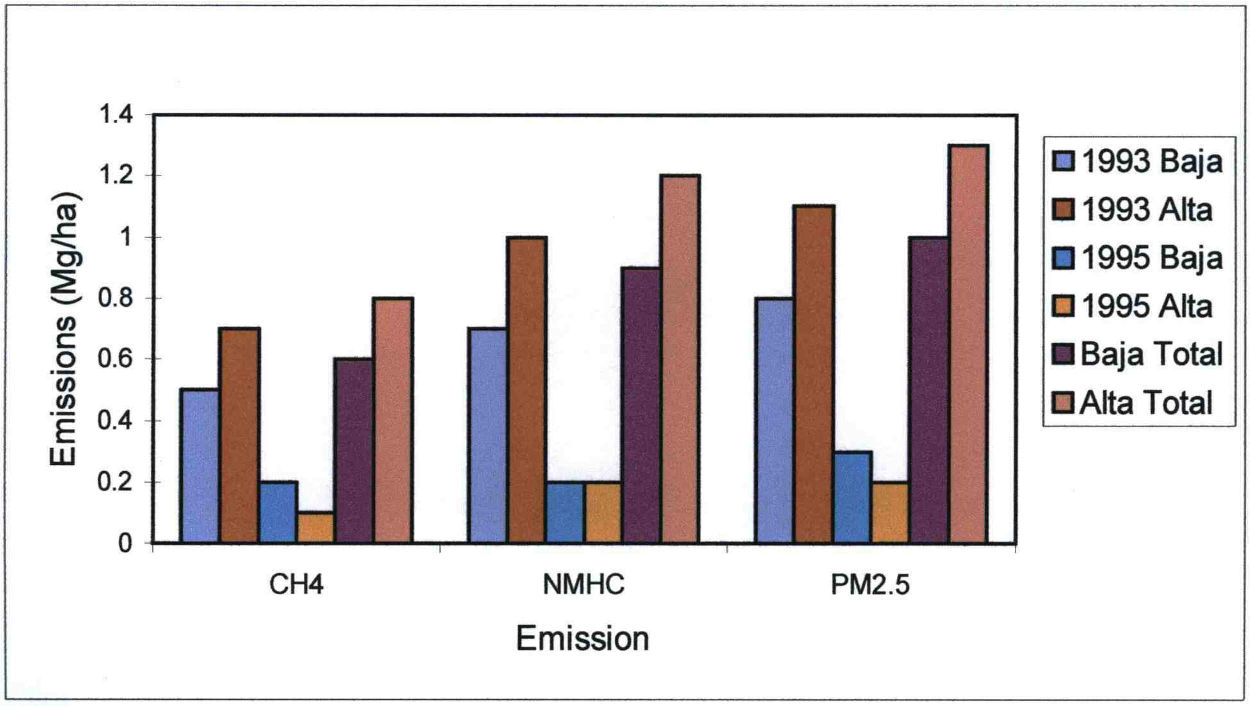

Figure 3.8: Total CO_2 emissions (Tg yr^{-1}) in all Mexican TDF during 1993 and 1995 after two fires. Baja is low severity and Alta is high severity fire conducted near the Chamela Biological Research Station Jalisco, Mexico. Chamela carbon totals were multiplied by total 1993 estimates (Masera 1997) of total Mexican TDF hectare losses and by TDF emission factors (Ward 1991).

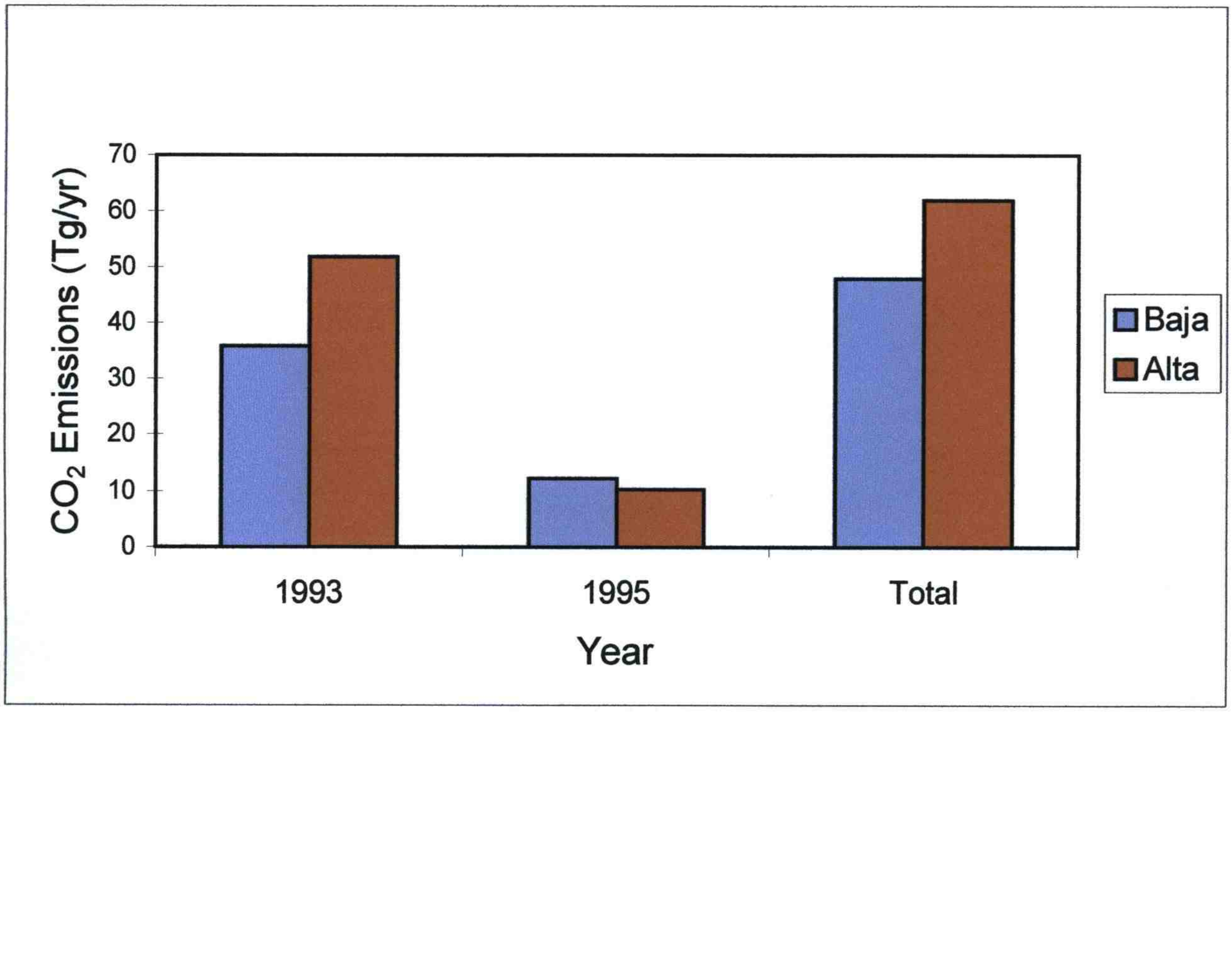

Table 3.1

Concentration Table: Mean nutrient concentrations (%) from 1993 to 1995 at the Ejido San Mateo site near the Chamela Biological Research Station, Jalisco, Mexico. N for each component is in parentheses after component title.

	Carbon (%)	Nitrogen (%)	Sulphur (%)	Calcium (%)	Potassium (%)	Phosphorus (%)
Fine Fuels						
Litter						
1993 (3)	40.8 ± .69	1.9 ± .12	.15 ± .007	2.9 ± .12.	37 ± .04	.08 ± .00
1994 (9)	33.2 ± 1.4	1.2 ± .41	.15 ± .12	1.6 ± .18	.81 ± .09	.09 ± .01
1995 (16)	42.8 ± .26	.94 ± .03	.10 ± .004	.65 ± .06	.78 ± .08	.06 ± .00
Dicot						
1993 (9)	46.0 ± .46	1.4 ± .08	.08 ± .004	1.2 ± .13.	45 ± .02	.09 ± .01
1994 (9)	46.0 ± .46	1.4 ± .08	.08 ± .004	1.2 ± .13	.45 ± .02	.09 ± .01
1995 (9)	46.0 ± .46	1.4 ± .08	.08 ± .004	1.2 ± .13	.45 ± .02	.09 ± .01
Att Fol						
1993 (4)	47.4 ± .25	3.2 ± .12	.33 ± .22	2.0 ± .14	1.7 ± .14.	16 ± .01
Live Grass						
95 (11)	45.2 ± .56	.59 ± .06	.06 ± .005	.18 ± .01	1.3 ± .09	.04 ± .00
Dead Grass						
94 (9)	44.0 ± .04	.41 ± .19	.09 ± .07	.26 ± .01	.91 ± .08	.03 ± .00
95 (14)	44.7 ± .12	.50 ± .02	.09 ± .006	.29 ± .02	1.2 ± .09	.05 ± .00
Manure						
95 (10)	41.5 ± 1.2	1.5 ± .06	.20 ± .02	1.1 ± .04	.39 ± .02	.22 ± .02
Corn						
94 (9)	45.2 ± .18	.68 ± .26	.08 ± .03	.25 ± .18	1.2 ± .93	.05 ± .04

Table 3.1 (continued)

	Carbon (%)	Nitrogen (%)	Sulphur (%)	Calcium (%)	Potassium (%)	Phosphorus (%)
Wood Debris						
1 Hour (0-0.64)						
93 (10)	47.2 ± .09	1.2 ± .22	.11 ± .13	1.5 ± .11.	64 ± .05	.07 ± .00
94 (10)	47.2 ± .09	1.2 ± .22	.11 ± .13	1.5 ± .11	.64 ± .05	.07 ± .00
95 (11)	47.8 ± .17	.76 ± .03	.06 ± .007	1.3 ± .07	.14 ± .00	.03 ± .00
10 Hour (0.65-2.54)						
93 (10)	46.5 ± .21	.84 ± .09	.07 ± .07	1.0 ± .10	.27 ± .03	.03 ± .00
94 (10)	46.5 ± .21	.84 ± .09	.07 ± .07	1.0 ± .10	.27 ± .03	.03 ± .00
95 (11)	47.8 ± .17	.76 ± .03	.06 ± .007	1.3 ± .07	.14 ± .00	.03 ± .00
100 Hour (2.55-7.62)						
93 (11)	48.0 ± .14	.67 ± .09	.05 ± .07	.93 ± .09	.27 ± .03	.02 ± .00
94 (27)	48.4 ± .24	.36 ± .16	.04 ± .08	.87 ± .05	.22 ± .06	.02 ± .00
95 (10)	47.8 ± .36	.51 ± .02	.11 ± .05	.97 ± .11	.18 ± .03	.02 ± .00
≥1000 Hour (7.62-20.5)						
93 (14)	48.9 ± .13	.54 ± .08	.04 ± .09	1.1 ± .11	.22 ± .06	.01 ± .00
94 (35)	48.7 ± .21	.37 ± .17	.03 ± .09.	.85 ± .04	.15 ± .01	.02 ± .00
95 (10)	48.3 ± .26	.42 ± .02	.03 ± .006	.86 ± .09	.14 ± .02	.02 ± .00
Ash						
93 (5)	10.3 ± .79	.59 ± .06	.17 ± .54	14.9 ± 2.2	1.9 ± .28	.24 ± .04
95 (16)	16.2 ± .88	.64 ± .03	.16 ± .01	2.7 ± .32	2.6 ± .14	.24 ± .02

Table 3.2: % Soil carbon and nutrients from 1993-1995 at the Chamela Research Station Jalisco, Mexico. Low describes the low severity fire data and high refers to the high severity fire data. Reference forest measurements taken as a control.

			1993	1994	1995
Carbon					
0-2.5 cm					
	Baja				
		Prefire	4.2 ± 0.5	3.9 ± 0.5	3.3 ± 0.2
		Postfire	4.4 ± 0.4		2.5 ± 0.2
	Alta				
		Prefire	6.0 ± 0.4	2.9 ± 0.3	3.2 ± 0.2
		Postfire	4.0 ± 0.4		2.4 ± 0.2
	Reference Forest		6.0 ± 1.1		5.0 ± 0.4
2.5-10 cm					
	Baja				
		Prefire	3.3 ± 0.4	2.7 ± 0.3	3.0 ± 0.3
		Postfire	2.9 ± 0.2		2.3 ± 0.3
	Alta				
		Prefire	2.7 ± 0.3	2.8 ± 0.4	3.1 ± 0.2
		Postfire	2.9 ± 0.3		2.2 ± 0.2
	Reference Forest		3.3 ± 0.8		2.9 ± 0.2
Nitrogen					
0-2.5 cm					
	Baja				
		Prefire	0.4 ± 0.05	0.4 ± 0.04	0.3 ± 0.02
		Postfire	0.5 ± 0.03		0.3 ± 0.03
	Alta				
		Prefire	0.5 ± 0.04	0.3 ± 0.02	0.3 ± 0.02
		Postfire	0.4 ± 0.04		0.2 ± 0.01
	Reference Forest		0.6 ± 0.1		0.5 ± 0.02
2.5-10 cm					
	Baja				
		Prefire	0.4 ± 0.04	0.3 ± 0.02	0.3 ± 0.03
		Postfire	0.3 ± 0.02		0.2 ± 0.03
	Alta				
		Prefire	0.3 ± 0.03	0.3 ± 0.03	0.3 ± 0.02
		Postfire	0.3 ± 0.03		0.2 ± 0.02
	Reference Forest		0.3 ± 0.1		0.3 ± 0.02

Table 3.2 (continued)

		1993	1994	1995
Sulphur				
0.2-5 cm				
Baja				
	Prefire	0.03 ± 0.00	0.02 ± 0.00	0.02 ± 0.00
	Postfire	0.04 ± 0.00		0.02 ± 0.00
Alta				
	Prefire	0.05 ± 0.00	0.02 ± 0.00	0.02 ± 0.00
	Postfire	0.03 ± 0.00		0.02 ± 0.00
Reference Forest		0.05 ± 0.01		0.05 ± 0.00
2.5-10 cm				
Baja				
	Prefire	0.04 ± 0.01	0.02 ± 0.00	0.02 ± 0.00
	Postfire	0.03 ± 0.00		0.02 ± 0.00
Alta				
	Prefire	0.03 ± 0.00	0.02 ± 0.00	0.02 ± 0.00
	Postfire	0.03 ± 0.00		0.02 ± 0.00
Reference Forest		0.03 ± 0.01		0.03 ± 0.00
Calcium				
0-2.5 cm				
Baja				
	Prefire	0.2 ± 0.03	0.2 ± 0.05	0.3 ± 0.08
	Postfire	0.3 ± 0.02		0.2 ± 0.07
Alta				
	Prefire	0.3 ± 0.04	0.2 ± 0.03	0.2 ± 0.05
	Postfire	0.4 ± 0.02		0.2 ± 0.07
Reference Forest		0.2 ± 0.06		0.4 ± 0.14
2.5-10				
Baja				
	Prefire	0.2 ± 0.02	0.2 ± 0.02	0.2 ± 0.1
	Postfire	0.2 ± 0.02		0.07 ± 0.02
Alta				
	Prefire	0.1 ± 0.02	0.1 ± 0.05	0.06 ± 0.01
	Postfire	0.2 ± 0.03		0.05 ± 0.01
Reference Forest		0.1 ± 0.03		0.1 ± 0.03

Table 3.2 (continued)

	1993	1994	1995
Potassium			
0-2.5			
Baja			
Prefire	0.6 ± 0.06	0.7 ± 0.06	0.5 ± 0.04
Postfire	0.7 ± 0.06		0.5 ± 0.04
Alta			
Prefire	0.6 ± 0.05	0.6 ± 0.02	0.5 ± 0.02
Postfire	0.6 ± 0.03		0.5 ± 0.02
Reference Forest	0.7 ± 0.05		0.6 ± 0.01
2.5-10			
Baja			
Prefire	0.7 ± 0.08	0.7 ± 0.05	0.5 ± 0.05
Postfire	0.6 ± 0.07		0.5 ± 0.04
Alta			
Prefire	0.5 ± 0.04	0.5 ± 0.03	0.5 ± 0.02
Postfire	0.6 ± 0.03		0.5 ± 0.02
Reference Forest	0.8 ± 0.03		0.6 ± 0.01
Phosphorus			
0-2.5 cm			
Baja			
Prefire	0.03 ± 0.00	0.04 ± 0.00	0.04 ± 0.005
Postfire	0.04 ± 0.00		0.04 ± 0.004
Alta			
Prefire	0.04 ± 0.01	0.03 ± 0.00	0.05 ± 0.004
Postfire	0.05 ± 0.01		0.04 ± 0.005
Reference Forest	0.03 ± 0.01		0.04 ± 0.002
2.5-10			
Baja			
Prefire	0.03 ± 0.00	0.03 ± 0.00	0.04 ± 0.005
Postfire	0.03 ± 0.00		0.04 ± 0.005
Alta			
Prefire	0.03 ± 0.01	0.03 ± 0.00	0.03 ± 0.004
Postfire	0.04 ± 0.01		0.03 ± 0.003
Reference Forest	0.03 ± 0.00		0.04 ± 0.003

Table 3.3: Total aboveground carbon (Mg ha^{-1}) and nutrient (kg ha^{-1}) dynamics from 1993-1995 at the Chamela Research Station Jalisco, Mexico. Low describes the low severity fire data and high refers to the high severity fire data.

	Carbon (Mg ha^{-1})	Nitrogen (kg ha^{-1})	Sulphur (kg ha^{-1})
1993 - Low			
Prefire	56.5 ± 1.3	856 ± 32	63.8 ± 2.6
Postfire	21.2 ± 8.0	253 ± 98	17.4 ± 6.8
Loss	35.3	603	46.4
% Loss	62.5	70.4	72.7
1993 - High			
Prefire	64.7 ± 0.6	944 ± 14	69.5 ± 1.1
Postfire	13.1 ± 2.0	150 ± 22	10.1 ± 1.5
Loss	51.6	794	59.4
% Loss	79.8	84.1	85.5
1994 - Low	19.0 ± 5.5	193 ± 54	20.2 ± 5.1
1994 - High	13.6 ± 4.1	145 ± 25	15.1 ± 1.8
1995 - Low			
Prefire	18.9 ± 3.4	220 ± 39	26.2 ± 3.6
Postfire	7.1 ± 1.4	71 ± 18	6.9 ± 1.4
Loss	11.8	149	19.3
% Loss	62.4	67.7	73.7
1995 – High			
Prefire	13.5 ± 1.3	179 ± 17	18.9 ± 2.6
Postfire	3.6 ± 1.4	35 ± 13	4.2 ± 0.1
Loss	9.9	144	14.5
% Loss	73.3	80.4	77.8
Total Fire Loss			
Low	47.1	752	65.7
% Loss	87.4	91.7	89.2
High	61.5	938	73.9
% Loss	94.4	96.3	94.0

Table 3.3 (continued)

	Calcium (kg ha^{-1})	Potassium (kg ha^{-1})	Phosphorus (kg ha^{-1})
1993 - Low			
Prefire	1365 ± 47	310 ± 9.5	25.2 ± 1.4
Postfire	453 ± 171	102 ± 39	5.6 ± 2.2
Loss	912	208	19.6
% Loss	66.8	67.1	77.8
1993 - High			
Prefire	1535 ± 19	346 ± 3.0	26.8 ± 0.5
Postfire	279 ± 62	61 ± 9.0	3.1 ± 0.4
Loss	1256	285	23.7
% Loss	81.8	82.4	88.4
1994 - Low	359 ± 104	115 ± 24.1	11.4 ± 2.8
1994 - High	259 ± 67	92 ± 6.3	8.9 ± 1.2
1995 - Low			
Prefire	311 ± 78	176 ± 15.3	13.5 ± 2.0
Postfire	134 ± 28	25 ± 5.5	3.4 ± 0.9
Loss	177	151	10.1
% Loss	56.9	85.8	74.8
1995 - High			
Prefire	230 ± 21	121 ± 13.5	11.8 ± 2.0
Postfire	67 ± 25	14 ± 5.5	1.6 ± 0.7
Loss	163	107	10.2
% Loss	70.9	88.4	86.4
Total Fire Loss			
Low	1089	359	29.7
% Loss	90.2	91.9	86.5
High	1419	392	33.9
% Loss	95.6	96.0	94.0

Table 3.4: TDF nutrient losses using Masera et al. (1997) data on total TDF biomass consumed in Mexico and our data on biomass loss and nutrient concentrations. Nutrient losses (Mg ha^{-1}) are based on 1993 Chamela TDF fire and 1995 Chamela pasture fire. Biomass consumed is Masera's total ha yr^{-1} loss estimates. Nutrient losses (Tg yr^{-1}) are the Chamela results multiplied by total Mexican TDF ha yr^{-1} losses. Baja are low severity fire losses and Alta are high severity losses.

Mexican TDF Baja Nutrient Consumption

	1993 Nutrient Loss (Mg ha^{-1})	1995 Nutrient Loss (Mg ha^{-1})	Biomass Consumed (ha yr^{-1})	1993 Nutrient Losses (Tg yr^{-1})	1995 Nutrient Losses (Tg yr^{-1})	Total Nutrient Losses (Tg yr^{-1})
Carbon	35.3	11.8	3.0×10^5	10.7	3.6	14.3
Nitrogen	0.6	0.1	3.0×10^5	0.2	0.04	0.2
Sulphur	0.04	0.02	3.0×10^5	0.01	0.006	0.02
Calcium	0.9	0.2	3.0×10^5	0.3	0.05	0.3
Potassium	0.2	0.2	3.0×10^5	0.06	0.05	0.1
Phosphorus	0.02	0.01	3.0×10^5	0.006	0.003	0.009

Mexican TDF Alta Nutrient Consumption

	1993 Nutrient Loss (Mg ha^{-1})	1995 Nutrient Loss (Mg ha^{-1})	Biomass Consumed (ha yr^{-1})	1993 Nutrient Losses (Tg yr^{-1})	1995 Nutrient Losses (Tg yr^{-1})	Total Nutrient Losses (Tg yr^{-1})
Carbon	51.6	9.9	3.0×10^5	15.7	3.0	18.7
Nitrogen	0.8	0.1	3.0×10^5	0.2	0.04	0.3
Sulphur	0.06	0.01	3.0×10^5	0.01	0.004	0.02
Calcium	1.3	0.2	3.0×10^5	0.4	0.05	0.4
Potassium	0.3	0.1	3.0×10^5	0.09	0.03	0.1
Phosphorus	0.02	0.01	3.0×10^5	0.007	0.003	0.01

Table 3.5: Emissions for Chamela using emission factors given by Ward et al. (1991) and Chamela biomass and nutrient data. 1993 data is Chamela TDF fire and 1995 data is Chamela pasture fire. Baja are low severity fire losses and Alta are high severity losses. Baja sites lost 74.6 Mg ha^{-1} in 1993 and 25.5 Mg ha^{-1} in 1995. Alta plots lost 108.1 Mg ha^{-1} in 1993 and 21.4 Mg ha^{-1} in 1995. These losses were each multiplied by the emission factor for tropical forests to get total emissions for each year in each treatment. Total emission loss is the addition of 1993 and 1995 emissions for each treatment.

Baja Emissions

	Emission Factor (g kg^{-1} fuel)	1993 Emission Loss (Mg ha^{-1})	1995 Emission Loss (Mg ha^{-1})	Total Emission Loss (Mg ha^{-1})
CO_2	1577	117.6	40.2	157.9
CO	81.4	6.1	2.1	8.1
CH_4	9.4	0.5	0.2	0.6
NMHC	6.4	0.7	0.2	0.9
$PM_{2.5}$	10.1	0.8	0.3	1.0

Alta Emissions

	Emission Factor (g kg^{-1} fuel)	1993 Emission Loss (Mg ha^{-1})	1995 Emission Loss (Mg ha^{-1})	Total Emission Loss (Mg ha^{-1})
CO_2	1577	170.5	33.7	204.2
CO	81.4	8.8	1.7	10.5
CH_4	9.4	0.7	0.1	0.8
NMHC	6.4	1.0	0.2	1.2
$PM_{2.5}$	10.1	1.1	0.2	1.3

Table 3.6: Emissions for Mexican 1993 TDF, 1995 pasture and total site loss (1993-1995) estimates using Masera's (1997) total TDF loss, Ward's (1991) emission factors and Chamela biomass and nutrient data Baja are low severity fire losses and Alta are high severity losses. Emissions are calculated by multiplying each fire severity losses by an emission factor and by total ha yr^{-1} losses.

1993	Baja Loss	Alta Loss	Emission Factor	Biomass Consumed	Total Baja Emissions	Total Alta Emissions
	(Mg ha^{-1})			(ha yr^{-1})	(Tg yr^{-1})	(Tg yr^{-1})
CO_2	74.6	108.1	1.577	3.0×10^5	35.8	51.8
CO	74.6	108.1	0.814	3.0×10^5	1.8	2.7
CH_4	74.6	108.1	0.094	3.0×10^5	0.22	0.31
NHMC	74.6	108.1	0.064	3.0×10^5	0.14	0.22
$PM_{2.5}$	74.6	108.1	0.101	3.0×10^5	0.23	0.33

1995	Baja Loss	Alta Loss	Emission Factor	Biomass Consumed	Total Baja Emissions	Total Alta Emissions
	(Mg ha^{-1})			(ha yr^{-1})	(Tg yr^{-1})	(Tg yr^{-1})
CO_2	25.5	21.4	1.577	3.0×10^5	12.2	10.3
CO	25.5	21.4	0.814	3.0×10^5	0.6	0.5
CH_4	25.5	21.4	0.094	3.0×10^5	0.07	0.06
NHMC	25.5	21.4	0.064	3.0×10^5	0.05	0.04
$PM_{2.5}$	25.5	21.4	0.101	3.0×10^5	0.08	0.07

Total	Baja Loss	Alta Loss	Emission Factor	Biomass Consumed	Total Baja Emissions	Total Alta Emissions
	(Mg ha^{-1})			(ha yr^{-1})	(Tg yr^{-1})	(Tg yr^{-1})
CO_2	103.4	127.3	1.577	3.0×10^5	48.0	62.1
CO	103.4	127.3	0.814	3.0×10^5	2.5	3.2
CH_4	103.4	127.3	0.094	3.0×10^5	0.3	0.4
NHMC	103.4	127.3	0.064	3.0×10^5	0.2	0.3
$PM_{2.5}$	103.4	127.3	0.101	3.0×10^5	0.3	0.4

Table 3.7. CO_2 emissions calculated for selected tropical forest ecosystems. Emission calculated by multiplying biomass loss (prefire minus postfire; Mg ha^{-1}) times emission factor for CO_2 in each forest ecosystem given by Ward et al. (1991). Prefire biomass, postfire biomass and CO_2 emissions are given as Mg ha^{-1}.

Forest Type / Site Year	Prefire	Postfire	CO_2 Emission	Study
Tropical Dry Forest / Mexico / El Cielo / Slash Fire				Steele, 1998
Low Severity 1993	118.2 ± 2.8	43.6 ± 16.4	117.6	
High Severity 1993	134.9 ± 1.4	26.8 ± 4.1	170.5	
Tropical Dry Forest / Brazil / Slash Fire				Kauffman et al.
Serra Talhada – 1990				1993
Low	73.8 ± 2.7	16.4 ± 3.0	90.5	
Medium	74.0 ± 5.0	8.3 ± 2.8	103.6	
High	73.7 ± 1.9	4.0 ± 1.1	110.0	
Tropical Woodland (Cerrado) / Brazil / Natural fuels				Kauffman
Campo cerrado - 1990	8.6 ± .75	2.2 ± .60	10.1	1994
Cerrado sensu stricto -1990	10.0 ± .47	1.6 ± .52	13.2	
Cerrado aberto - 1993	24.8 ± 2.5	11.4 ± 1.2	21.1	1998
Cerrado denso - 1993	24.9 ± 2.9	17.0 ± 2.6	12.5	
Tropical Evergreen / Brazil / Slash Fire				Kauffman 1995
Jacunda - 1992	292.4 ± 35.8	139.9 ± 24.3	240.5	
Maraba - 1992	434.6 ± 72.2	207.1 ± 53.7	358.8	
Santa Barbara - 1992	290.2 ± 20.4	165.1 ± 19.2	197.3	
Jamari - 1992	361.2 ± 36.8	155.4 ± 24.1	324.5	
Tropical Cattle Pasture / Mexico / El Cielo / from TDF				Steele, 1998
Low Severity 1995	40.3 ± 6.9	14.8 ± 2.9	18.7	
High Severity 1995	29.0 ± 2.8	7.6 ± 3.0	11.9	
Tropical Cattle Pastures / Brazil / from Tropical evergreen forest				Kauffman 1995
Francisco - 1991	53.3 ± 4.8	8.8 ± 2.0	73.5	
Durval - 1991	119.2 ± 35.0	94.7 ± 35.2	40.4	
Joao - 1991	72.7 ± 13.1	38.2 ± 9.0	57.0	
Tropical Grassland / Brazil				Kauffman et al.
Campo limpo - 1990	7.1 ± .55	.002 ± 0.0	11.7	1994
Campo limpo - 1993	5.5 ± 0.3	0.4 ± 0.2	8.4	1998
Tropical Savanna / Brazil / Natural fuels				Kauffman
Campo sujo - 1990	7.3 ± .51	.237 ± .05	12.2	1994
Campo sujo - 1993	9.3 ± 0.8	1.4 ± 0.1	13.6	1998

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Chapter 4: Conclusion

During the initial 1993 slash fire, there was a 75 Mg ha^{-1} (62%) decline in the total aboveground biomass (TAGB) in the Baja plots and 108 Mg ha^{-1} (80%) decline in Alta TAGB. Decomposition between fires resulted in a 13 Mg h ha^{-1} decline in Baja and 3 Mg ha^{-1} in Alta plots. The 1995 pasture fire reduce TAGB by 26 Mg ha^{-1} (63%) in Baja sites and 21 Mg ha^{-1} in the Alta plots. For the three-year study, Baja site TAGB declined 103 Mg ha^{-1} (87%) and 127 Mg ha^{-1} (94%). Since there was little ash retention on-site, we calculated all the TAGB losses on actual biomass measurements without ash. The only significant difference ($p<.1$) between treatments occurred in the large woody debris (>7.6 cm diam).

The two fires resulted in a 49 Mg ha^{-1} (87%) decline in Carbon in the Baja sites and a 61 Mg ha^{-1} (94%) decline in the Alta plots. We estimated that, at this rate of loss, total annual Carbon loss in Mexican TDF would range from 11 to 16 Tg yr^{-1}.

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Figure 1. Total Aboveground Biomass (Mg ha^{-1}) chart of biomass loss through time (1993-1995). Stump, tree, total wood and fine fuel proportion of TAGB and losses through time at the El Cielo study site Jalisco, Mexico. Pre is prefire data and post is postfire data. L is low severity fire result and H is high fire severity result. Vertical lines are SE bars for TAGB.

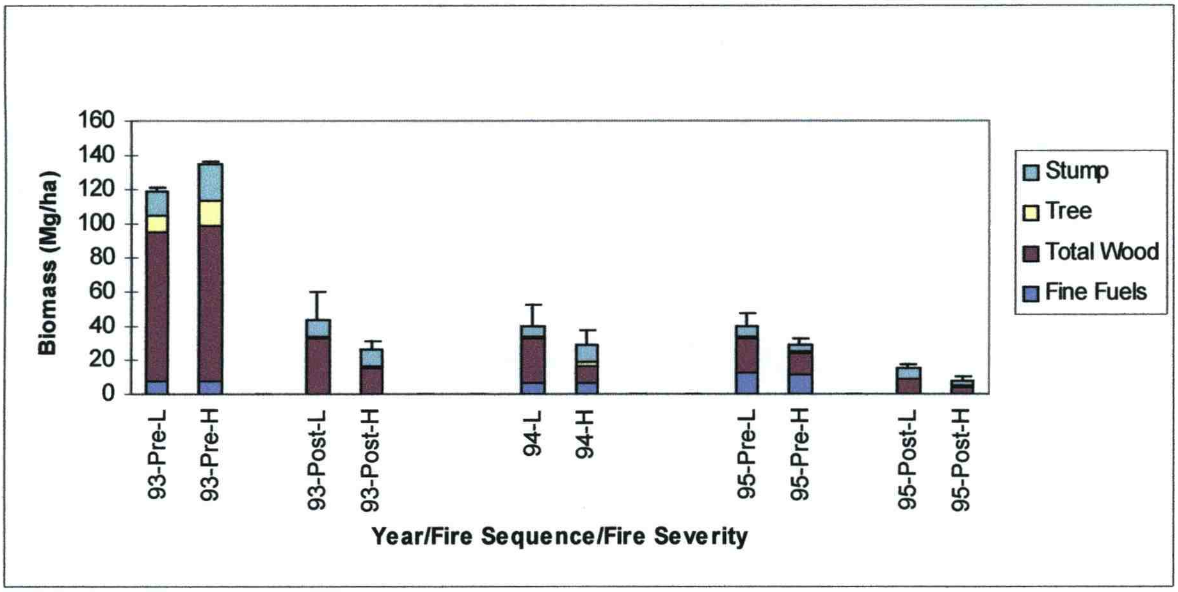


Figure 2. Total Aboveground Wood Biomass (Mg ha^{-1}) chart of loss through time (1993-1995) in 5 wood debris timelag classes at the El Cielo study site Jalisco, Mexico. Pre is prefire data and post is postfire data. L is low severity fire result and H is high fire severity result. Vertical lines are SE bars for TAGB.

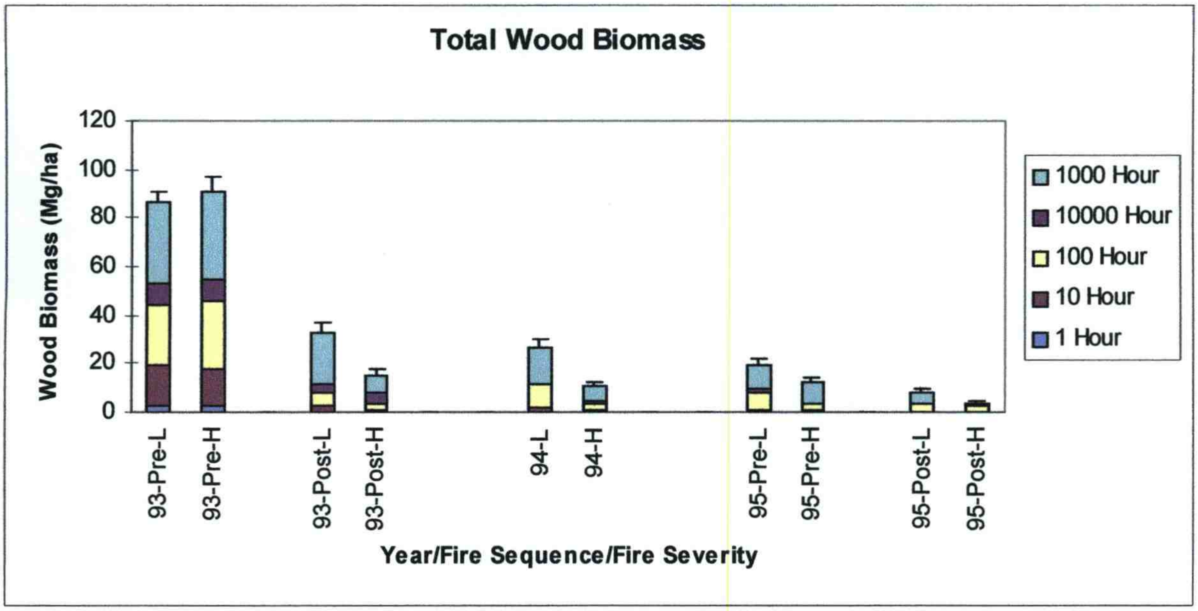


Figure 3. Total Aboveground Fine Fuel Biomass (Mg ha^{-1}) chart of loss through time (1993-1995) in 7 fine fuel components (litter, manure live grass, dead grass, corn, dicots and, attached foliage) at the El Cielo study site Jalisco, Mexico. Pre is prefire data and post is postfire data. L is low severity fire result and H is high fire severity result. Vertical lines are SE bars for TAGB.

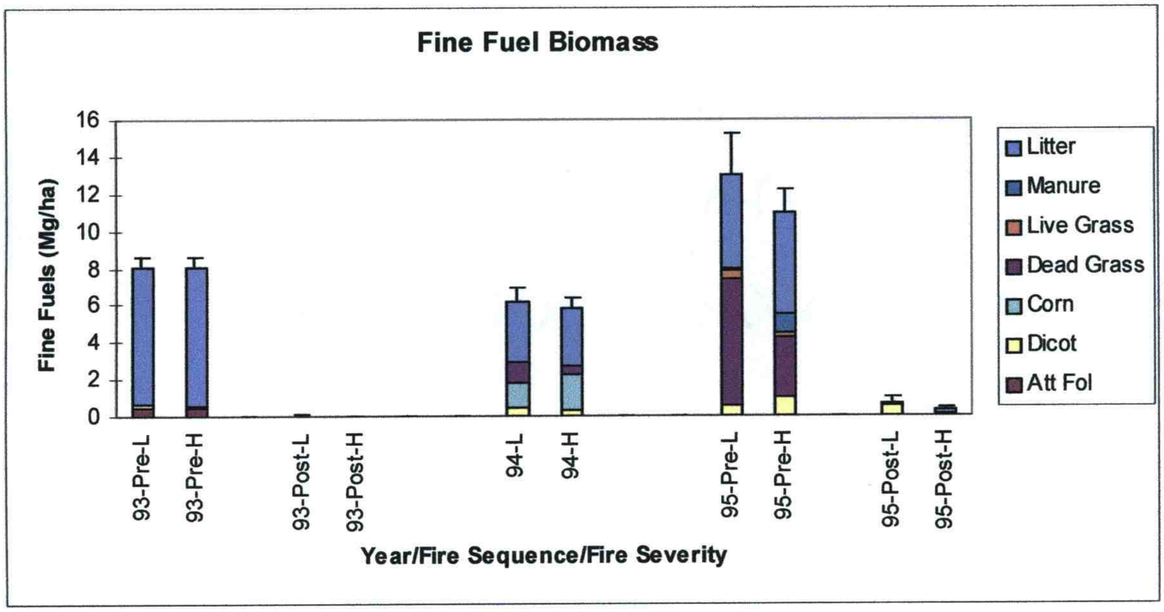


Figure 4. Total Aboveground Biomass (Mg ha^{-1}) chart of biomass loss through time (1993-1995). TAGB, total wood and fine fuel losses through time at the El Cielo study site Jalisco, Mexico. Pre is prefire data and post is postfire data. Low is low severity fire result and High is high fire severity result. Vertical lines are SE bars for TAGB.

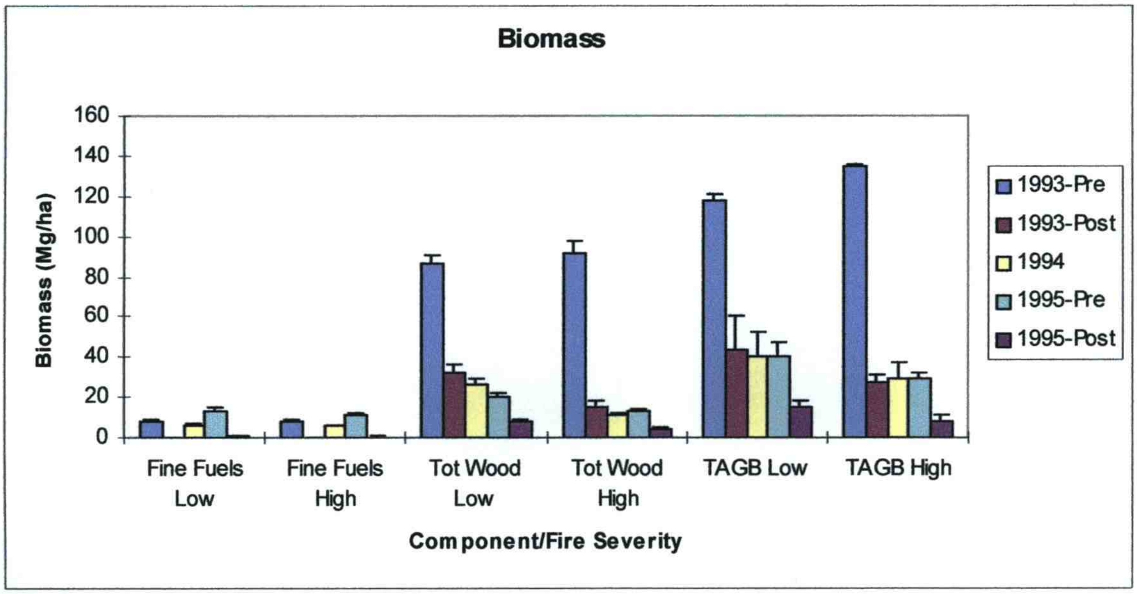


Figure 5. Total Aboveground Biomass (Mg ha^{-1}) chart of biomass loss through time (1993-1995). TAGB, tree and stump losses through time at the El Cielo study site Jalisco, Mexico. Pre is prefire data and post is postfire data. Low is low severity fire result and High is high fire severity result. Vertical lines are SE bars for TAGB.

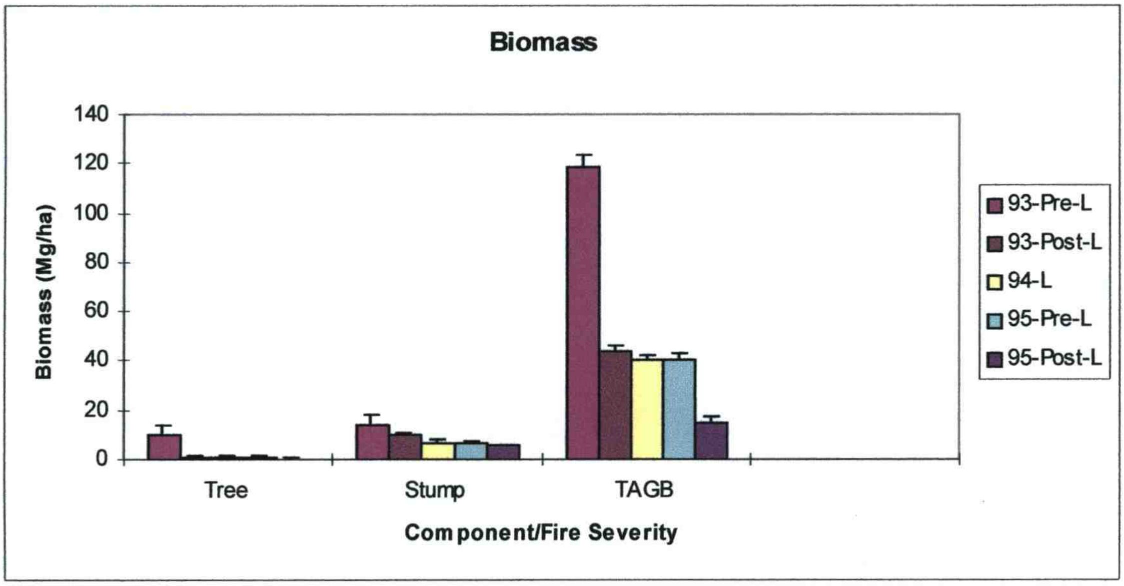


Figure 6. Total Aboveground Carbon (Mg ha^{-1}) chart of carbon losses through time (1993-1995) El Cielo study site Jalisco, Mexico. Pre is prefire data and post is postfire data. Low is low severity fire result and High is high fire severity result. Vertical lines are SE bars for TAGC.

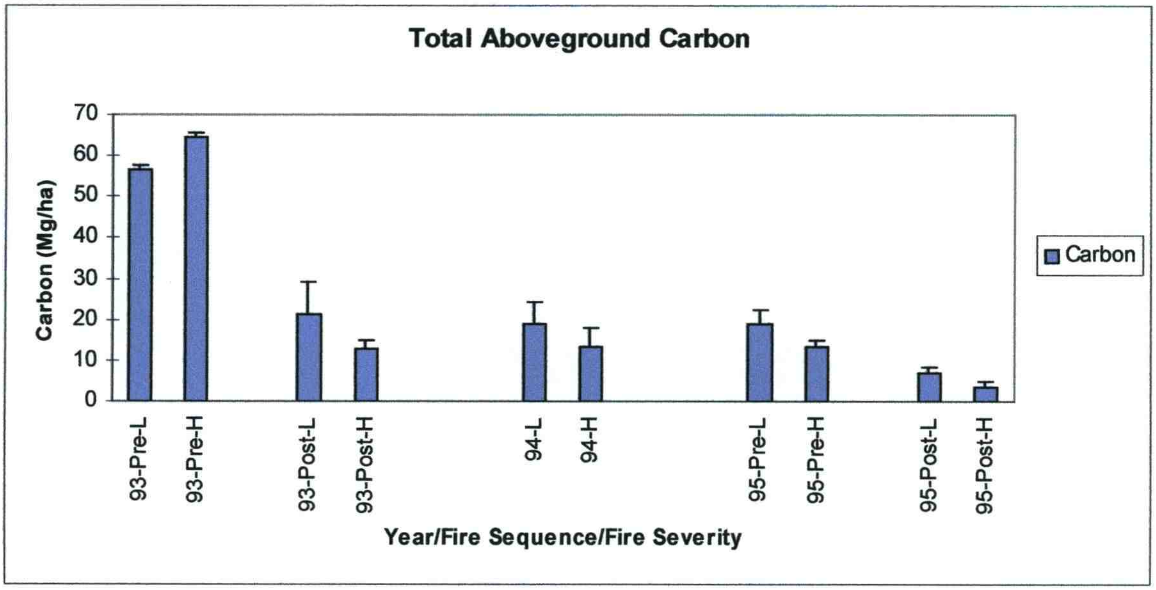


Figure 7. Total Aboveground Nutrients (kg ha^{-1}) chart of nutrient (Nitrogen (N), Sulphur (S), Calcium (Ca), Potassium (K) and, Phosphorus (P) losses through time (1993-1995) El Cielo study site Jalisco, Mexico. Pre is prefire data and post is postfire data. Low is low severity fire result and High is high fire severity result. Vertical lines are SE bars for TAGN.

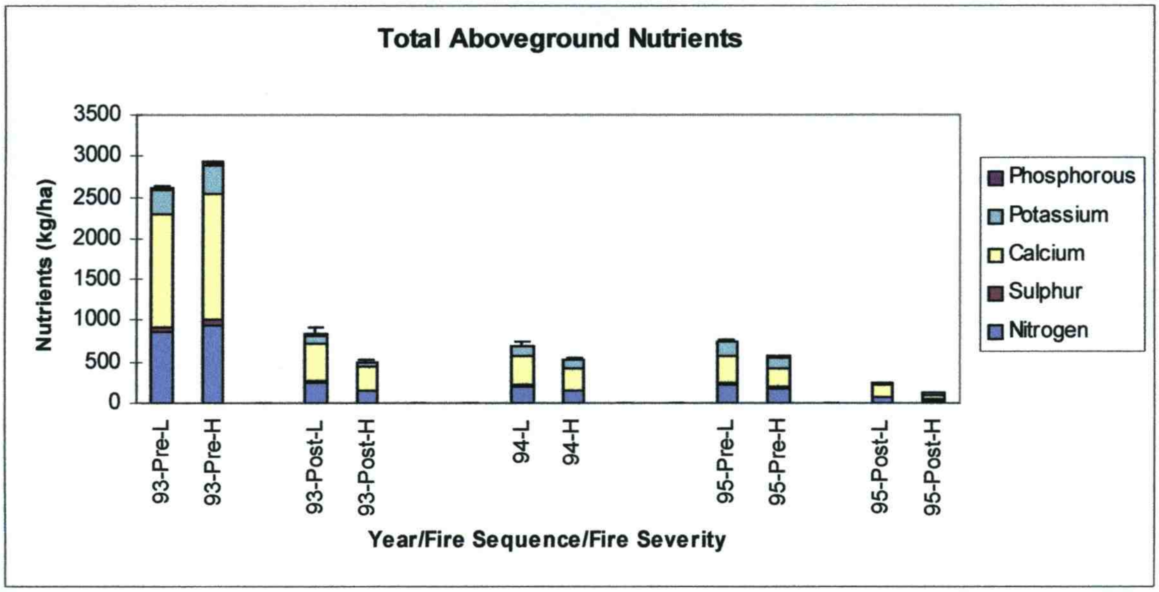


Figure 8. Total Aboveground Nitrogen (kg ha^{-1}) chart of nitrogen losses through time (1993-1995) El Cielo study site Jalisco, Mexico. Pre is prefire data and post is postfire data. Low is low severity fire result and High is high fire severity result. Vertical lines are SE bars for TAGN.

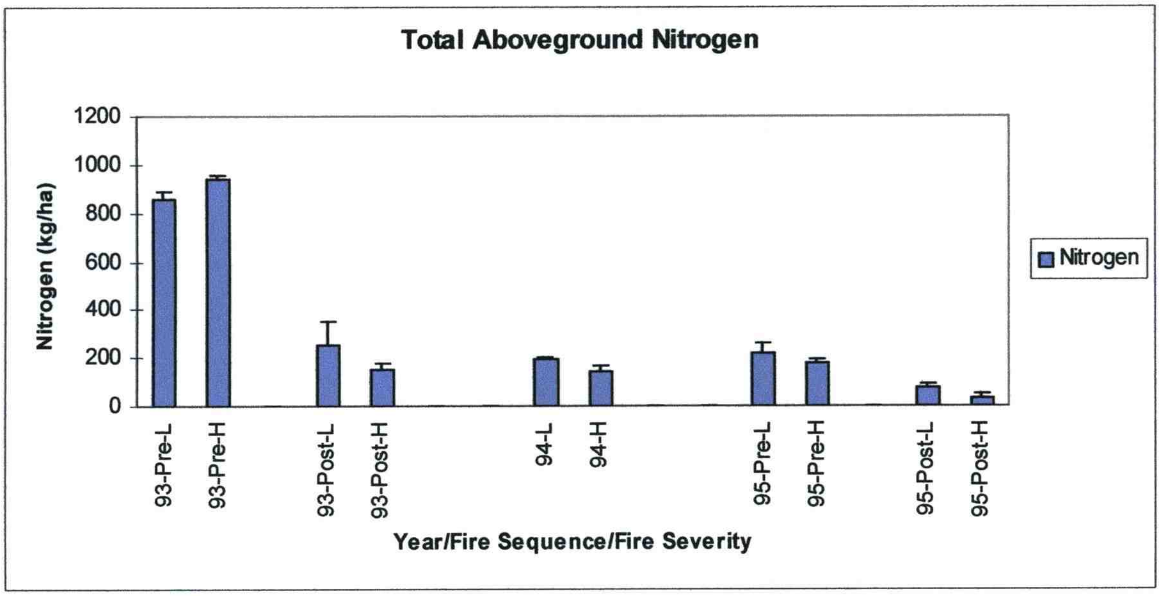


Figure 9. Total Aboveground Sulphur (kg ha^{-1}) chart of sulphur losses through time (1993-1995) El Cielo study site Jalisco, Mexico. Pre is prefire data and post is postfire data. Low is low severity fire result and High is high fire severity result. Vertical lines are SE bars for TAGS.

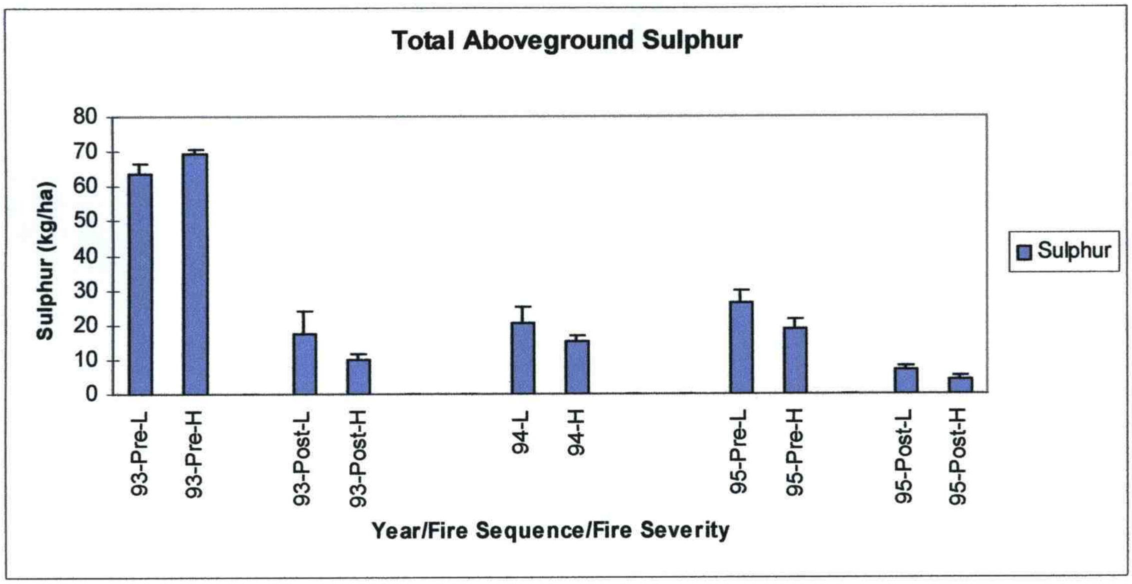


Figure 10. Total Aboveground Calcium (kg ha^{-1}) chart of calcium losses through time (1993-1995) El Cielo study site Jalisco, Mexico. Pre is prefire data and post is postfire data. Low is low severity fire result and High is high fire severity result. Vertical lines are SE bars for TAGCa.

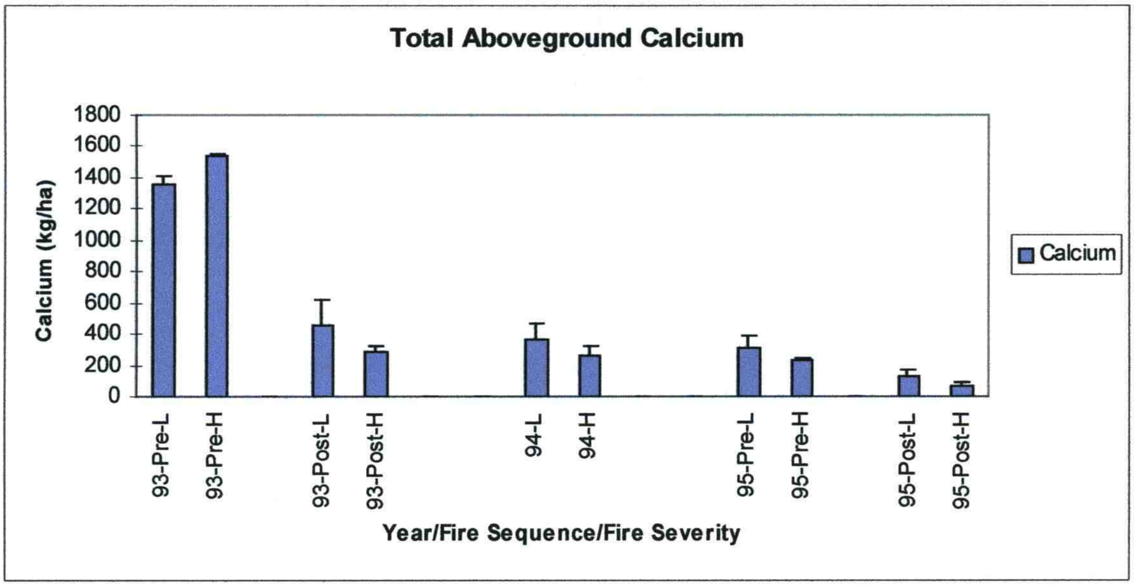


Figure 11. Total Aboveground Potassium (kg ha^{-1}) chart of potassium losses through time (1993-1995) El Cielo study site Jalisco, Mexico. Pre is prefire data and post is postfire data. Low is low severity fire result and High is high fire severity result. Vertical lines are SE bars for TAGK.

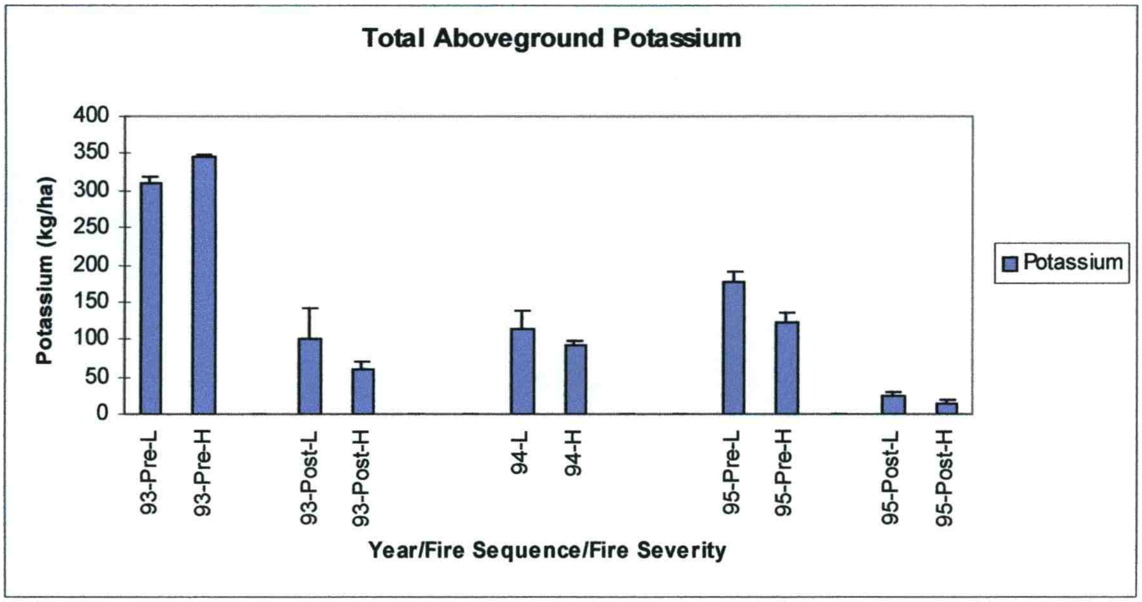


Figure 12. Total Aboveground Phosphorus (kg ha^{-1}) chart of phosphorus losses through time (1993-1995) El Cielo study site Jalisco, Mexico. Pre is prefire data and post is postfire data. Low is low severity fire result and High is high fire severity result. Vertical lines are SE bars for TAGP.

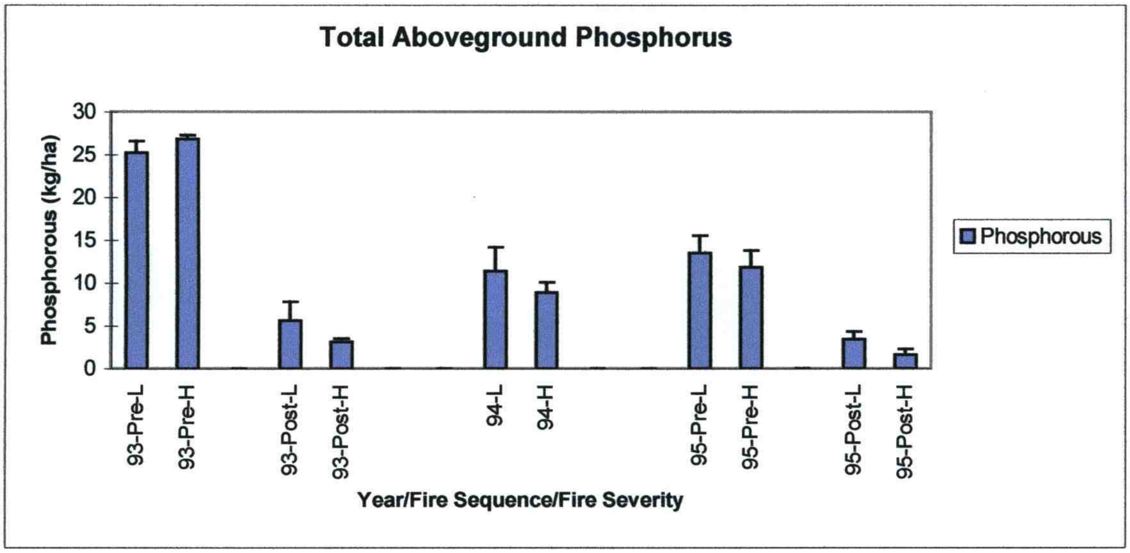


Figure 13: Total CO emissions (Tg yr^{-1}) in all Mexican TDF during 1993 and 1995 after two fires. Baja is low severity and Alta is high severity fire conducted near the Chamela Biological Research Station Jalisco, Mexico. Chamela carbon totals were multiplied by total 1993 estimates (Masera 1997) of total Mexican TDF hectare losses and by TDF emission factors (Ward 1993).

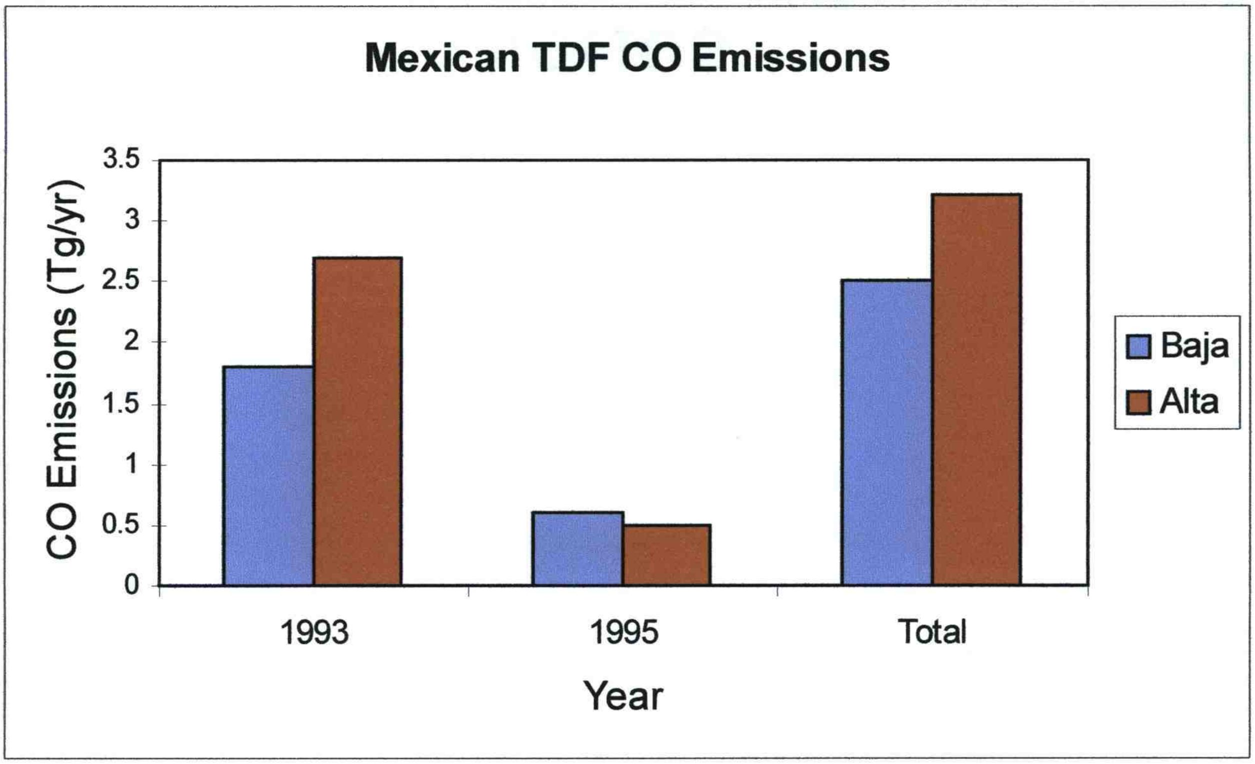


Figure 14: Total CH_4, NMHC, $PM_{2.5}$ emissions (Tg yr^{-1}) in all Mexican TDF during 1993 and 1995 after two fires. Baja is low severity and Alta is high severity fire conducted near the Chamela Biological Research Station Jalisco, Mexico. Chamela carbon totals were multiplied by total 1993 estimates (Masera 1997) of total Mexican TDF hectare losses and by TDF emission factors (Ward 1993).

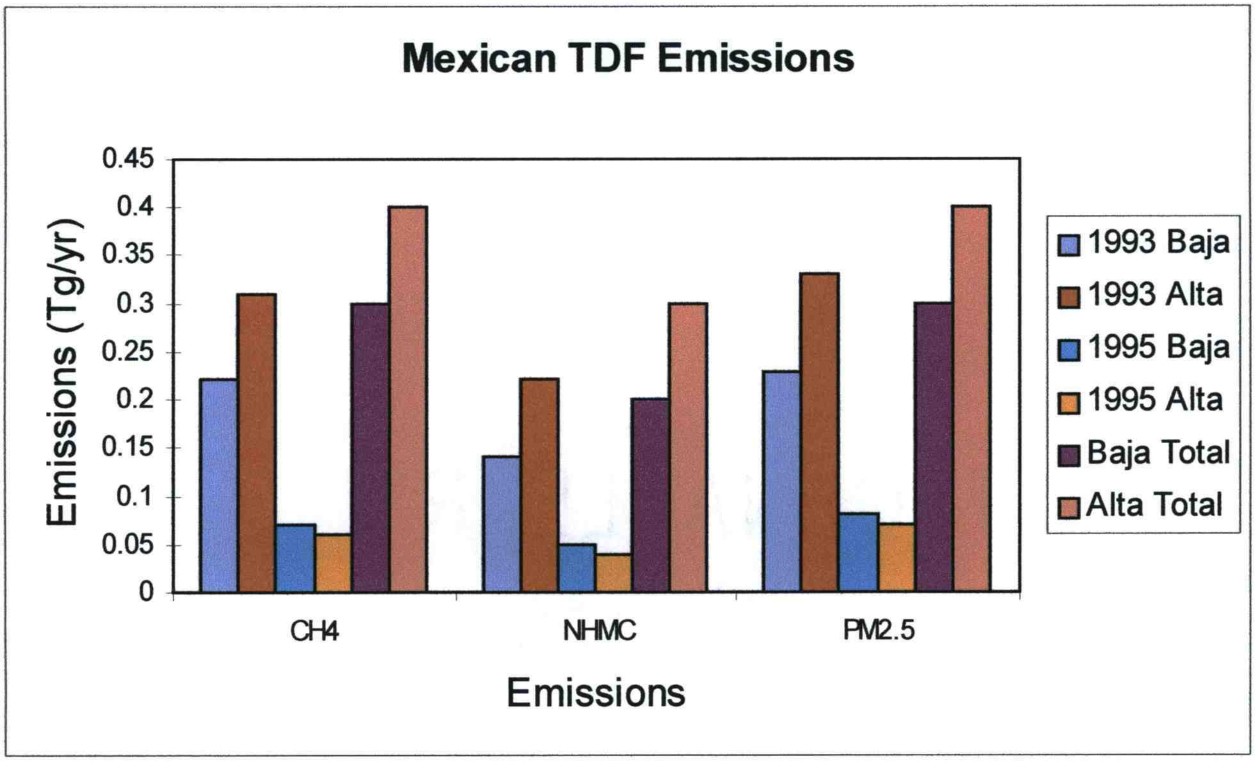


Figure 15: Estimate of total CH_4 emissions (Tg yr^{-1}) in all Mexican TDF during 1993 and 1995 after two fires. Baja is low severity and Alta is high severity fire conducted near the Chamela Biological Research Station Jalisco, Mexico. Chamela carbon totals were multiplied by total 1993 estimates (Masera 1997) of total Mexican TDF hectare losses and by TDF emission factors (Ward 1991).

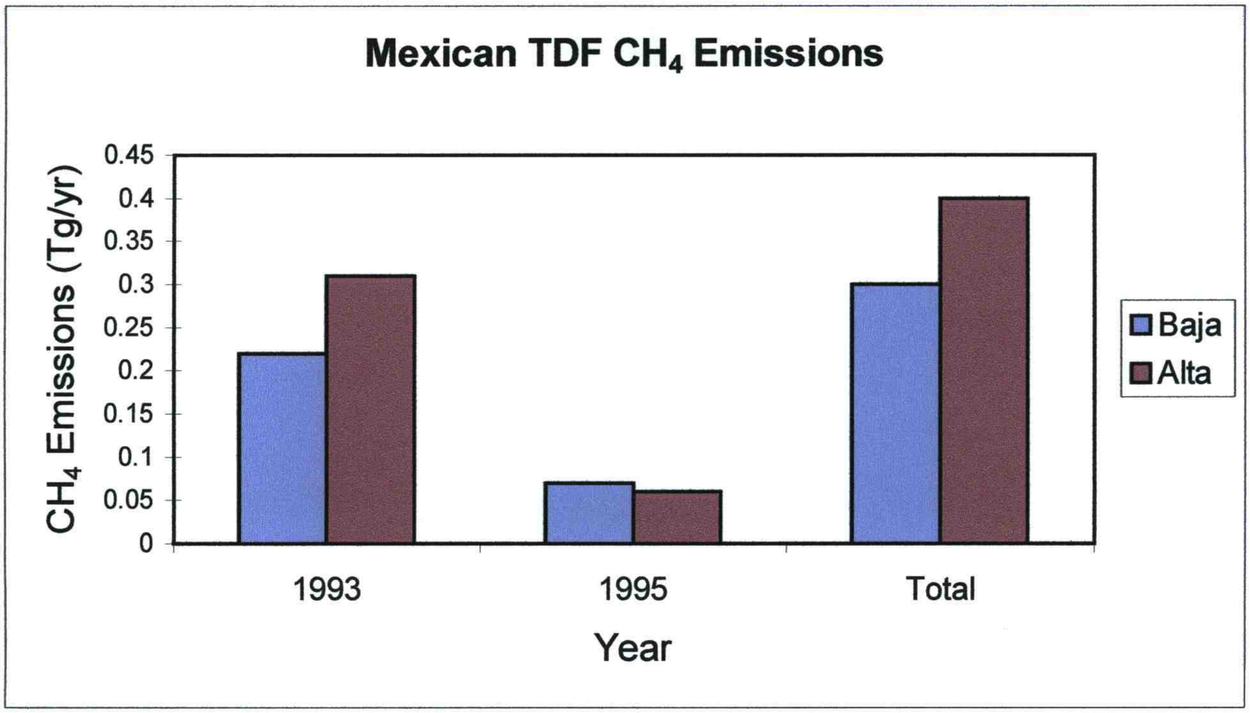


Figure 16: Estimate of total NMHC emissions (Tg yr^{-1}) in all Mexican TDF during 1993 and 1995 after two fires. Baja is low severity and Alta is high severity fire conducted near the Chamela Biological Research Station Jalisco, Mexico. Chamela carbon totals were multiplied by total 1993 estimates (Masera 1997) of total Mexican TDF hectare losses and by TDF emission factors (Ward 1991).

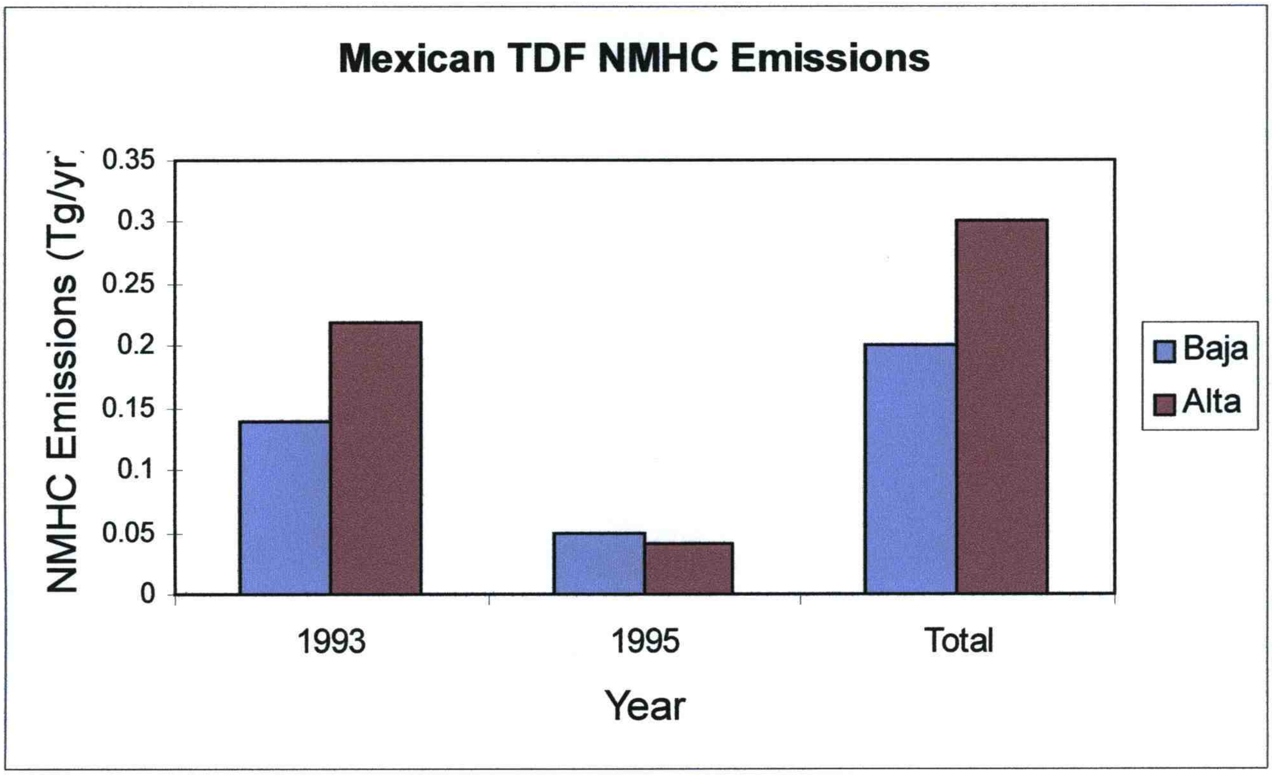


Figure 17: Estimate of total $PM_{2.5}$ emissions (Tg yr^{-1}) in all Mexican TDF during 1993 and 1995 after two fires. Baja is low severity and Alta is high severity fire conducted near the Chamela Biological Research Station Jalisco, Mexico. Chamela carbon totals were multiplied by total 1993 estimates (Masera 1997) of total Mexican TDF hectare losses and by TDF emission factors (Ward 1991).

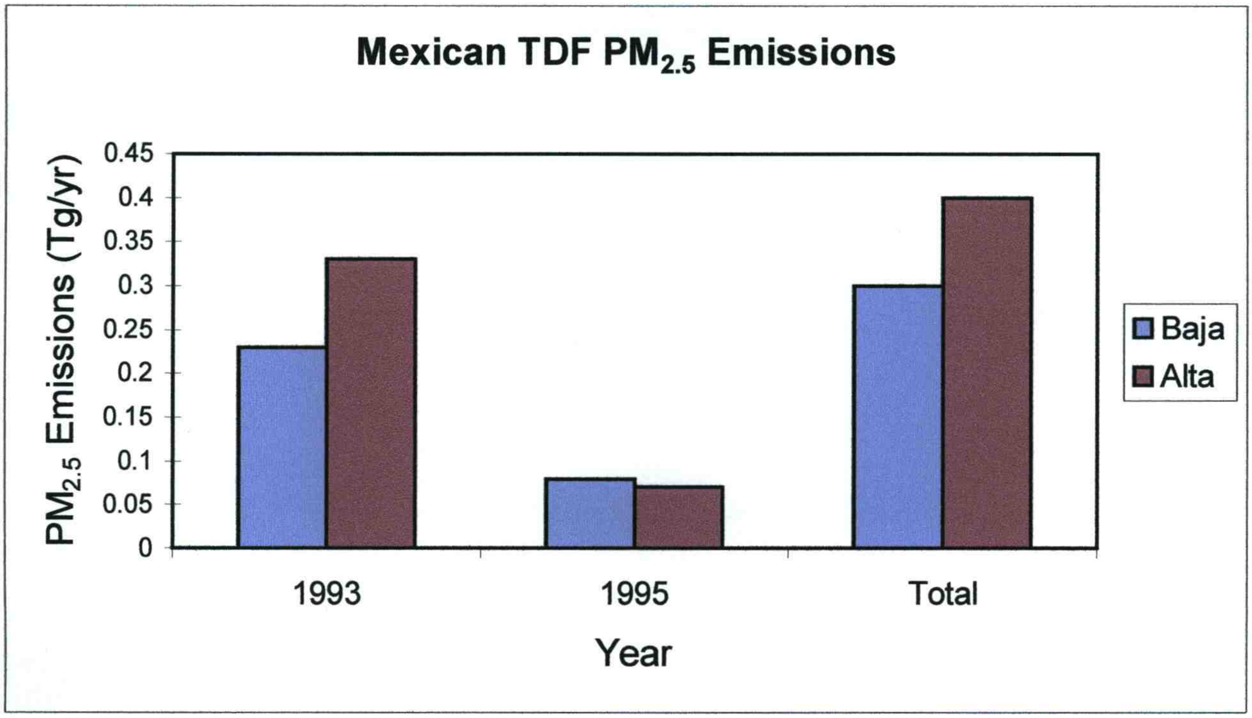
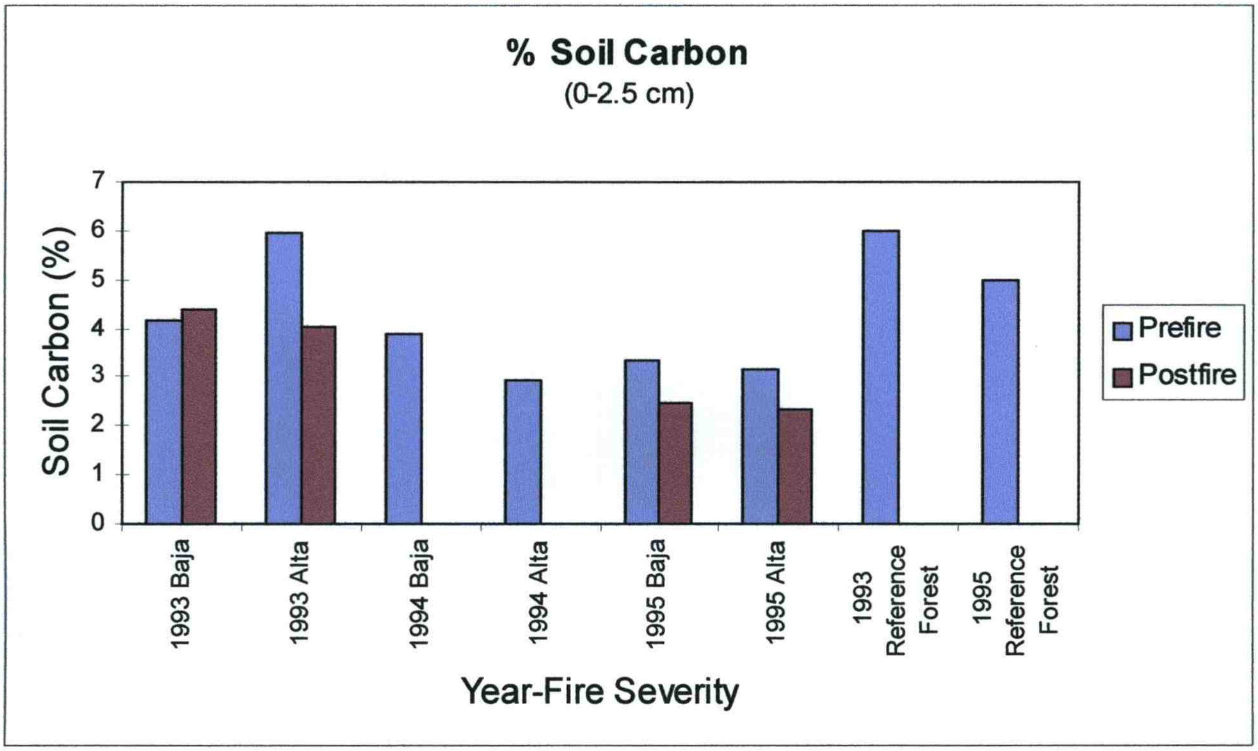


Figure 18: Soil carbon (0-2.5 cm) (%) in a study conducted near the Chamela Biological Research Station Jalisco, Mexico (1993-1995), after two fires. Baja is low severity and Alta is high severity fire. Nearby reference forest was sampled as a control.



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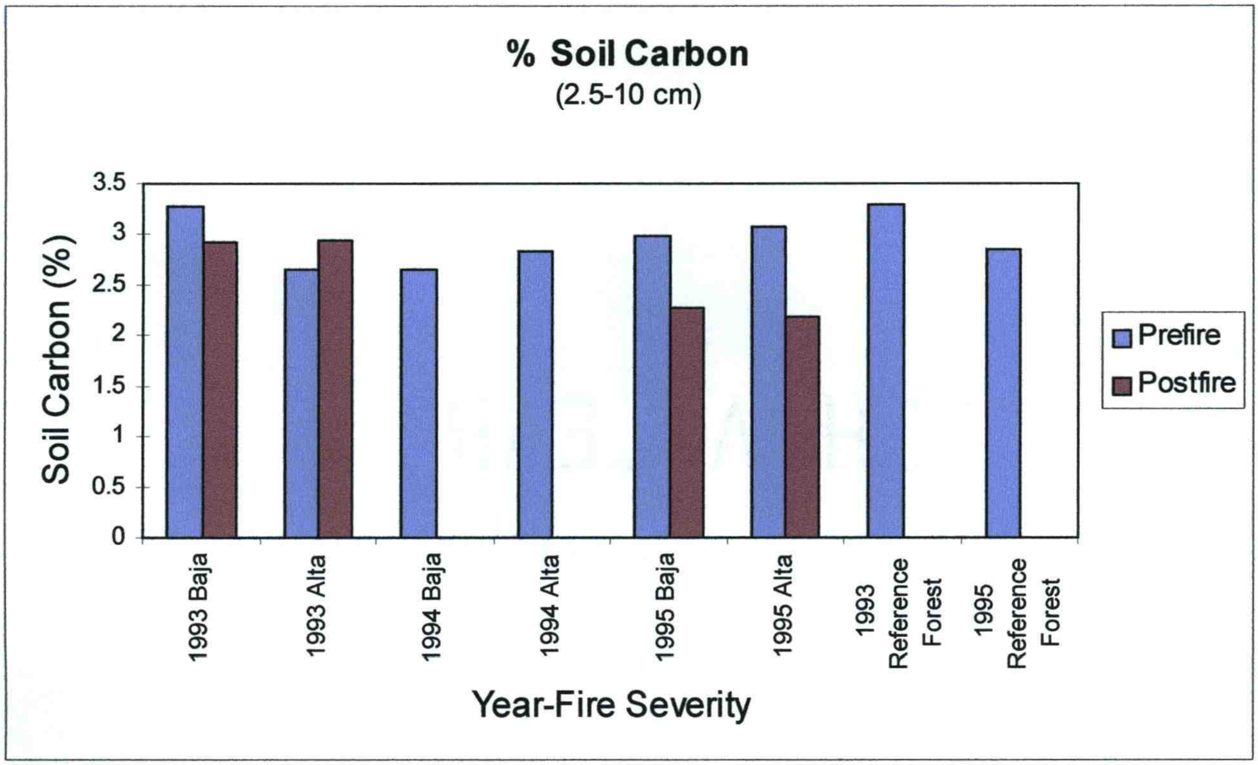


Figure 20: Soil nitrogen (0-2.5 cm) (%) in a study conducted near the Chamela Biological Research Station Jalisco, Mexico (1993-1995), after two fires. Baja is low severity and Alta is high severity fire. Nearby reference forest was sampled as a control.

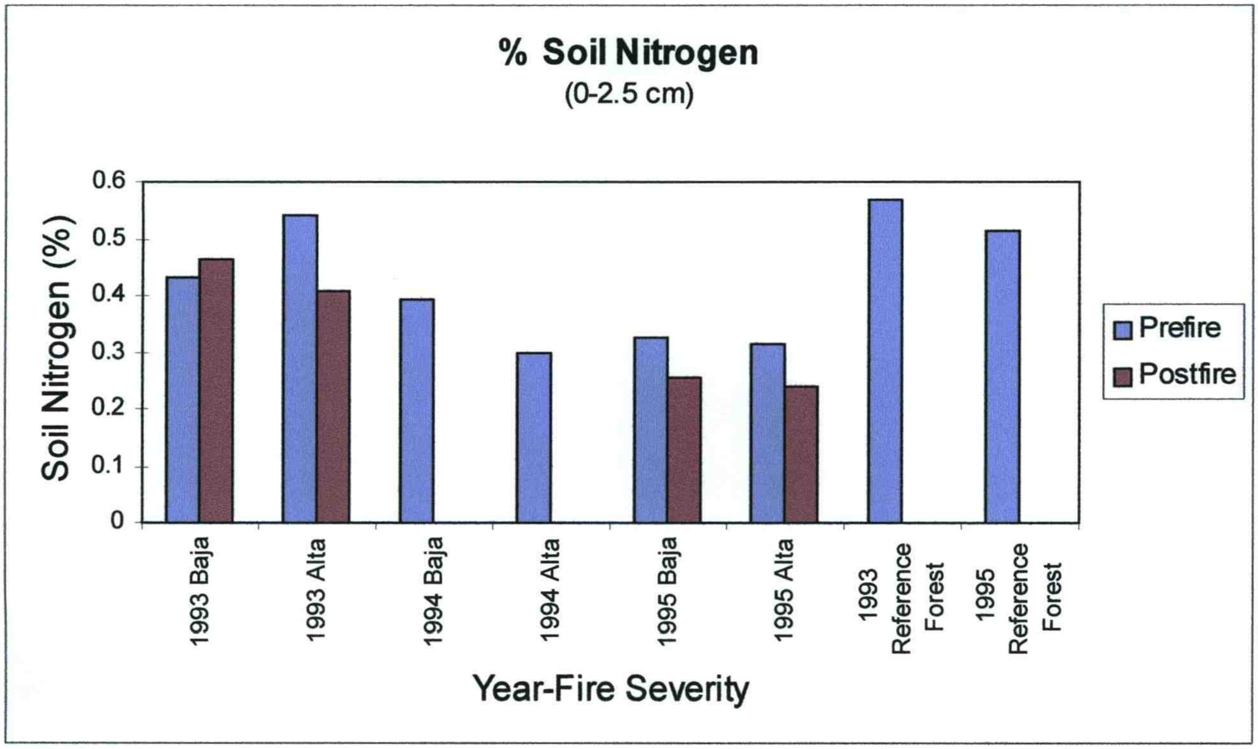


Figure 21: Soil nitrogen (2.5-10 cm) (%) in a study conducted near the Chamela Biological Research Station Jalisco, Mexico (1993-1995), after two fires. Baja is low severity and Alta is high severity fire. Nearby reference forest was sampled as a control.

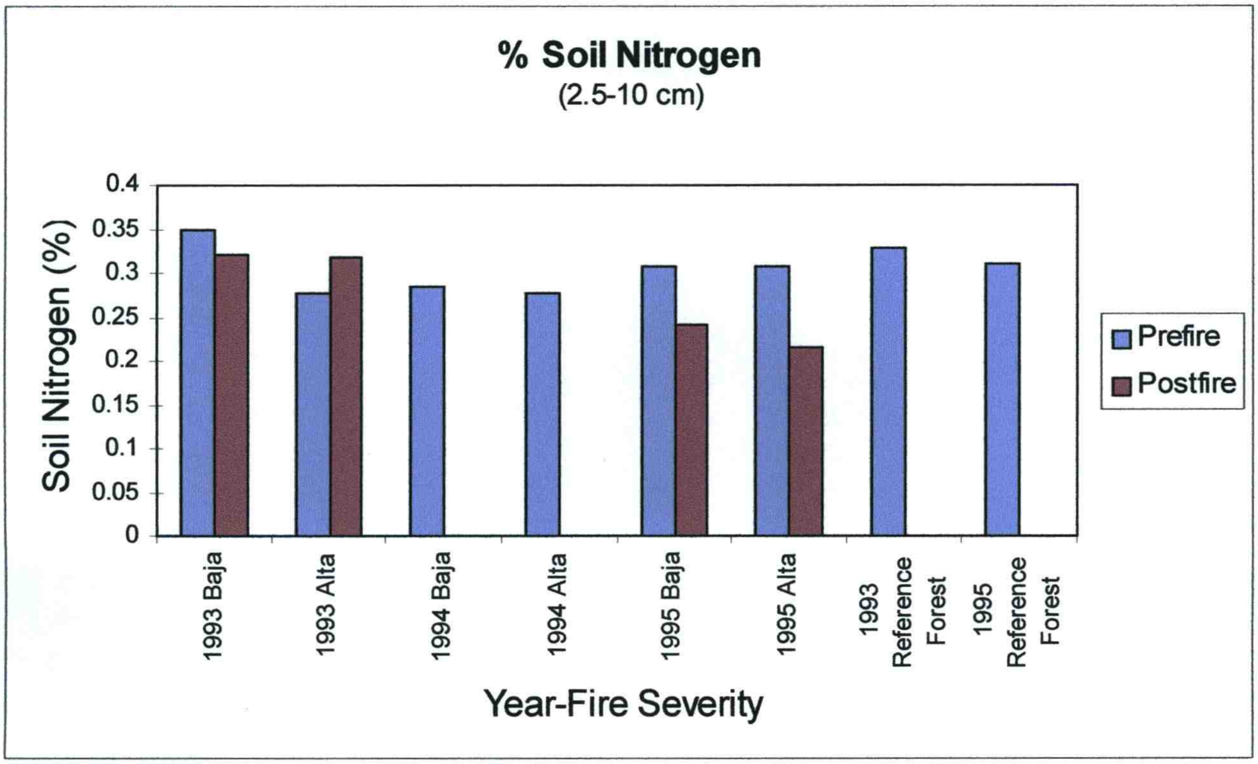


Figure 22: Soil sulphur (0-2.5 cm) (%) in a study conducted near the Chamela Biological Research Station Jalisco, Mexico (1993-1995), after two fires. Baja is low severity and Alta is high severity fire. Nearby reference forest was sampled as a control.

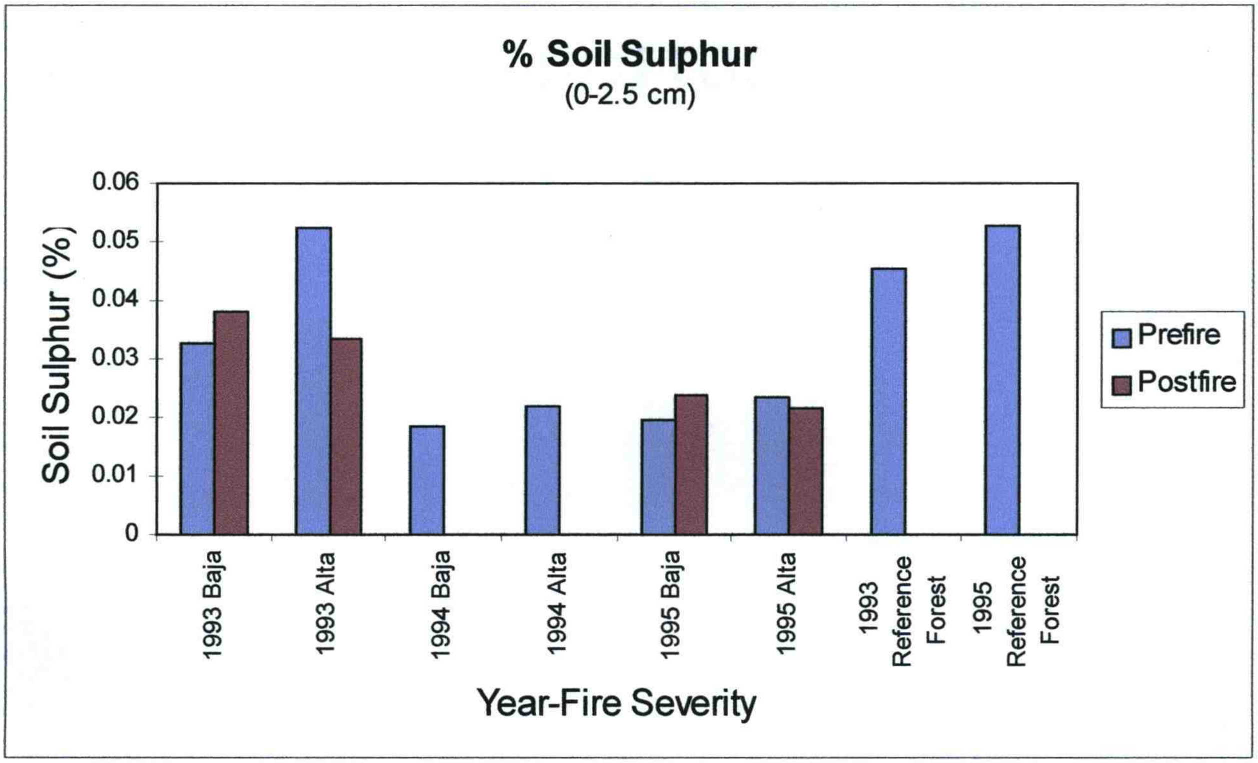


Figure 23: Soil sulphur (2.5-10 cm) (%) in a study conducted near the Chamela Biological Research Station Jalisco, Mexico (1993-1995), after two fires. Baja is low severity and Alta is high severity fire. Nearby reference forest was sampled as a control.

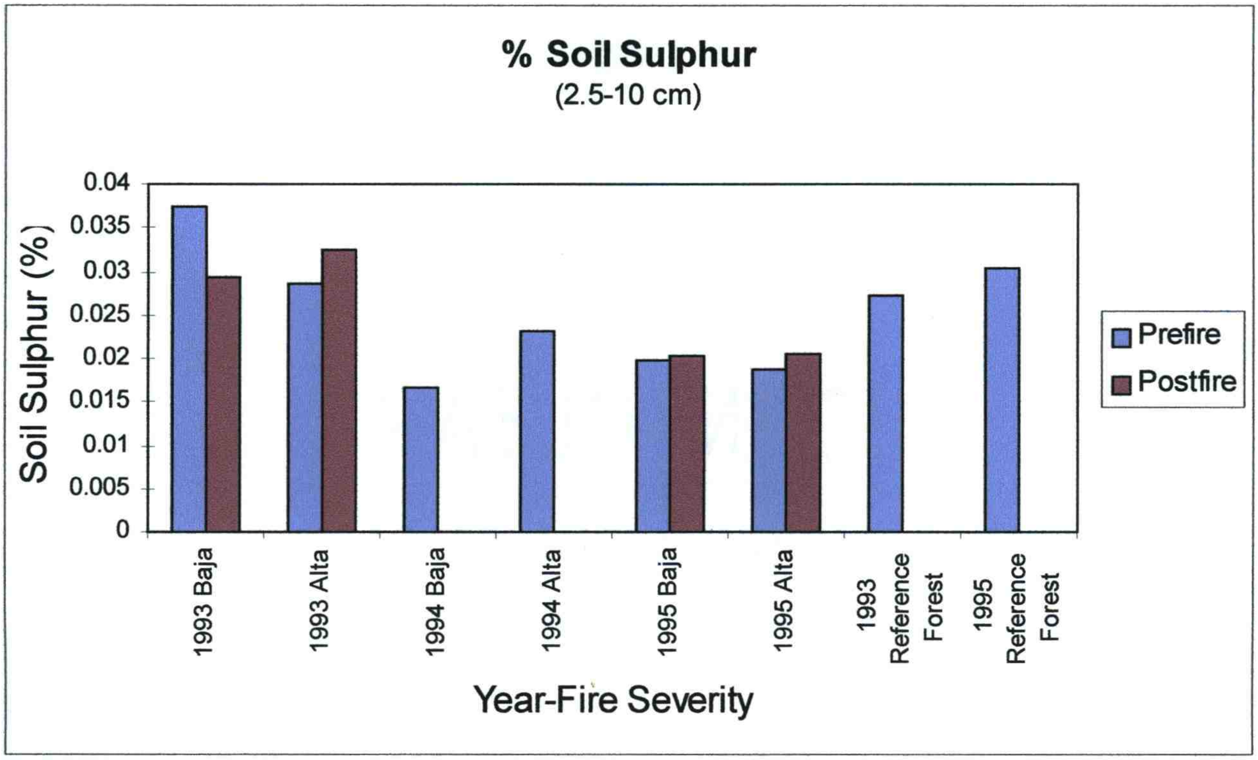


Figure 24: Soil calcium (0-2.5 cm) (%) in a study conducted near the Chamela Biological Research Station Jalisco, Mexico (1993-1995), after two fires. Baja is low severity and Alta is high severity fire. Nearby reference forest was sampled as a control.

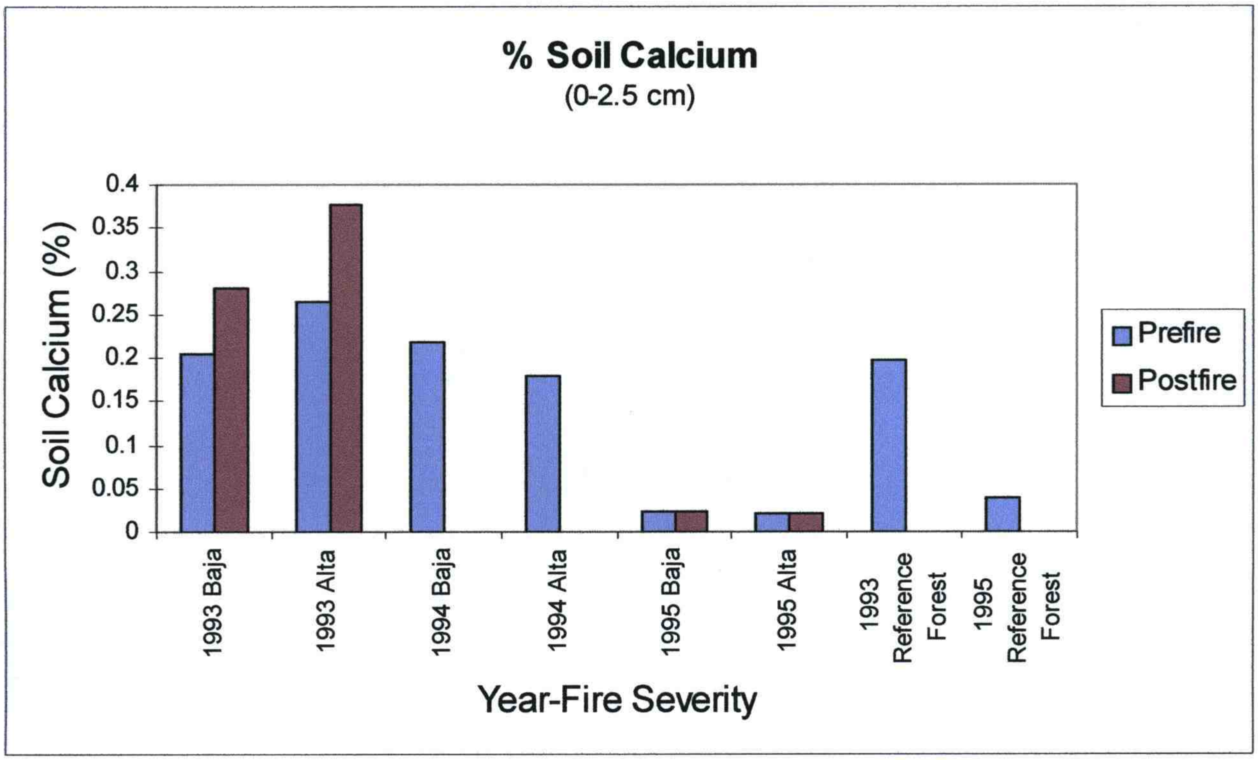


Figure 25: Soil calcium (2.5-10 cm) (%) in a study conducted near the Chamela Biological Research Station Jalisco, Mexico (1993-1995), after two fires. Baja is low severity and Alta is high severity fire. Nearby reference forest was sampled as a control.

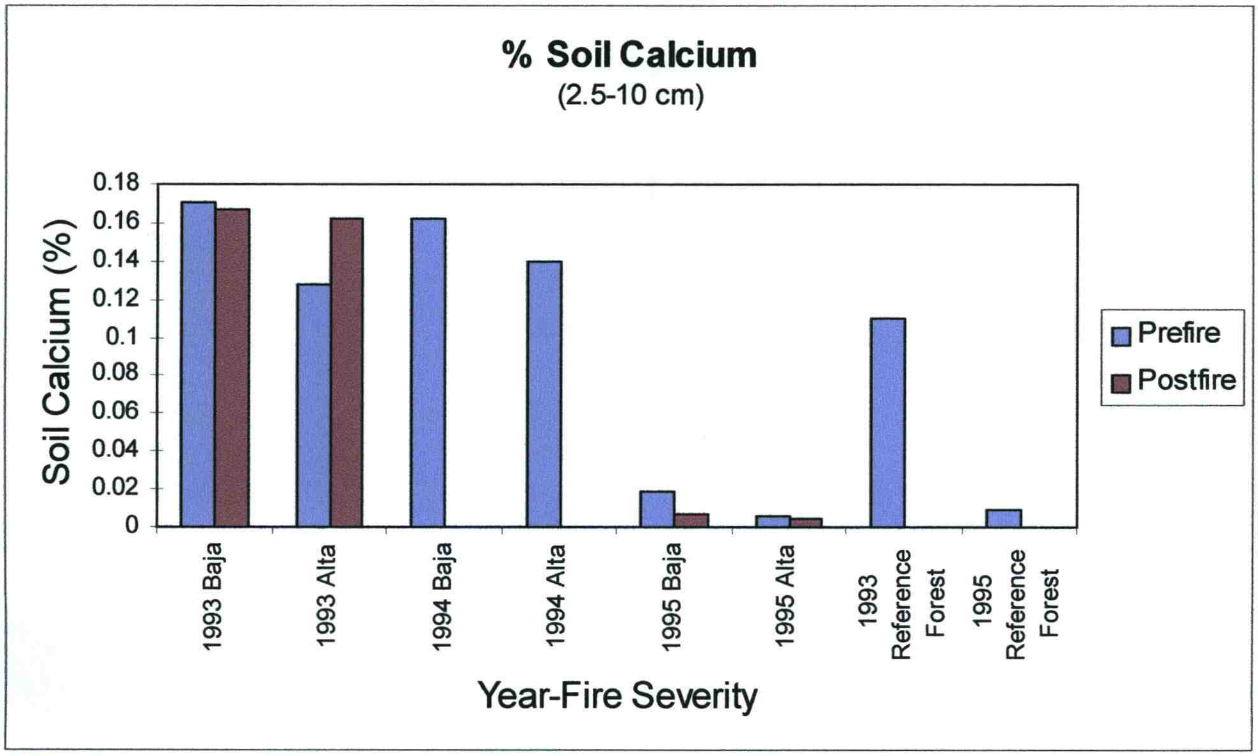


Figure 26: Soil potassium (0-2.5 cm) (%) in a study conducted near the Chamela Biological Research Station Jalisco, Mexico (1993-1995), after two fires. Baja is low severity and Alta is high severity fire. Nearby reference forest was sampled as a control.

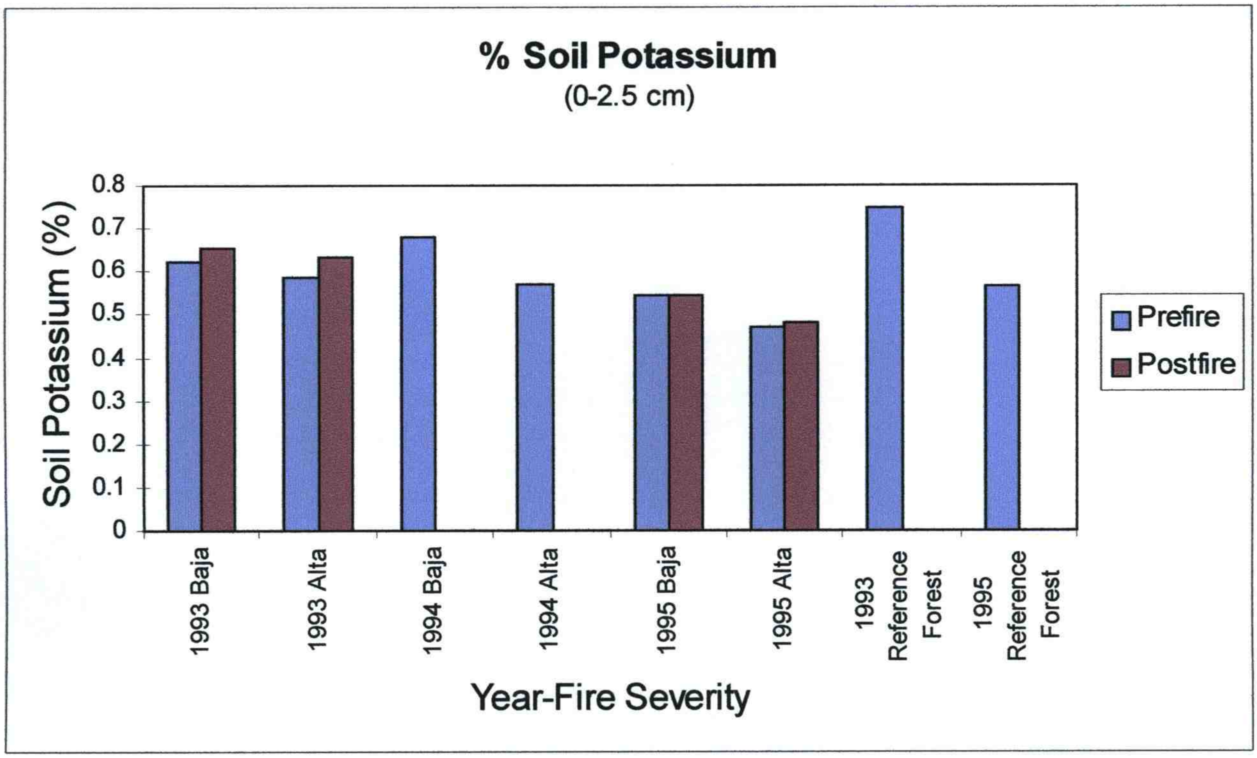


Figure 27: Soil potassium (2.5-10 cm) (%) in a study conducted near the Chamela Biological Research Station Jalisco, Mexico (1993-1995), after two fires. Baja is low severity and Alta is high severity fire. Nearby reference forest was sampled as a control.

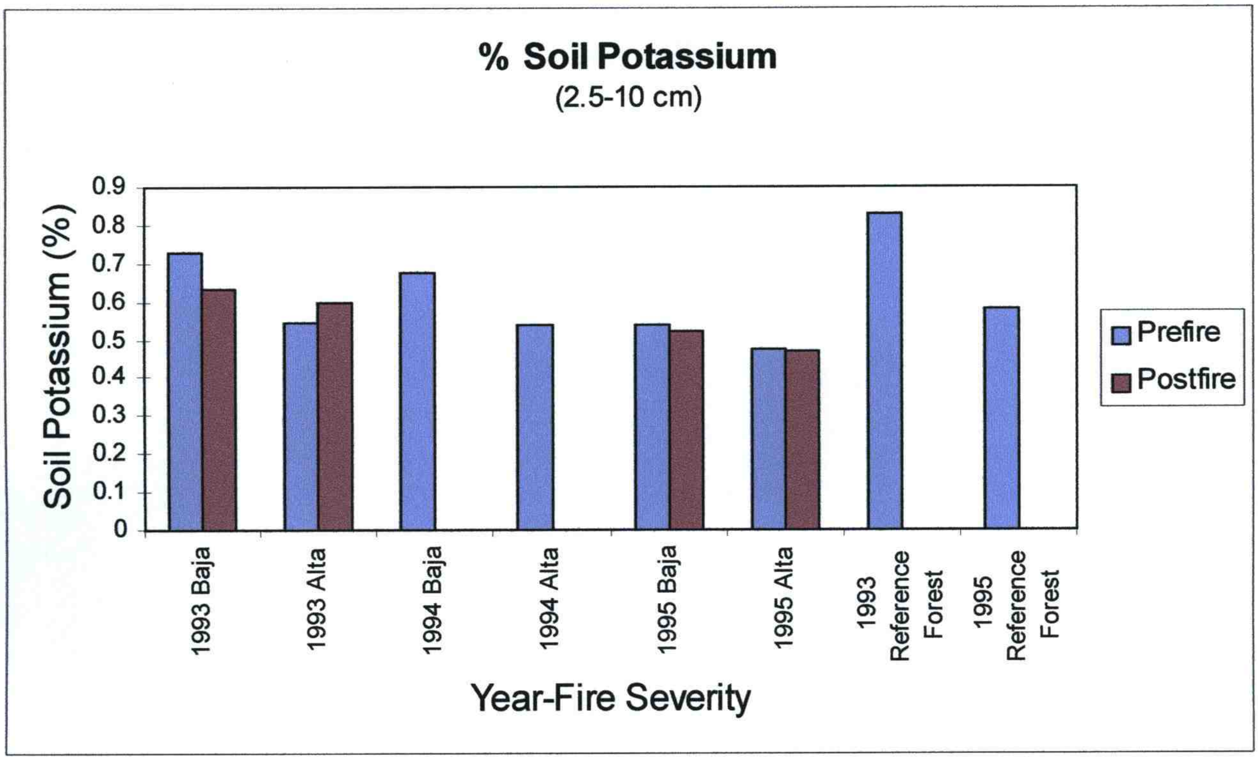


Figure 28: Soil phosphorus (0-2.5 cm) (%) in a study conducted near the Chamela Biological Research Station Jalisco, Mexico (1993-1995), after two fires. Baja is low severity and Alta is high severity fire. Nearby reference forest was sampled as a control.

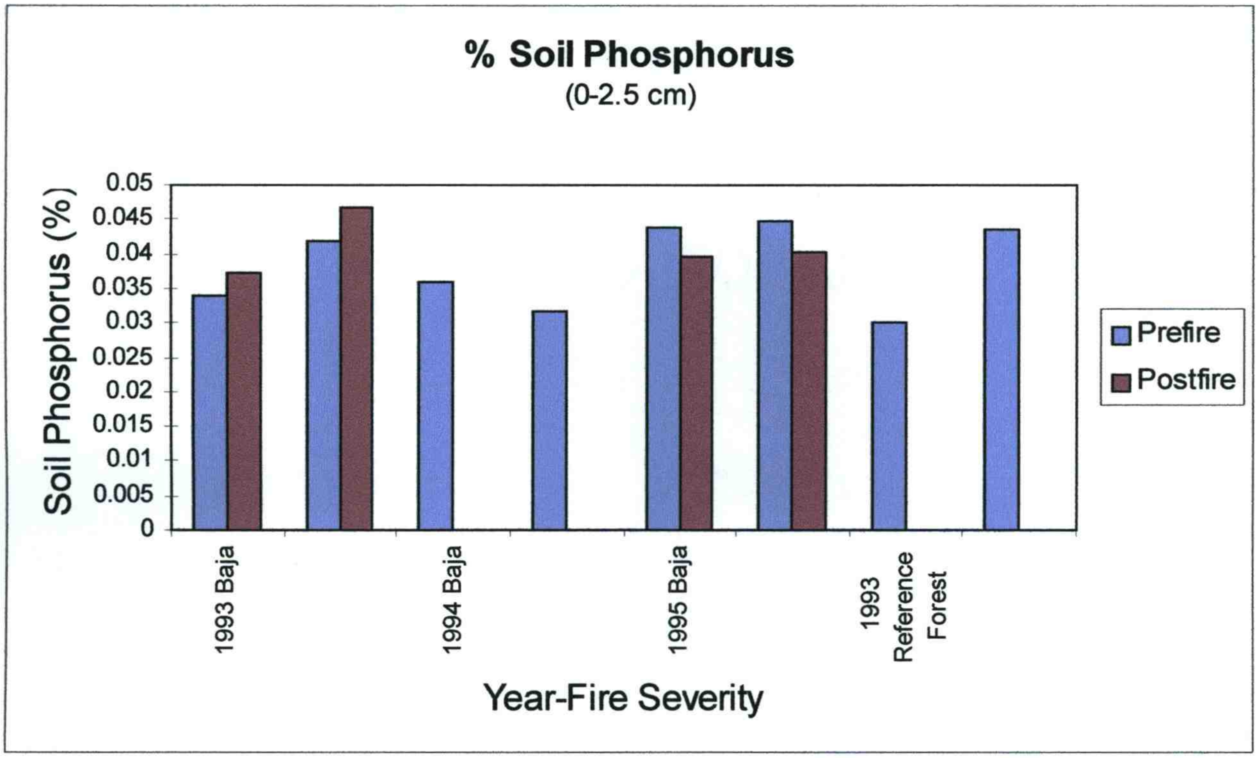


Figure 29: Soil phosphorus (2.5-10 cm) (%) in a study conducted near the Chamela Biological Research Station Jalisco, Mexico (1993-1995), after two fires. Baja is low severity and Alta is high severity fire. Nearby reference forest was sampled as a control.

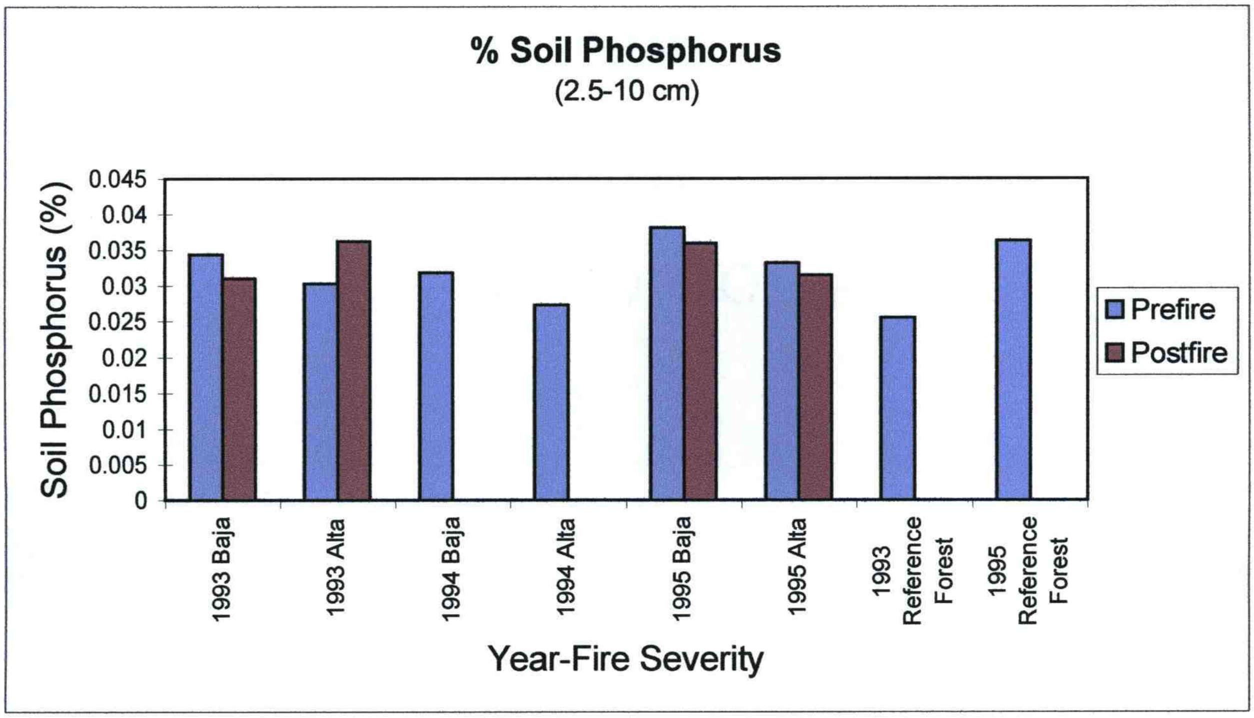


Figure 30: % Carbon and nutrient loss in TDF comparison. Based upon 1993 Chamela TDF fires and a study conducted in Serra Tallhada, Brazil. Cha=chamela and ST= Serra Tallhada. L is low severity and H is high severity fire.

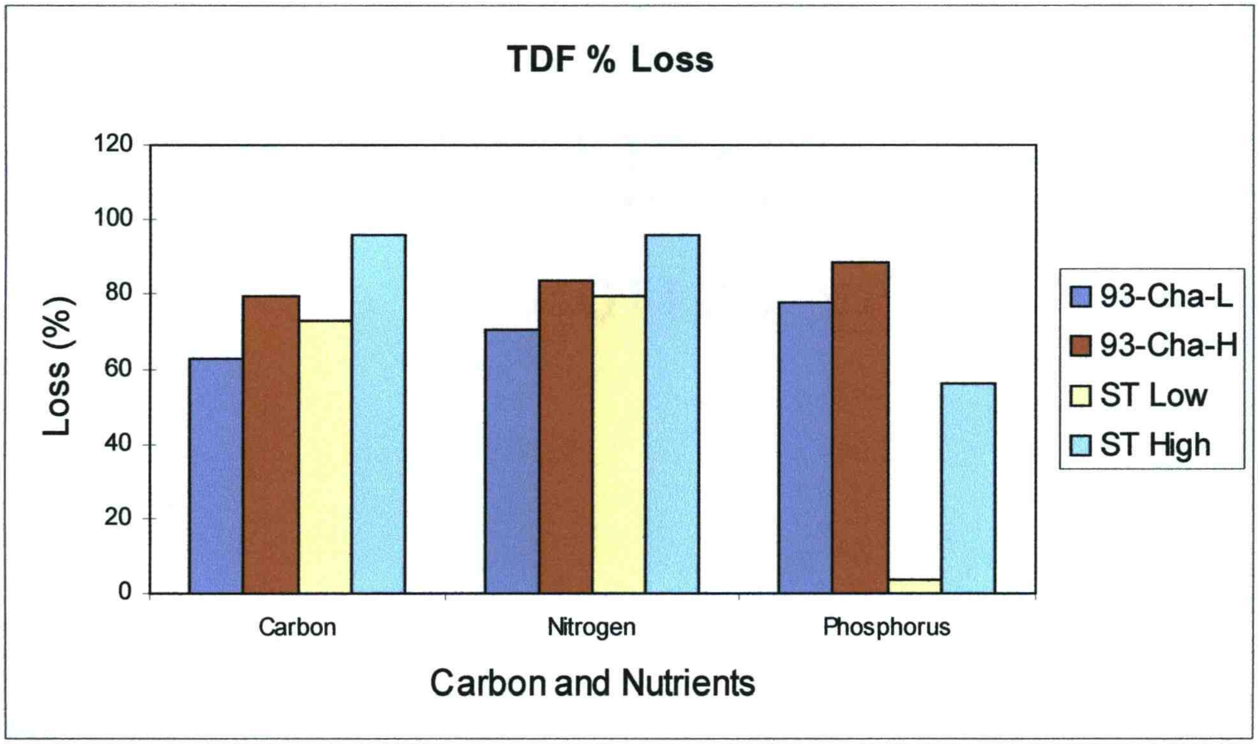


Figure 31: % Carbon and nutrient loss in Tropical forest pasture comparisons. Based upon 1995 Chamela pasture and studies in Brazilian forest ecosystems. Cha=Chamela, Cl and Cs are grasslands, the remaining are TMF pasture sites. L is low severity and H is high severity fire.

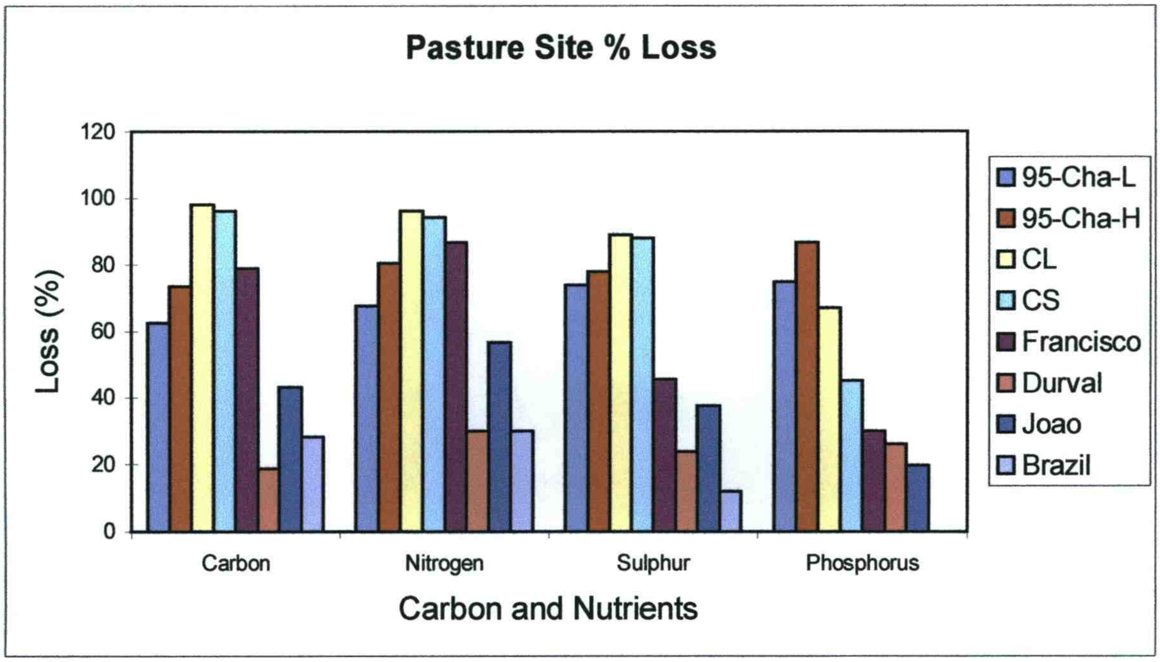


Figure 32: % Carbon and nutrient loss in Tropical forest comparisons. Based upon 1993 Chamela TDF and studies in Brazilian forest ecosystems. Cha=Chamela, CC and Css are tropical woodland (Cerrado), the remaining are TMF evergreen forest and one TMF pasture site. L is low severity and H is high severity fire.

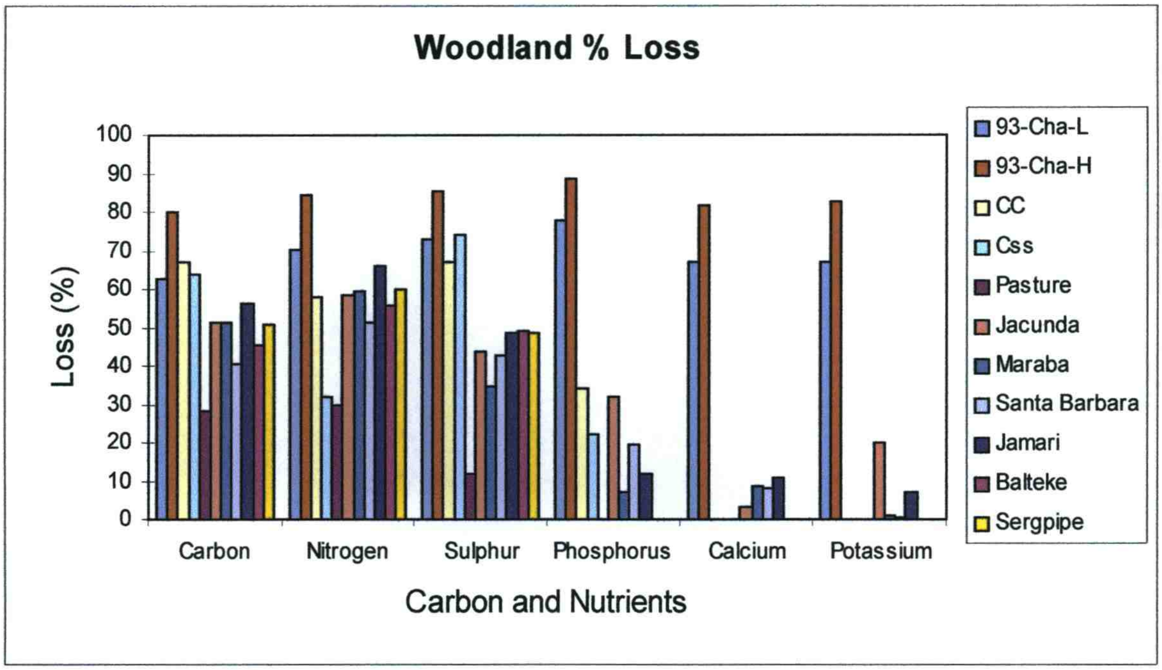


Figure 33: 1993 Baja prefire biomass pie chart divided by component. Data collected in 1993 in a study conducted near the Chamela Biological Research Station Jalisco, Mexico before a TDF fire. Baja data is for low severity fire.

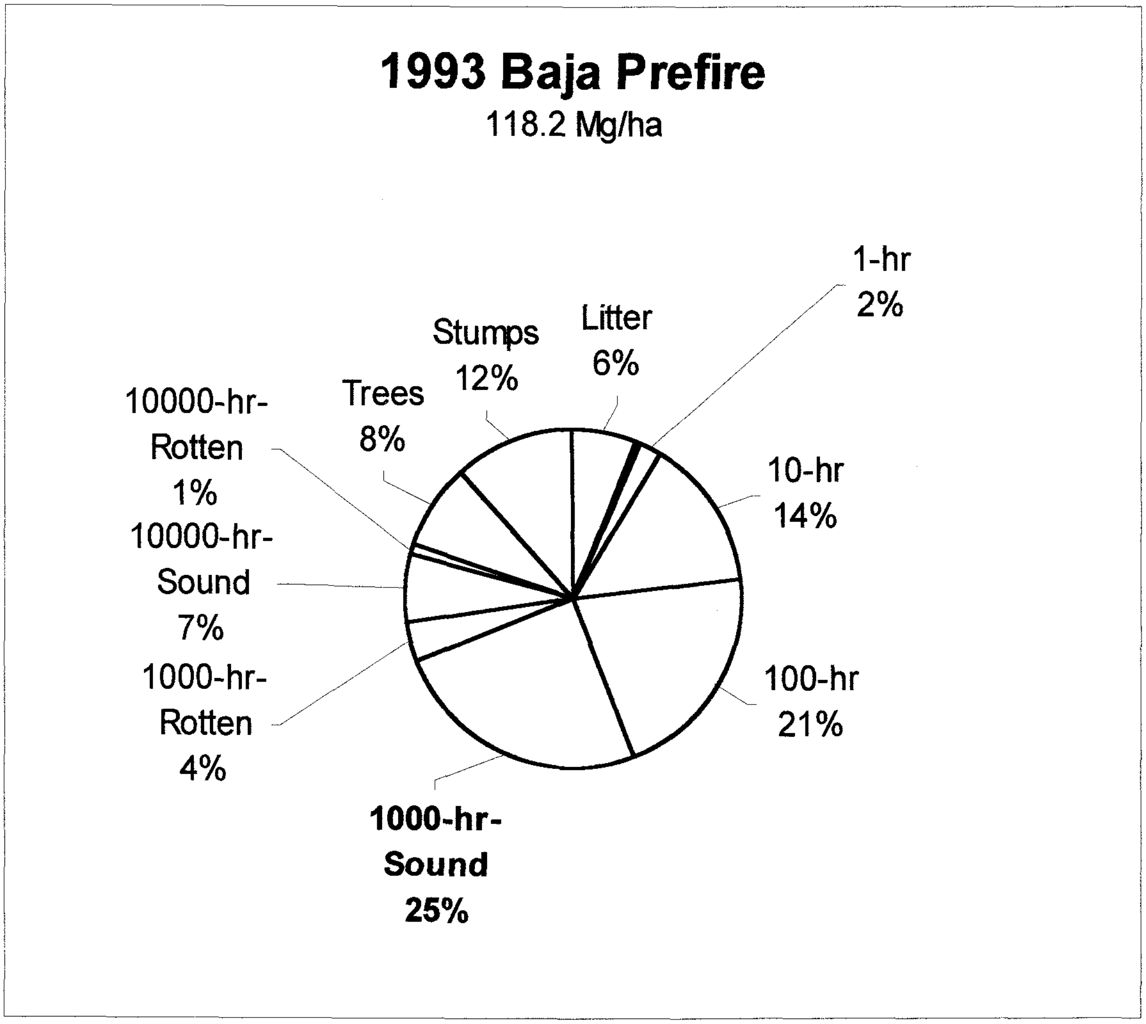


Figure 34: 1993 Baja postfire biomass pie chart divided by component. Data collected in 1993 in a study conducted near the Chamela Biological Research Station Jalisco, Mexico after a TDF fire. Baja data is for low severity fire.

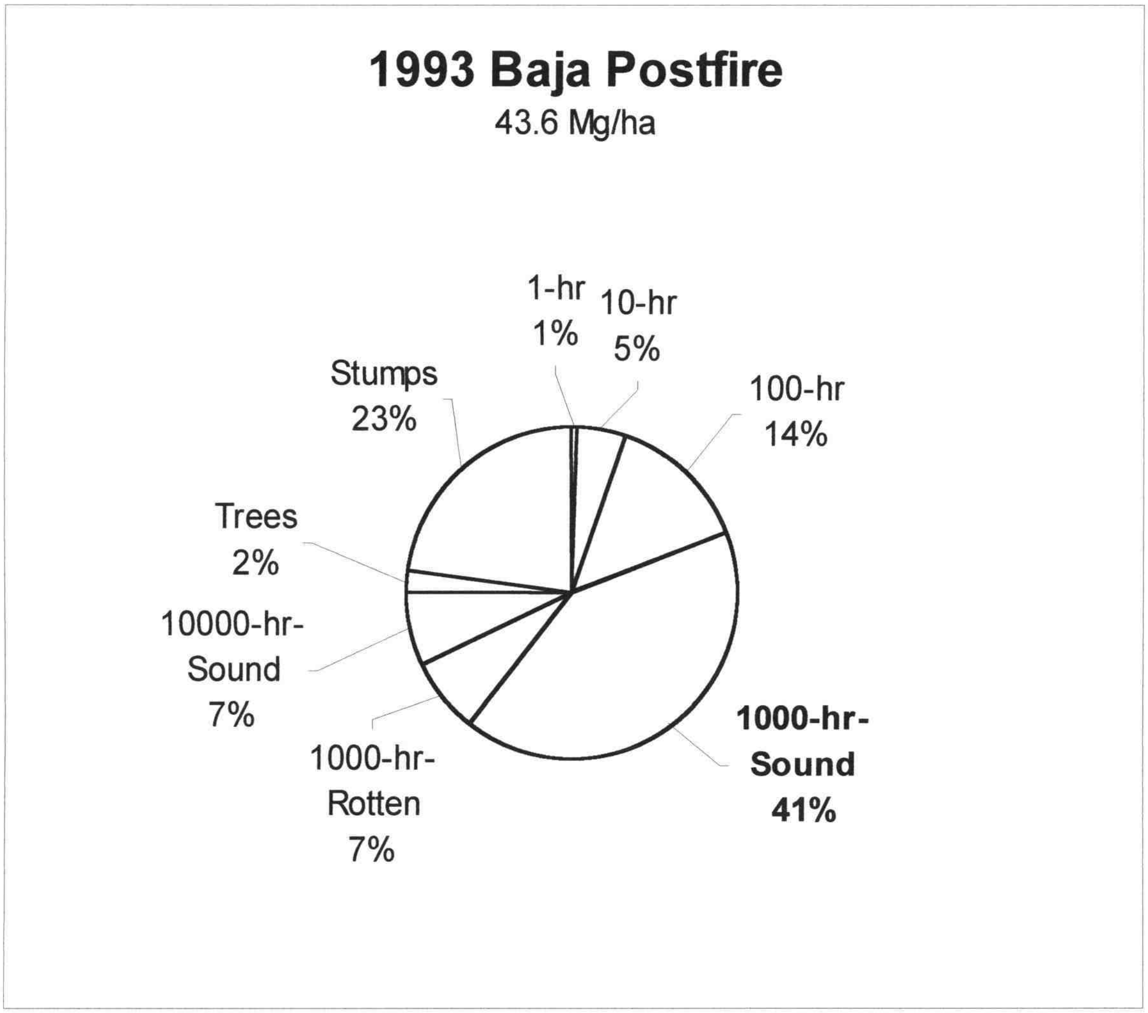


Figure 35: 1993 Alta prefire biomass pie chart divided by component. Data collected in 1993 in a study conducted near the Chamela Biological Research Station Jalisco, Mexico before a TDF fire. Alta data is for high severity fire.

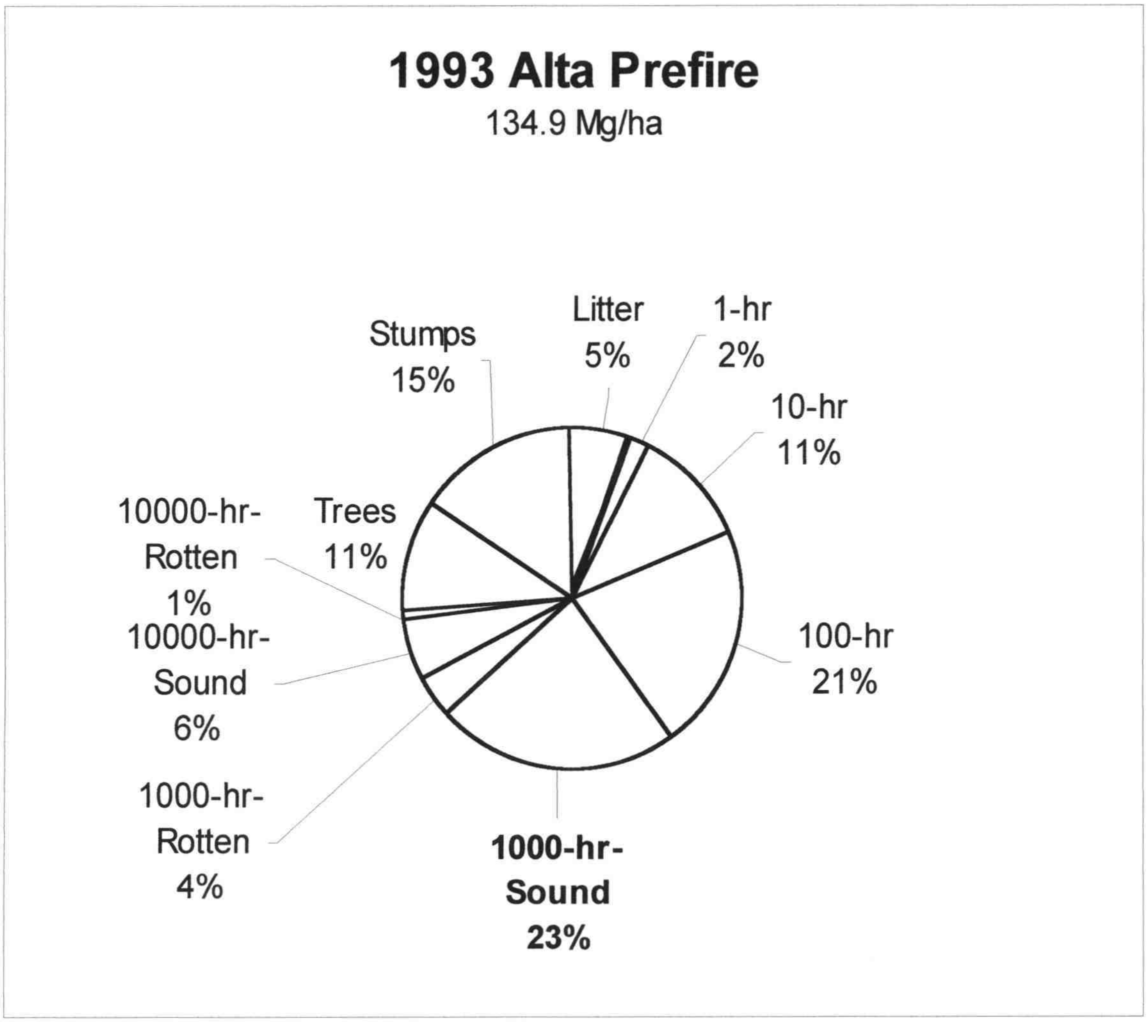


Figure 36: 1993 Alta postfire biomass pie chart divided by component. Data collected in 1993 in a study conducted near the Chamela Biological Research Station Jalisco, Mexico after a TDF fire. Alta data is for high severity fire.

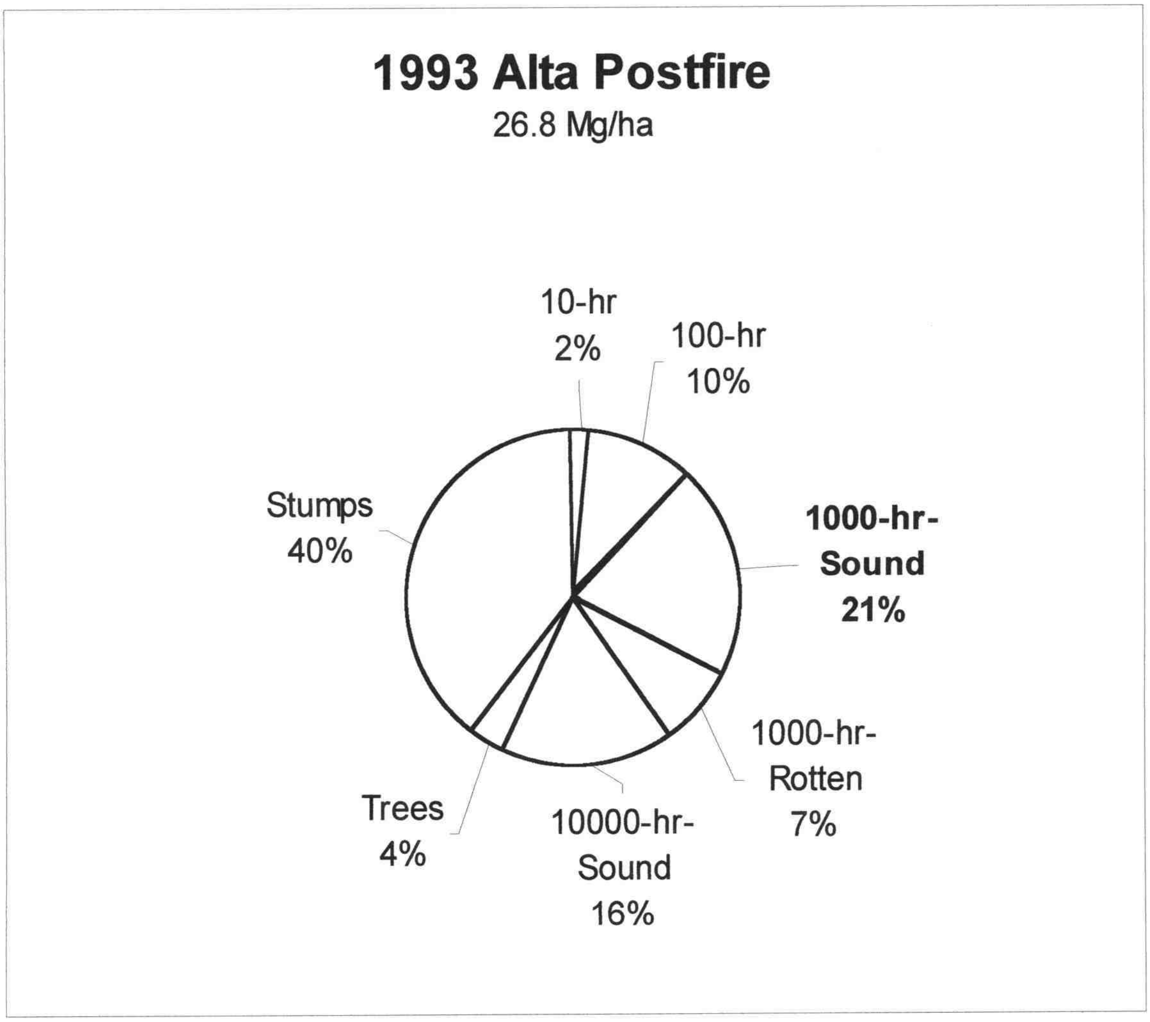


Figure 37: 1994 Baja biomass pie chart divided by component. Data collected in 1994 during a non-fire year in a study conducted near the Chamela Biological Research Station Jalisco, Mexico. Baja data is for low severity fire plots.

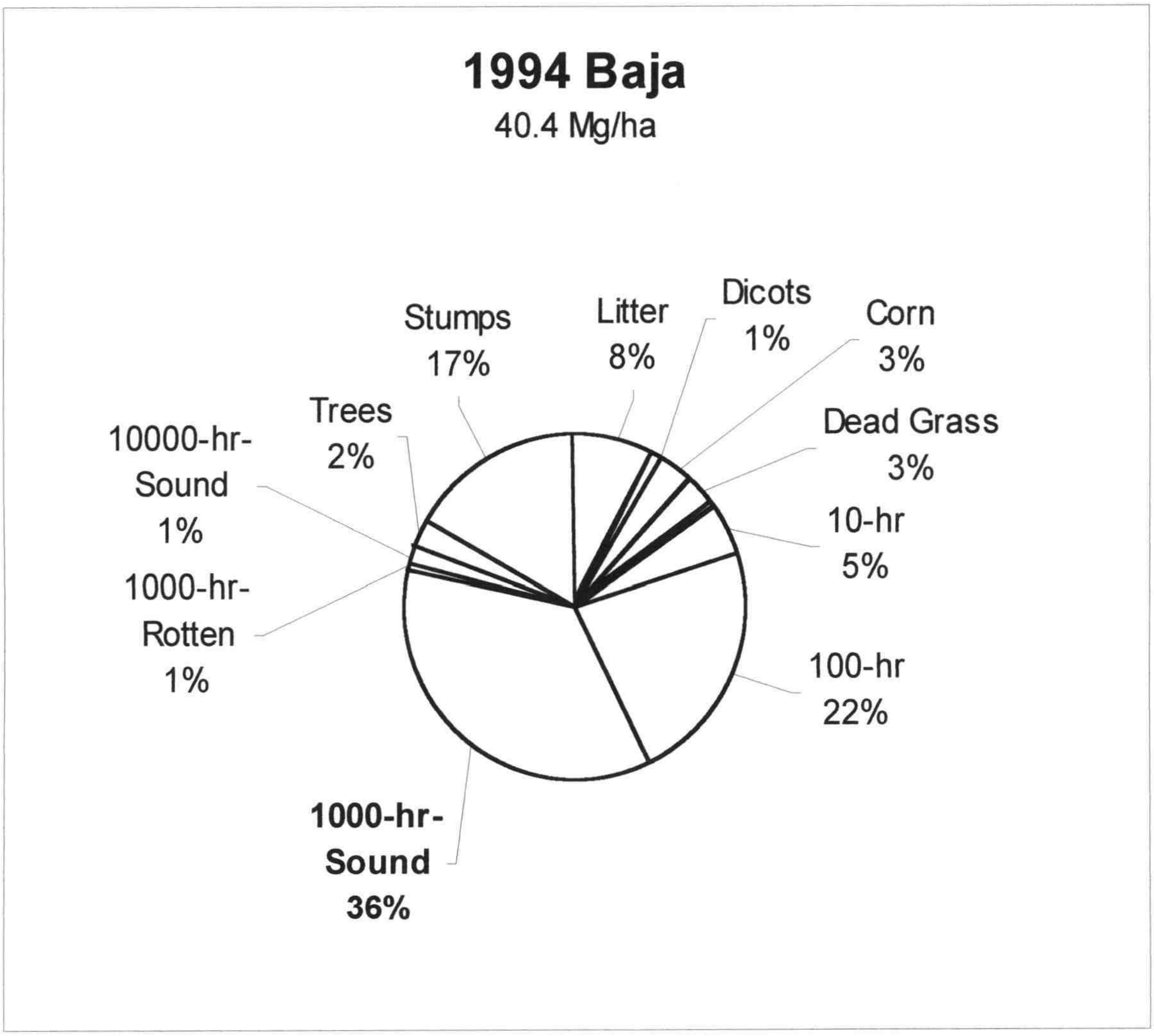


Figure 38: 1994 Alta biomass pie chart divided by component. Data collected in 1994 during a non-fire year in a study conducted near the Chamela Biological Research Station Jalisco, Mexico. Alta data is for high severity fire plots.

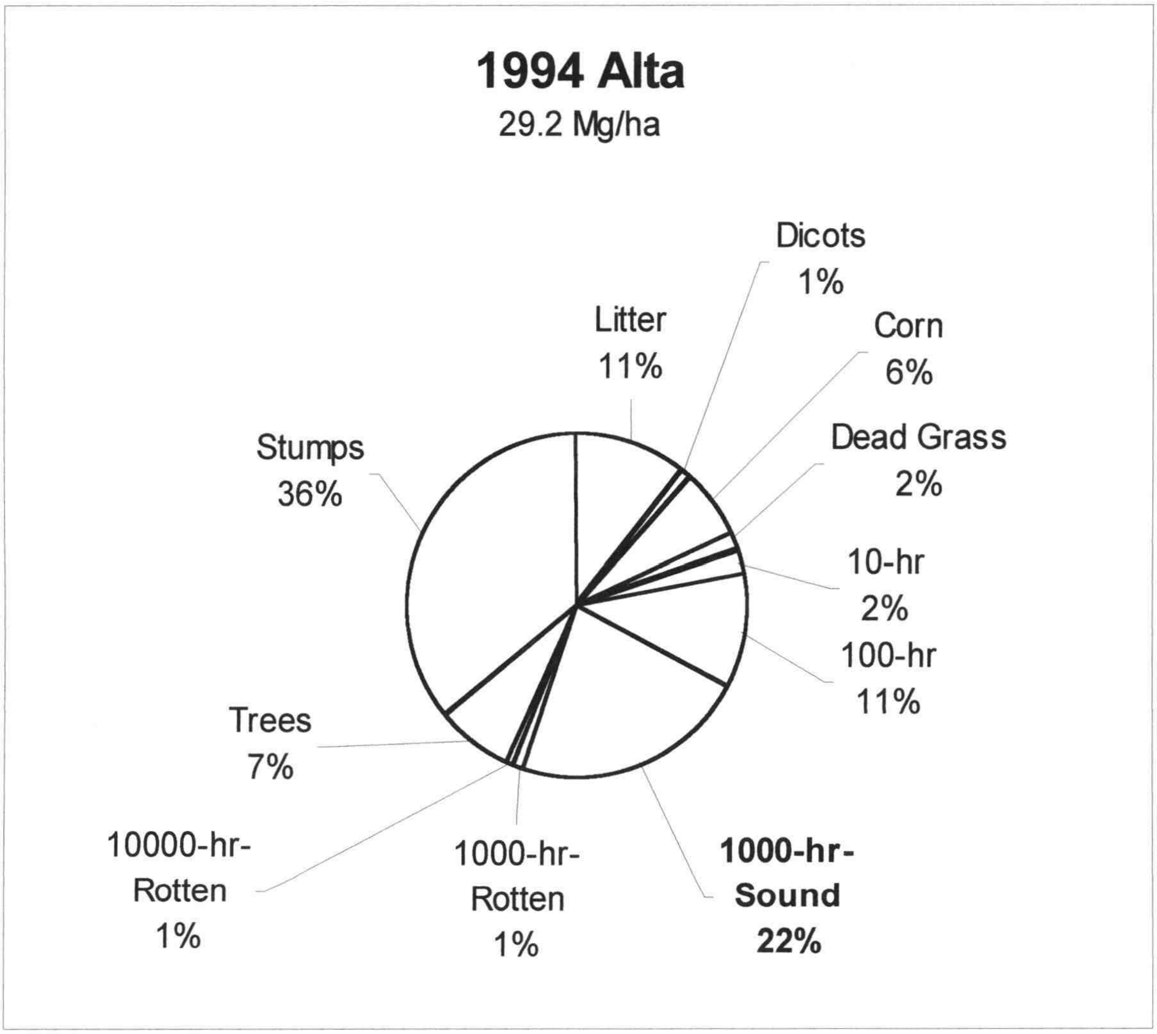


Figure 39: 1995 Baja prefire biomass pie chart divided by component. Data collected in 1993 in a study conducted near the Chamela Biological Research Station Jalisco, Mexico before a pasture fire. Baja data is for low severity fire.

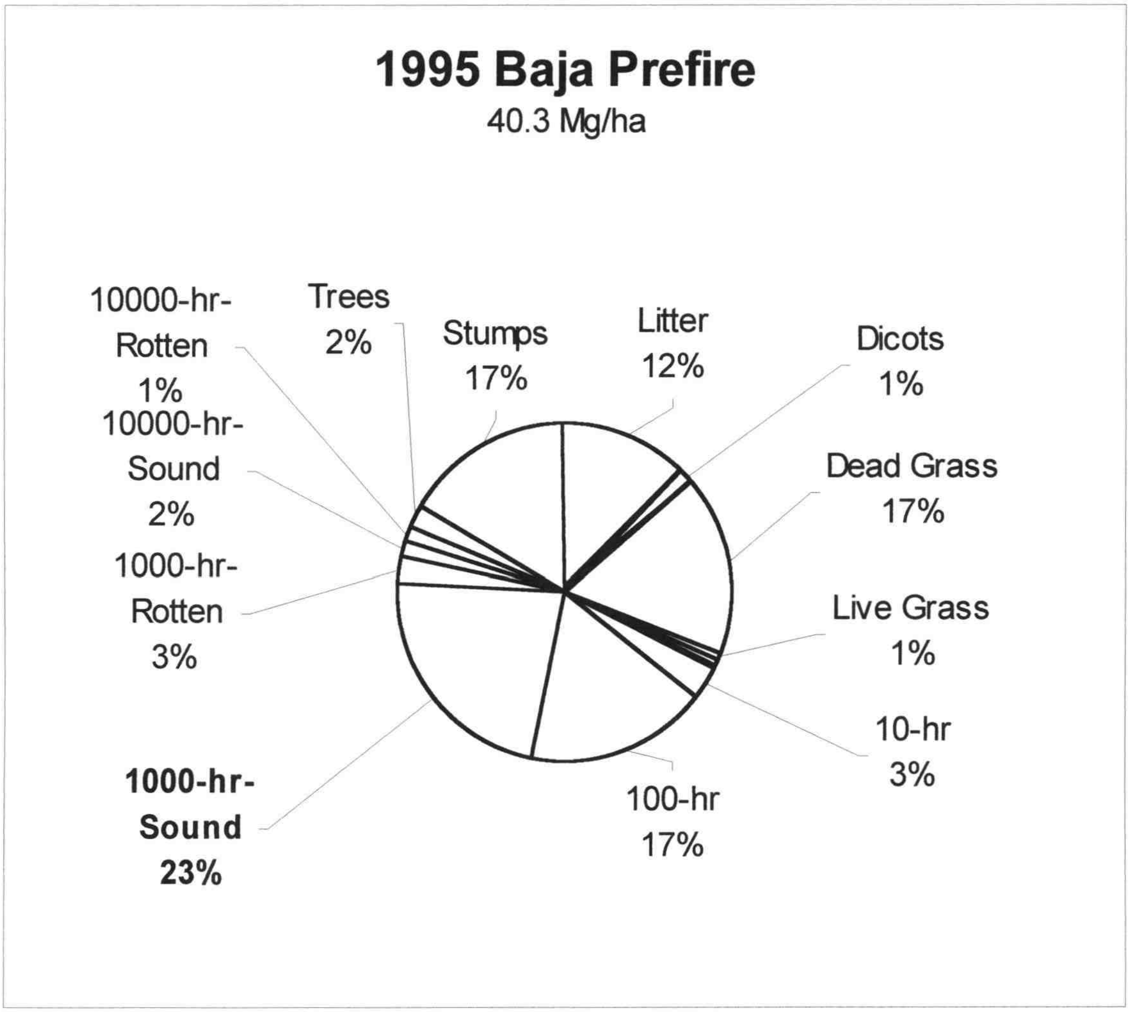


Figure 40: 1995 Baja postfire biomass pie chart divided by component. Data collected in 1993 in a study conducted near the Chamela Biological Research Station Jalisco, Mexico after a pasture fire. Baja data is for low severity fire.

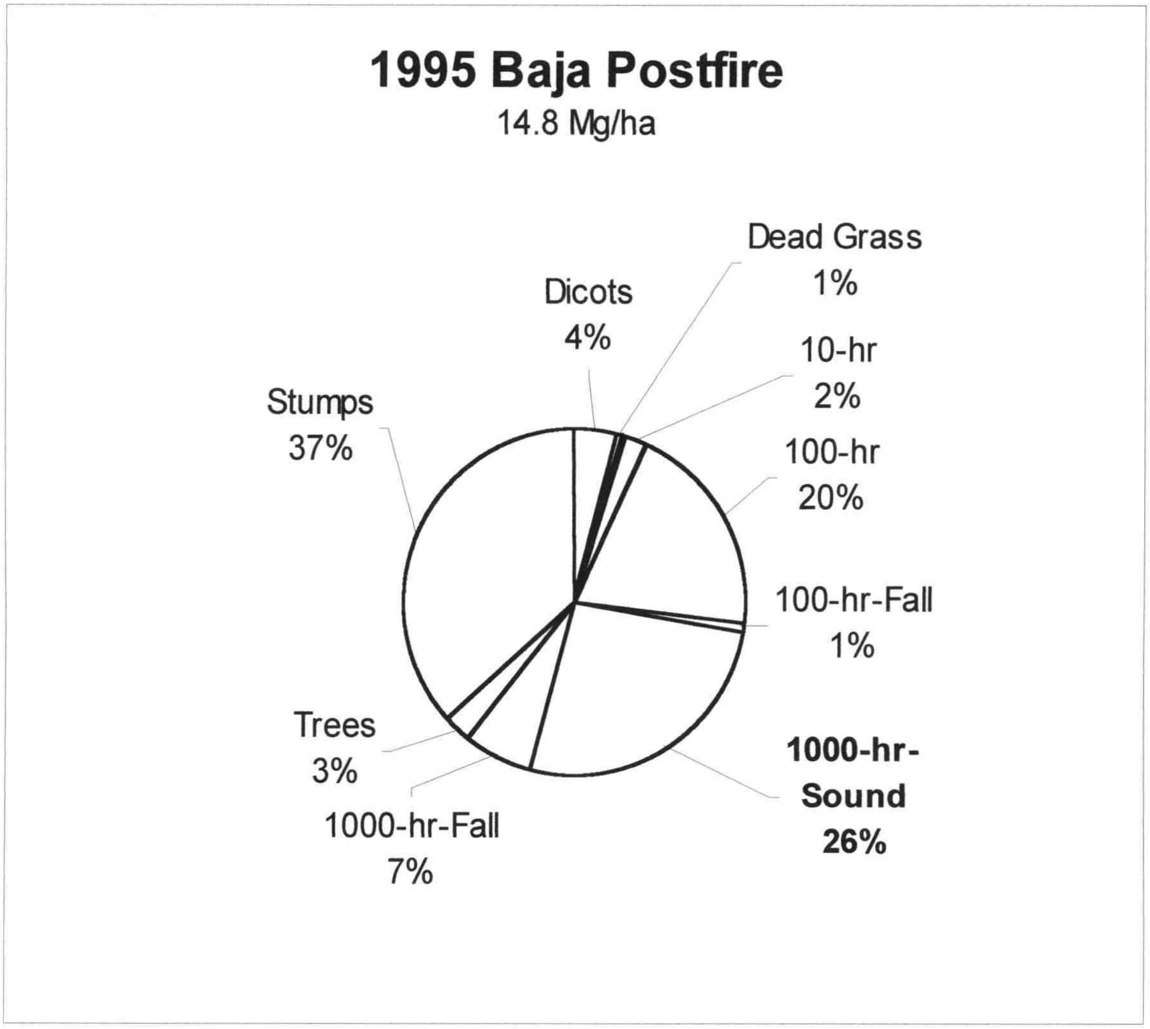


Figure 41: 1995 Alta prefire biomass pie chart divided by component. Data collected in 1993 in a study conducted near the Chamela Biological Research Station Jalisco, Mexico before a pasture fire. Alta data is for high severity fire.

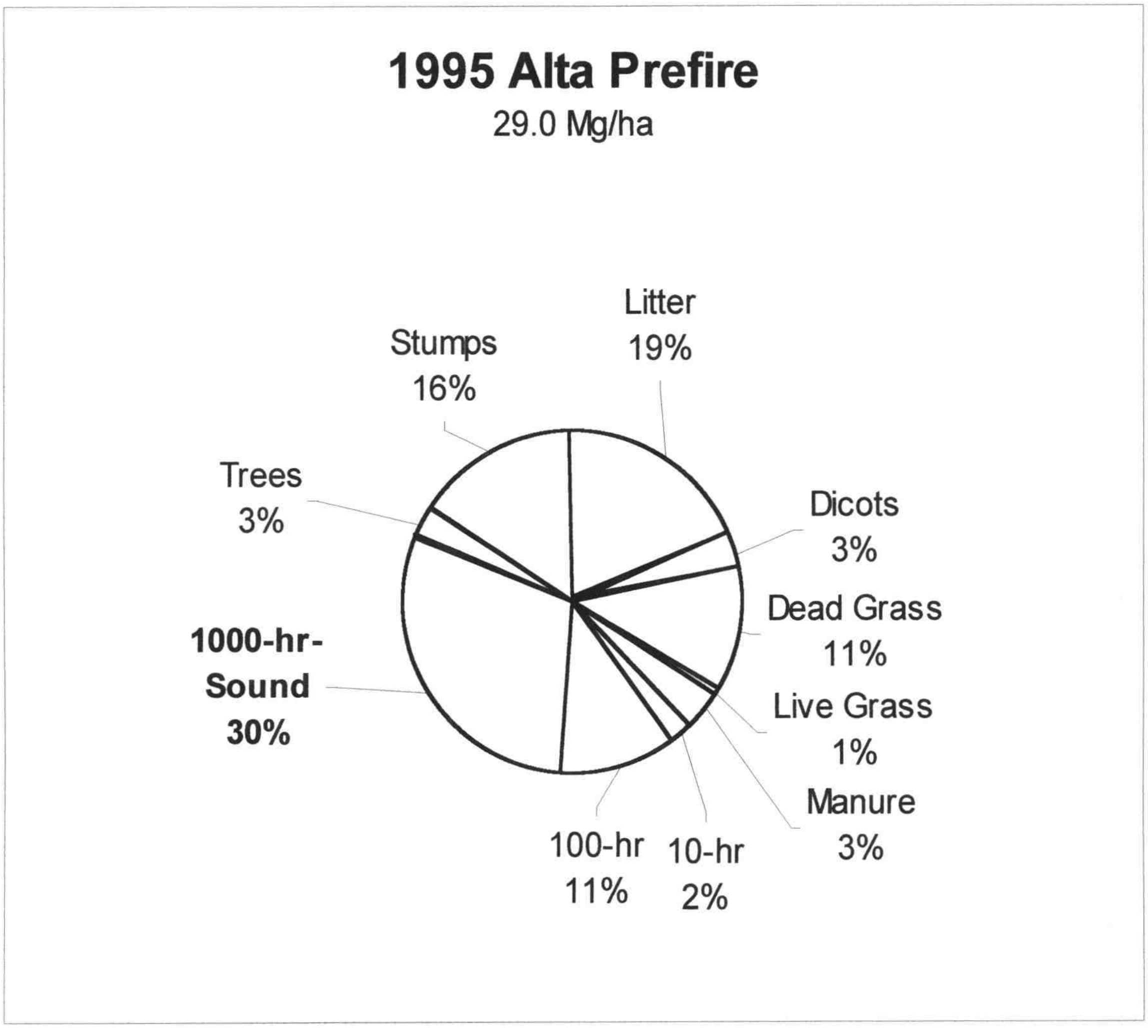


Figure 42: 1995 Alta postfire biomass pie chart divided by component. Data collected in 1993 in a study conducted near the Chamela Biological Research Station Jalisco, Mexico after a pasture fire. Alta data is for high severity fire.

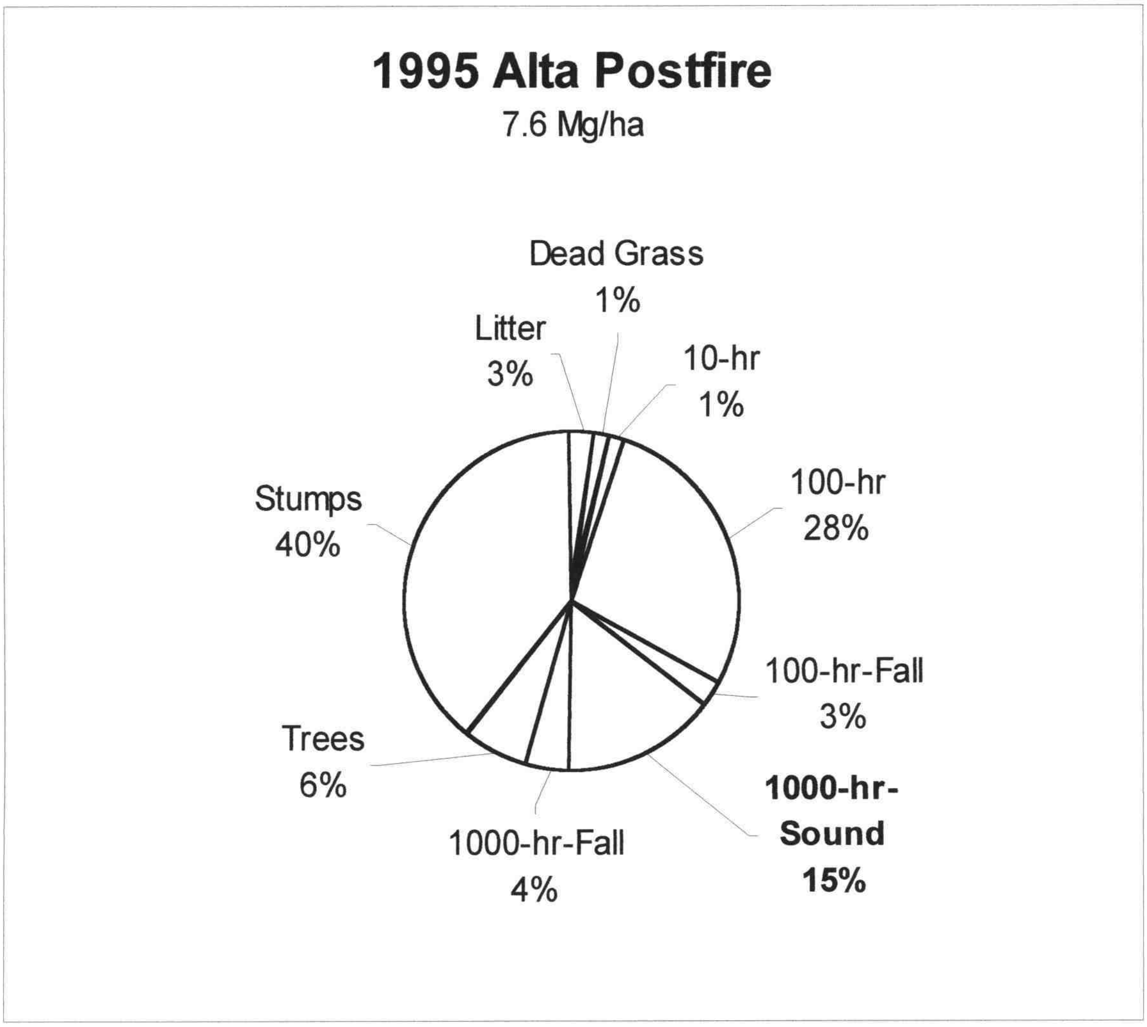


Figure 43: Carbon pools divided by component. Data collected 1993-1995 in a study conducted near the Chamela Biological Research Station Jalisco, Mexico.

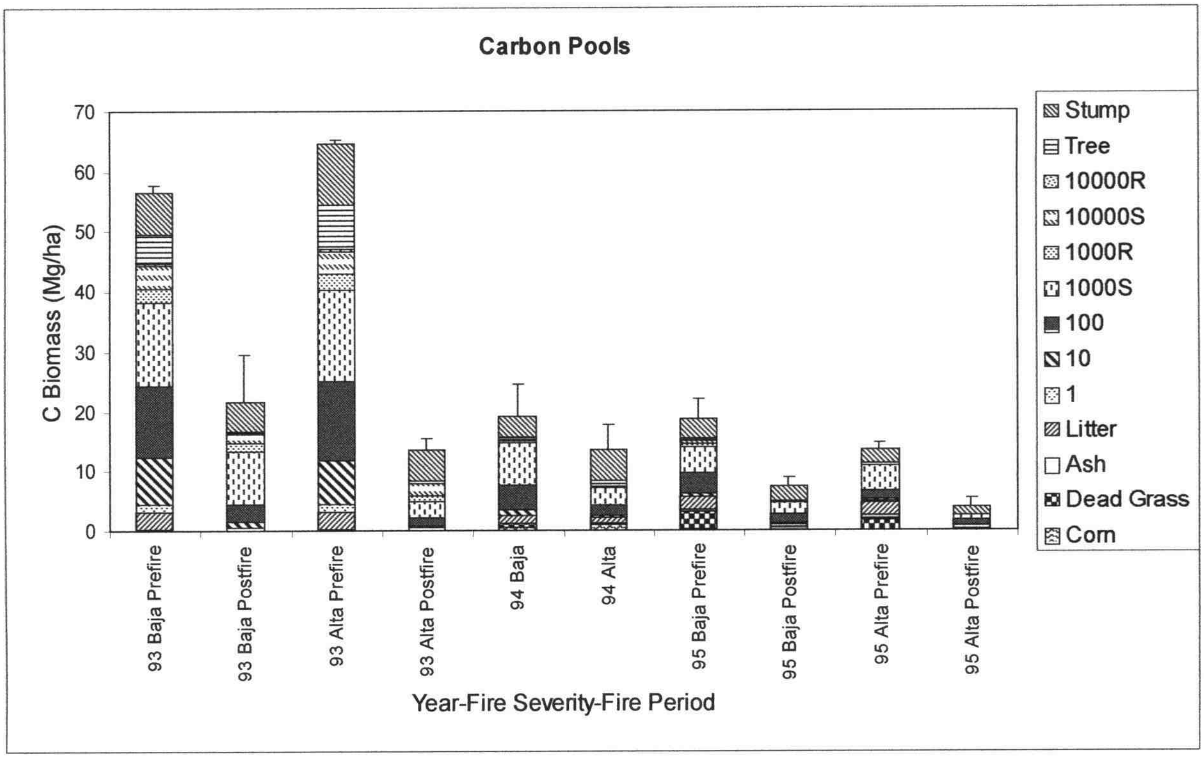
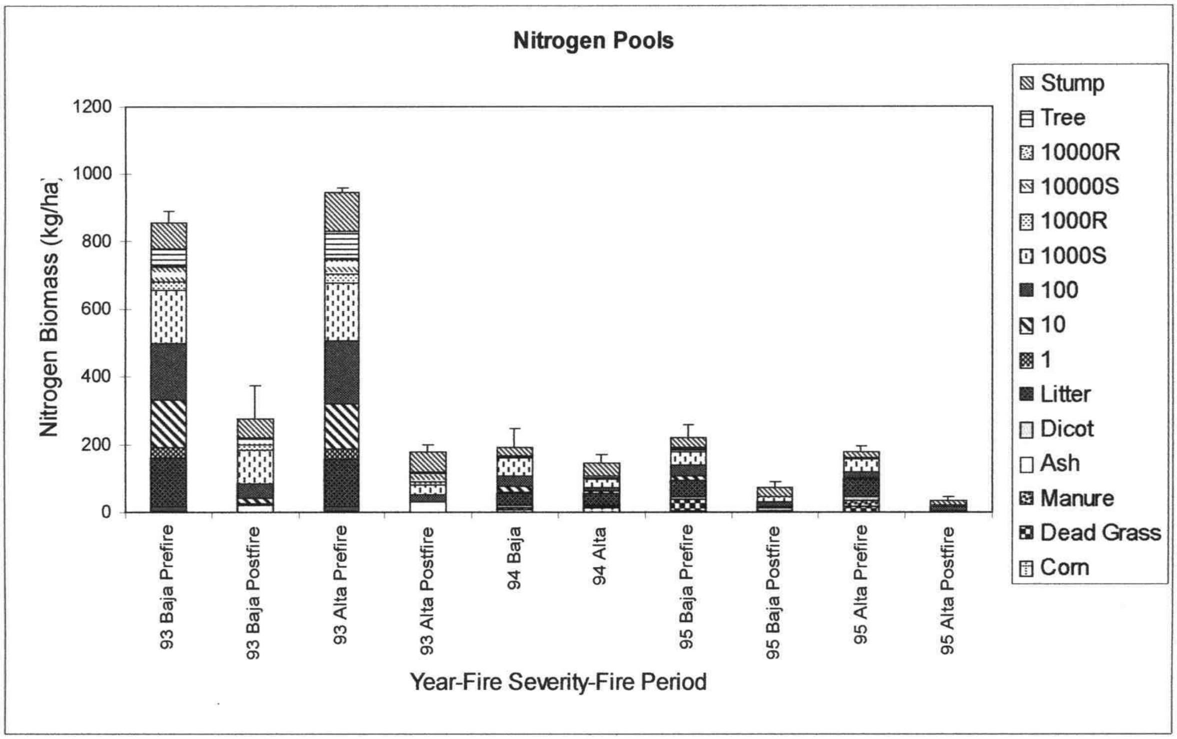


Figure 44: Nitrogen pools divided by component. Data collected 1993-1995 in a study conducted near the Chamela Biological Research Station Jalisco, Mexico.



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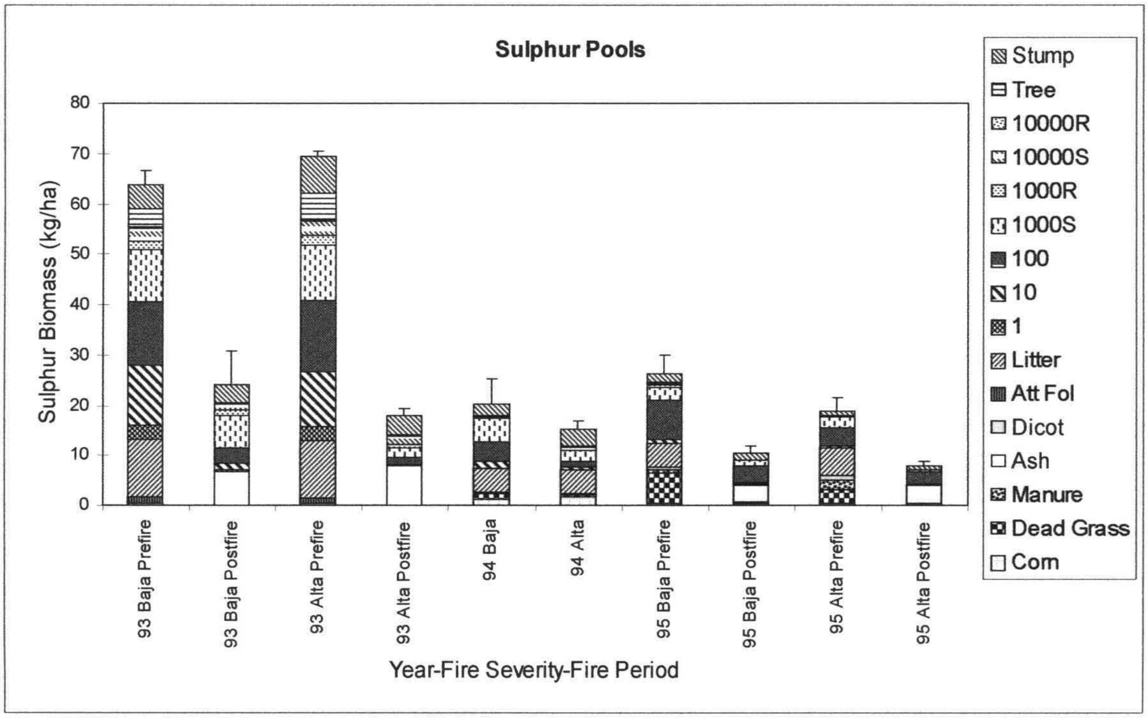


Figure 46: Calcium pools divided by component. Data collected 1993-1995 in a study conducted near the Chamela Biological Research Station Jalisco, Mexico.

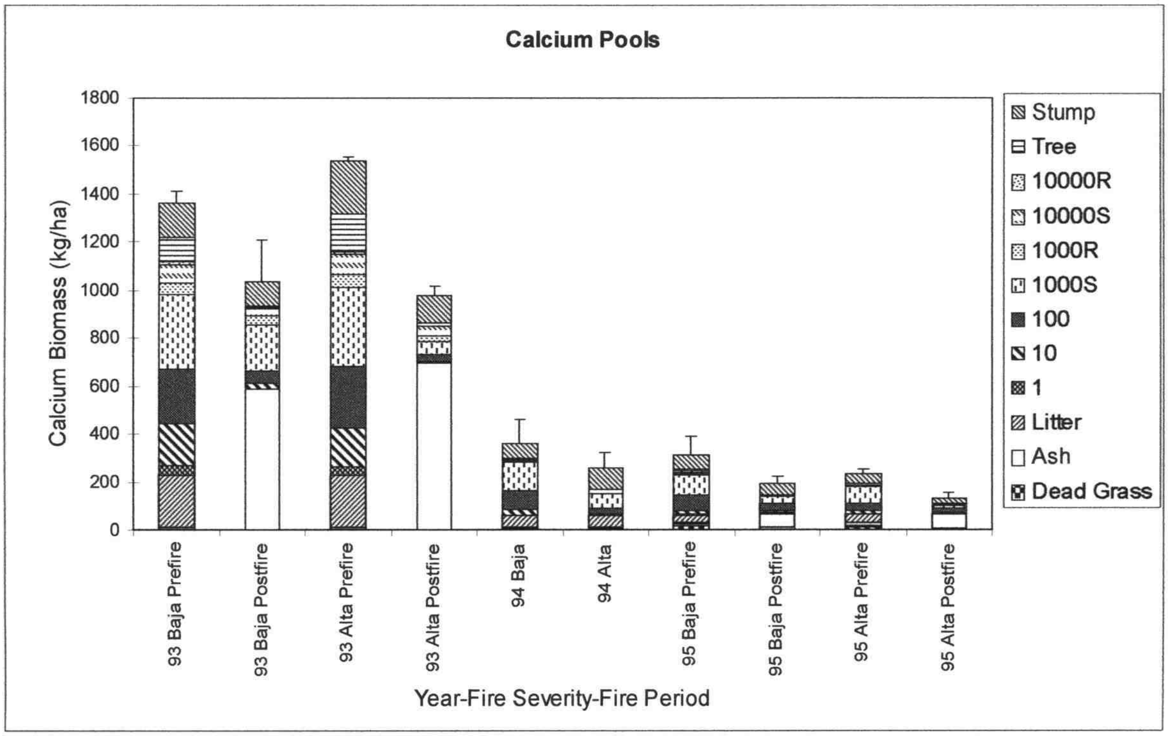
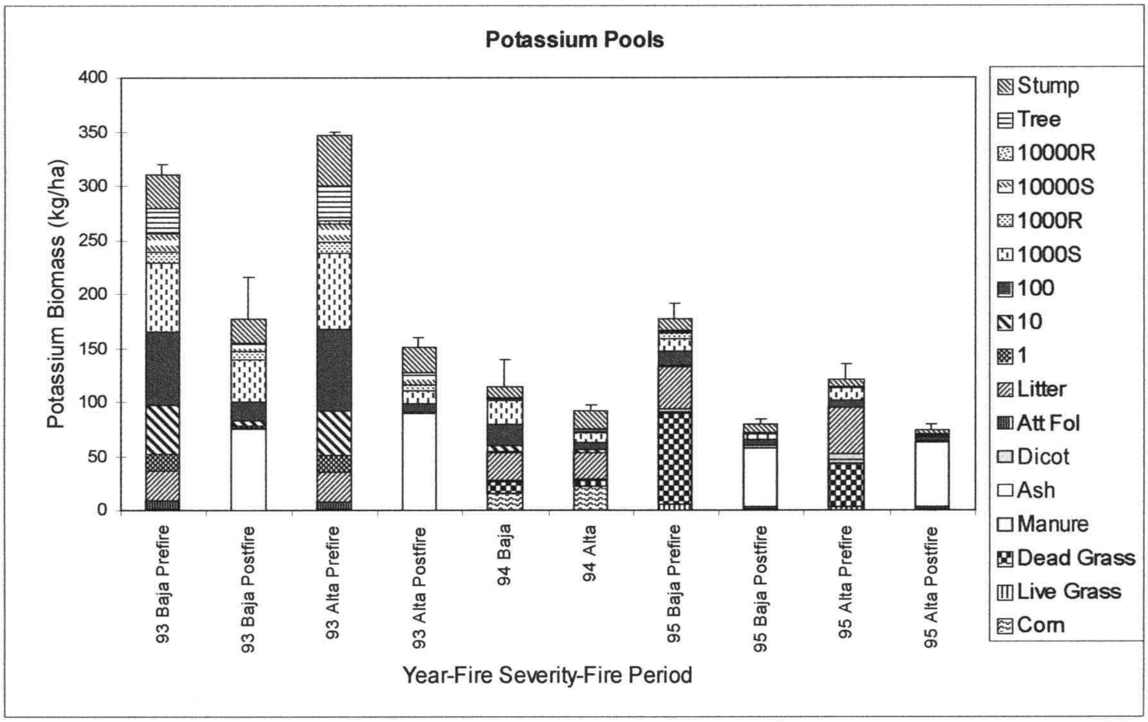


Figure 47: Potassium pools divided by component. Data collected 1993-1995 in a study conducted near the Chamela Biological Research Station Jalisco, Mexico.



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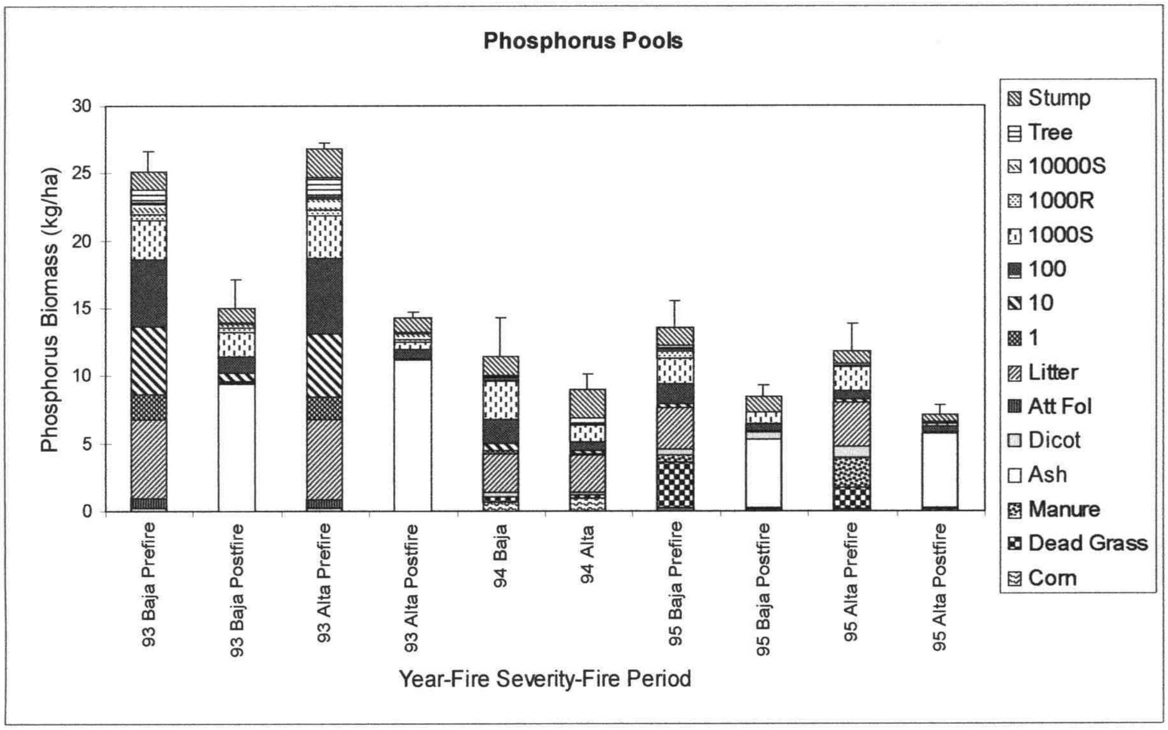


Figure 49. Comparison of forest combustion (%) among other Latin American tropical ecosystem fire studies. TDF-C is 1993 TDF fire at the El Cielo study site Jalisco, Mexico. Pasture-C is 1995 Chamela pasture fire. Low is the Chamela low severity fire result and High is the Chamela high fire severity result.

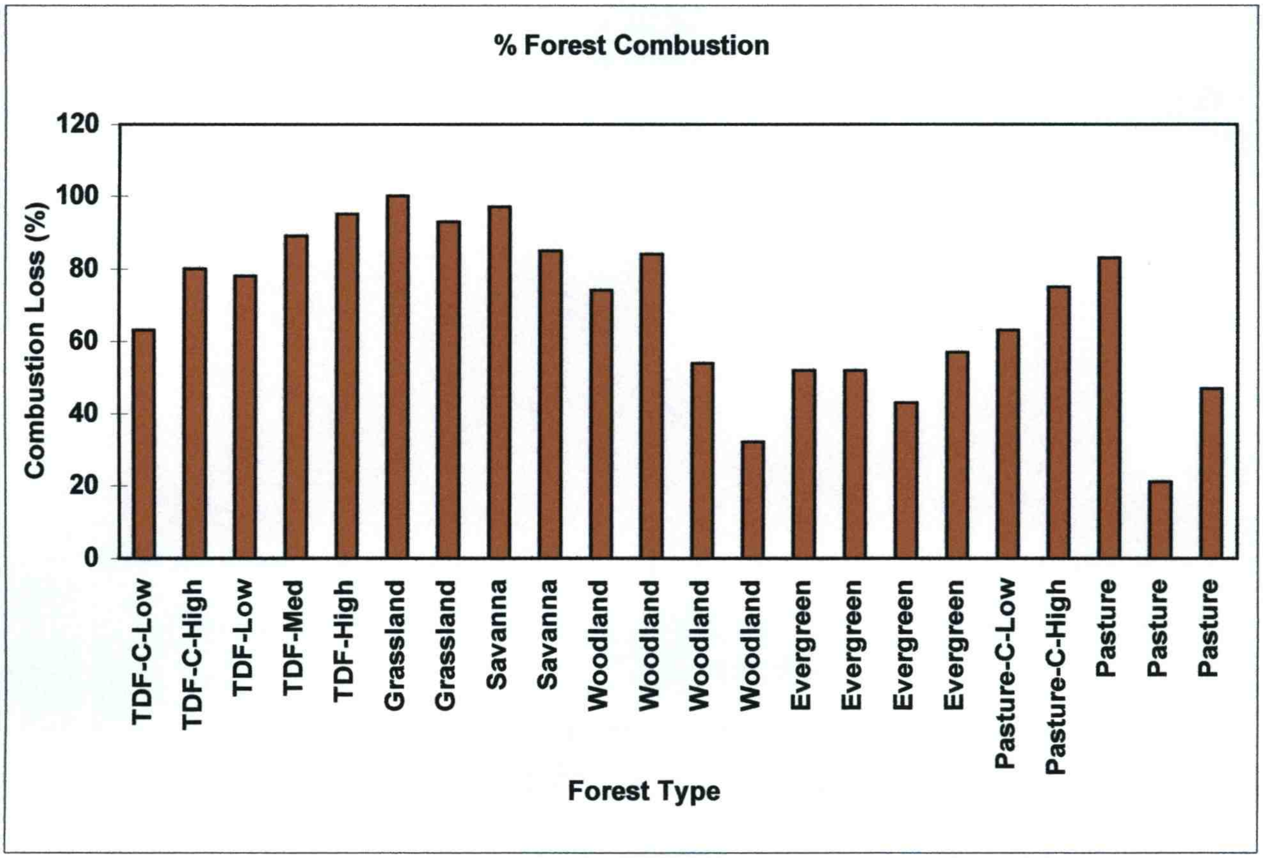
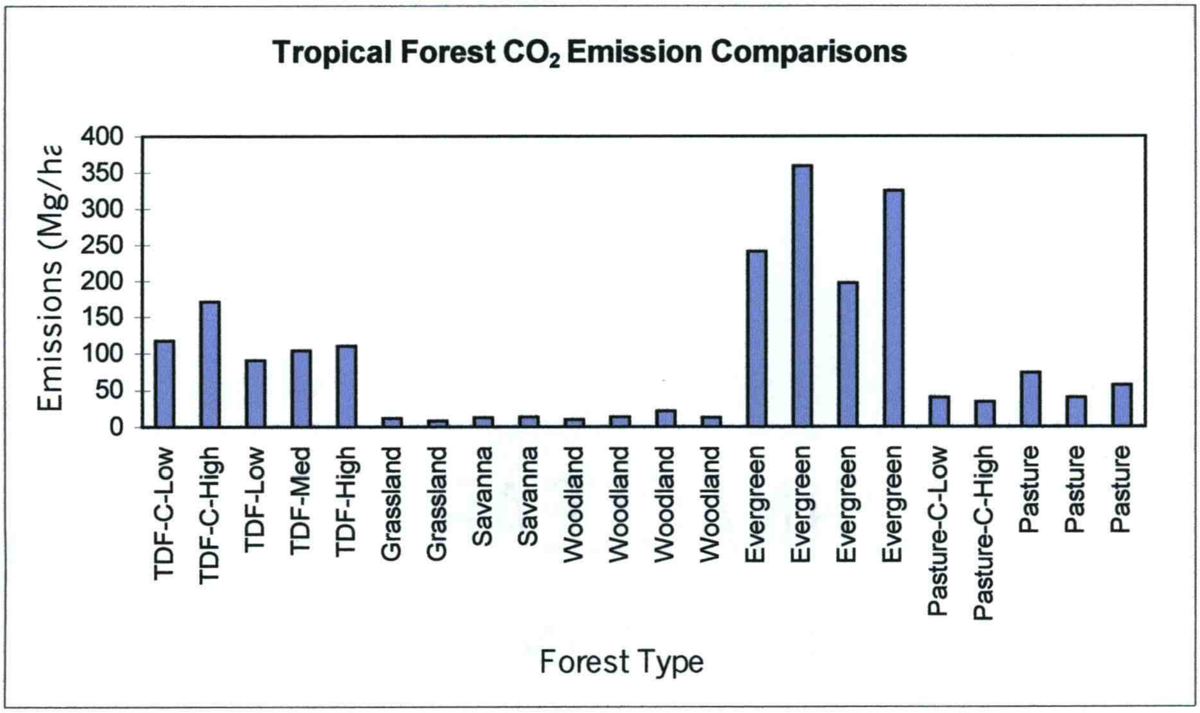


Figure 50. Comparison of CO_2 emissions (Mg ha^{-1}) among other Latin American tropical ecosystem fire studies. TDF-C is 1993 TDF fire at the El Cielo study site Jalisco, Mexico. Pasture-C is 1995 Chamela pasture fire. Low is the Chamela low severity fire result and High is the Chamela high fire severity result. Biomass data for ecosystem type was multiplied by Ward's (1991) emission data for each forest type (i.e. TDF, Pasture, Evergreen Forest, Tropical Grassland, Tropical Woodland and, Tropical Savanna).



List of Appendix Tables

Table 1

Fire Behavior Table: Fire behavior data for two separate fires in 1993 and one single fire in 1995 near the Chamela Biological Research Station, Jalisco, Mexico. Data includes slash and burn dates and fire behavior data collected during burns.

1993 Fire Data

Treatment	High	High	High	Low	Low	Low	Low
Plot	1C & 2A	3B	Mean	1A	2C	3C	Mean
Slash Date	Jan 1993			Feb 1993			
Fire Date	3 May (95 days)	9 May		9 Apr (65 Days)	9 Apr	10 Apr	
Duration (min)		3	3	39		51	45
Winds (mph)	7	9	8	9	7	9	8.3
Flame (Average, meters)							
Length	4.6	4.6	4.6	5.4	5.2	3.8	4.8
Height	3.3	3.3	3.3	4.4	3.5	2.5	3.47
Depth	4.3	4.8	4.55	3.0	5.1	2.6	3.57
Angle $(^{0})$	57.4	45.7	51.55	67.8	63.2	62.9	64.63
Spread (m/min)	6.3	26.1	16.2			1.2	1.2
Humidity (%)	47		47	53.3			53.3
Temp (F^{0})	82		82	79.7			79.7

1995 Fire Data

Single Fire	15 June 1995
Winds (mph)	8
Flame (Average, meters)	
Length	3.5
Height	4.3
Depth	18
Angle $(^{0})$	65.8
Spread (m/min)	133
Humidity (%)	67
Temp (F^{0})	87

Table 2

Dynamics Tables: Dynamics of aboveground pools of carbon, nitrogen, sulphur, calcium, potassium and phosphorus from 1993 to 1995 at the Ejido San Mateo site near the Chamela Biological Research Station, Jalisco, Mexico. Tables include: Prefire biomass, nutrient concentrations (%) of TAGB, Postfire Biomass, Total nutrient losses, and % of total nutrient pools lost by fire. Columns show high and low severity burns in 1993 and 1995 and total loss from prefire 1993 to postfire 1995.

							Cumulative Losses	
	Low Severity 1993	High Severity 1993	Low Severity 1994	High Severity 1994	Low Severity 1995	High Severity 1995	Low Severity 1993-1995	High Severity 1993-1995
				Carbon (Mg ha^{-1})				
Prefire	56.5 ± 1.3	64.6 ± .62	19.0 ± 5.5	13.6 ± 4.1	18.9 ± 3.4	13.5 ± 1.3	56.5 ± 1.3	64.7 ± .62
% of TAGB	47.8 ± .09	47.9 ± .04	46.9 ± .26	46.1 ± .86	46.7 ± .29	46.5 ± .19	47.8 ± .09	48.0 ± .04
Postfire	21.2 ± 8.0	13.1 ± 2.0			7.1 ± 1.4	3.6 ± 1.4	7.1 ± 1.4	3.6 ± 1.4
Released	35.3 ± 9.2	51.6 ± 1.4			11.7 ± 2.3	9.8 ± .68	49.4 ± 2.6	61.0 ± .81
Ash	.41 ± .08	.48 ± .04			.34 ± .02	.37 ± .03	.34 ± .02	.37 ± .03
Post + ash	21.6 ± 7.9	13.5 ± 1.9			7.5 ± 1.4	4.0 ± .15	7.5 ± 1.4	4.0 ± 1.5
Site Loss	34.9 ± 9.1	51.1 ± 1.3			11.4 ± 2.3	9.5 ± .68	49.1 ± 2.5	60.7 ± .83
% Loss	61.1 ± 15.1	79.1 ± 2.8			60.0 ± 2.6	71.4 ± 8.1	86.7 ± 2.8	93.8 ± 2.2
				Nitrogen (kg ha^{-1})				
Prefire	855.9 ± 32.0	943.9 ± 14.2	192.8 ± 53.6	144.8 ± 24.6	220.3 ± 39.4	178.9 ± 16.8	855.9 ± 32.0	943.9 ± 14.2
% of TAGB	.72 ± .02	.70 ± .003	.48 ± .006	.53 ± .05	.55 ± .004	.62 ± .01	.72 ± .02	.70 ± .003
Postfire	252.6 ± 97.6	150.1 ± 22.1			71.4 ± 17.6	35.1 ± 13.3	71.4 ± 17.6	35.1 ± 13.3
Released	603.4 ± 129.4	793.8 ± 8.4			148.9 ± 25.5	143.8 ± 11.2	784.5 ± 49.6	908.8 ± 2.2
Ash	23.3 ± 4.8	27.7 ± 2.5			13.4 ± .98	14.7 ± 1.1	13.4 ± .98	14.7 ± 1.1
Post + ash	275.9 ± 93.1	177.8 ± 19.8			84.8 ± 16.7	49.8 ± 14.2	84.8 ± 16.7	49.8 ± 14.2
Site Loss	580.1 ± 124.9	766.0 ± 6.0			135.6 ± 26.1	129.1 ± 10.7	771.1 ± 48.6	894.1 ± 1.5
% Loss	66.8 ± 12.6	81.2 ± 1.8			61.2 ± 4.3	72.7 ± 5.9	89.9 ± 2.4	94.8 ± 1.4

Table 2 (continued)

	Low Severity 1993	High Severity 1993	Low Severity 1994	High Severity 1994	Low Severity 1995	High Severity 1995	Cumulative Losses Low Severity 1993-1995	Cumulative Losses High Severity 1993-1995
				Potassium (kg ha^{-1})				
Prefire	309.9 ± 9.5	346.2 ± 3.0	114.5 ± 24.1	91.5 ± 6.3	172.9 ± 16.8	121.0 ± 13.3	309.9 ± 9.5	346.2 ± 3.0
% of TAGB	.26 ± .004	.26 ± .0007	.30 ± .02	.35 ± .06	.46 ± .09	.42 ± .02	.26 ± .004	.26 ± .0007
Postfire	101.6 ± 38.6	60.6 ± 9.0			24.5 ± 5.5	14.2 ± 5.5	24.5 ± 5.5	14.2 ± 5.5
Released	208.3 ± 48.1	285.6 ± 6.1			148.4 ± 21.7	106.7 ± 12.0	285.5 ± 14.9	332.0 ± 2.8
Ash	75.5 ± 15.6	89.9 ± 8.1			54.5 ± 4.0	60.0 ± 4.4	54.5 ± 4.0	60.0 ± 4.4
Post + ash	177.1 ± 24.9	150.5 ± 3.6			79.0 ± 1.5	74.3 ± 9.3	79.0 ± 1.5	74.3 ± 9.3
Site Loss	132.8 ± 34.3	195.7 ± 2.9			94.0 ± 18.1	46.7 ± 9.7	230.9 ± 11.0	272.0 ± 6.4
% Loss	42.2 ± 10.1	56.5 ± .86			53.3 ± 5.0	38.1 ± 6.0	74.4 ± 1.3	79.0 ± 2.5
				Calcium (kg ha^{-1})				
Prefire	1365.1 ± 46.5	1534.8 ± 18.9	359.1 ± 103.8	258.5 ± 67.0	310.6 ± 77.5	230.4 ± 20.5	1365.1 ± 46.5	1534.8 ± 8.9
% of TAGB	1.2 ± .01	1.1 ± .002	.89 ± .005	.90 ± .02	.75 ± .06	.80 ± .02	1.2 ± .01	1.1 ± .002
Postfire	452.9 ± 171.3	279.1 ± 42.9			133.7 ± 28.2	67.1 ± 25.2	133.7 ± 28.2	67.1 ± 25.2
Released	912.2 ± 216.7	1255.7 ± 24.1			176.9 ± 52.6	163.3 ± 9.5	1231.3 ± 73.1	1467.7 ± 6.4
Ash	584.2 ± 121.0	695.6 ± 62.4			57.3 ± 4.2	63.0 ± 4.7	.39 ± .0	.37 ± .03
Post + ash	1037.0 ± 75.8	974.7 ± 30.3			191.0 ± 24.0	130.1 ± 29.2	191.0 ± 24.0	130.1 ± 29.2
Site Loss	328.0 ± 119.6	560.1 ± 42.9			119.6 ± 55.7	100.3 ± 11.0	1174.1 ± 69.2	1404.7 ± 10.7
% Loss	23.5 ± 8.1	36.5 ± 2.5			34.6 ± 9.3	44.7 ± 7.8	85.9 ± 2.3	91.6 ± 1.8

Table 2 (continued)

	Low Severity 1993	High Severity 1993	Low Severity 1994	High Severity 1994	Low Severity 1995	High Severity 1995	Cumulative Losses Low Severity 1993-1995	Cumulative Losses High Severity 1993-1995
				Phosphorus (kg ha^{-1})				
Prefire	25.2 ± 1.4	26.8 ± .47	11.4 ± 2.8	8.9 ± 1.2	13.2 ± 1.7	11.8 ± 1.9	25.2 ± 1.4	26.8 ± .47
% of TAGB	.02 ± .001	.02 ± .0002	.03 ± .001	.03 ± .004	.03 ± .001	.04 ± .003	.02 ± .001	.02 ± .0002
Postfire	5.6 ± 2.3	3.1 ± .42			3.4 ±.90	1.6 ± .67	3.4 ± .90	1.6 ± .67
Released	19.7 ± 3.6	23.7 ± .20			9.7 ± 1.2	10.1 ± 1.5	21.8 ± 2.3	25.2 ± .27
Ash	9.4 ± 2.0	11.2 ± 1.0			5.0 ± .37	5.5 ± .41	5.0 ± .37	5.5 ± .41
Post + ash	15.0 ± .90	14.3 ± .62			8.4 ± .54	7.2 ± 1.0	8.4 ± 5.4	7.2 ± 1.0
Site Loss	10.2 ± 1.8	12.5 ± .97			4.7 ± 1.3	4.6 ± 1.2	16.8 ± 1.9	19.6 ± .57
% Loss	40.0 ± 5.5	46.6 ± 3.0			34.5 ± 6.3	38.0 ± 6.7	66.1 ± 4.1	73.4 ± 3.3
				Sulphur (kg ha^{-1})				
Prefire	63.8 ± 2.6	69.5 ± 1.1	20.2 ± 5.1	15.1 ± 1.8	26.2 ± 3.6	18.9 ± 2.6	63.8 ± 2.6	69.5 ± 1.1
% of TAGB	.05 ± .002	.05 ± .0003	.05 ± .002	.06 ± .008	.07 ± .003	.06 ± .003	.05 ± .002	.05 ± .0003
Postfire	17.4 ± 6.8	10.1 ± 1.5			6.9 ± 1.4	4.2 ± .96	6.9 ± 1.4	4.2 ± .96
Released	46.5 ± 9.4	59.4 ± .46			19.2 ± 2.7	14.7 ± 2.1	56.9 ± 4.0	65.3 ± .52
Ash	6.6 ± 1.4	7.8 ± .70			3.4 ± .25	3.7 ± .28	3.4 ± .25	3.7 ± .28
Post + ash	24.0 ± 5.6	17.9 ± .83			10.3 ± 1.1	7.9 ± 1.2	10.3 ± 1.1	7.9 ± 1.2
Site Loss	39.9 ± 8.1	51.6 ± .30			15.8 ± 2.8	11.0 ± 1.9	53.5 ± 3.8	61.5 ± .33
% Loss	61.1 ± 10.7	74.2 ± .77			59.8 ± 4.3	57.6 ± 4.8	83.6 ± 2.5	88.6 ± 1.5

Table 3 Significance Tables: P-Values of comparisons between block means for data collected at the Ejido San Mateo site near the Chamela Biological Research Station, Jalisco, Mexico. Table 1: Comparisons between Prefire Low Severity versus Prefire High Severity for 1993, 1994 and 1995 and Postfire Low Severity versus Postfire High Severity for 1993 and 1995.

	1993 Prefire Low-Prefire High	1993 Postfire Low-Postfire High	1994 Prefire Low-Prefire High	1995 Prefire Low-Prefire High	1995 Postfire Low-Postfire High
Fine Fuels					
Litter	.983		.876	.547	
Att Fol	.443	.105			
Dicot	.867		.694	.554	.247
Corn			.033		
Live Grass				.579	
Dead Grass			.263	.168	.415
Manure				.342	
Wood					
0-0.64	.802	.106	.368	.520	.177
0.65-2.54	.348	.406	.457	.529	.496
2.55-7.62					
Sound	.376	.156	.120	.133	.155
Fall					.619
7.63-20.5					
Sound	.705	.130	.232	.828	.081
Fall					.621
Rotten	.450	.583	.921	.301	
>20.5					
Sound	.986	.723			
Rotten	.728				
Totals					
Fine Fuels	.959	.105	.816	.405	.519
Wood	.556	.227	.216	.314	.035
Biomass	.551	.227	.224	.134	.041
Tree	.469	.880	.469	.959	.880
Stump	.333	.921	.663	.512	.505
TAGB	.006	.377	.473	.206	.159
Ash		.366			.413

Table 3 (continued)

Significance Tables: P-Values of comparisons between block means for data collected at the Ejido San Mateo site near the Chamela Biological Research Station, Jalisco, Mexico. Table 2: Comparisons within severity treatments. Differences between prefire versus postfire for both severities for 1993 and 1995.

	93 Low Prefire-Postfire	93 High Prefire-Postfire	95 Low Prefire-Postfire	95 High Prefire-Postfire
Fine Fuels				
Litter	.002	.000	.000	.001
Att Fol	.002	.001		
Dicot	.081	.093	.989	.107
Corn				
Live Grass			.184	.125
Dead Grass			.029	.008
Manure				.213
Wood				
0-0.64	.002	.001	.552	.182
0.65-2.54	.002	.000	.297	.095
2.55-7.62				
Sound	.003	.001	.115	.283
7.63-20.5				
Sound	.179	.003	.072	.001
Rotten	.587	.023	.261	
>20.5				
Sound	.418	.195		
Rotten		.120		
Totals				
Fine Fuels	.003	.000	.002	.002
Wood	.015	.000	.118	.002
Biomass	.009	.000	.008	.000
Tree	.092	.043	.602	.565
Stump	.630	.048	.750	.608
TAGB	.011	.000	.027	.006

Table 3 (continued)

Significance Tables: P-Values of comparisons between block means for data collected at the Ejido San Mateo site near the Chamela Biological Research Station, Jalisco, Mexico. Table 3: Comparisons within severity treatments. Differences between postfire 1993 and prefire 1995 to compare decomposition and regrowth and differences between Prefire 1993 and postfire 1995 for both severities.

	1993 Postfire-1995 Prefire Low Severity	1993 Postfire-1995 Prefire High Severity	1993 Prefire-1995 Postfire Low Severity	1993 Prefire-1995 Postfire High Severity
Fine Fuels				
Litter	.000	.001	.002	.000
Att Fol	.104		.001	.001
Dicot	.247	.107	.406	.093
Corn				
Live Grass	.184	.125		
Dead Grass	.028	.007	.102	.139
Manure		.213		
Wood				
0-0.64	.212	.193	.001	.001
0.65-2.54	.683	.508	.000	.000
2.55-7.62				
Sound	.776	.782	.001	.000
7.63-20.5				
Sound	.270	.011	.001	.002
Rotten	.380	.015	.000	
>20.5				
Sound	.479	.046	.132	.007
Rotten				.120
Totals				
Fine Fuels	.002	.001	.003	.000
Wood	.399	.146	.000	.000
Biomass	.998	.008	.000	.000
Tree	.977	.914	.079	.036
Stump	.485	.198	.284	.002
TAGB	.861	.674	.000	.000
Ash	.008	.279	.000	.000

Table 3 (continued)

Significance Tables: P-Values of comparisons between block means for data collected at the Ejido San Mateo site near the Chamela Biological Research Station, Jalisco, Mexico. Table 4: Comparisons between severities for differences in combustion rates. Data for Low severity combustion rates versus High severity combustion rates for 1993 and 1995. Differences in combustion rates with losses from 1993 Prefire to 1993 Postfire (Total combustion over study length).

	Combustion Factors		
	1993	1995	1993-1995
Fine Fuels			
Litter			
Att Fol	.152		
Dicot		.191	.295
Live Grass			
Dead Grass		.320	
Manure			
Wood			
0-0.64	.152	.307	.223
0.65-2.54	.421	.495	.523
2.55-7.62			
Sound	.155	.245	.155
7.63-20.5			
Sound	.088	.050	.044
Rotten			
>20.5			
Sound	.281		
Rotten	.580		
Totals			
Fine Fuels	.162	.531	.464
Wood	.163	.247	.030
Biomass	.178	.245	.031
Tree	.473	.876	.652
Stump	.328	.304	.277
TAGB	.312	.259	.116

Table 3 (continued)

Significance Tables: P-Values of comparisons for data collected at the Ejido San Mateo site near the Chamela Biological Research Station, Jalisco, Mexico. Table 5: Nutrient statistics for Carbon, Nitrogen, and Sulphur. Comparisons are: 1) Prefire-Prefire: Comparison between severities' prefire biomass, 2) Postfire-Postfire: Comparison between severities' postfire biomass, 3) Prefire-Postfire: Comparisons within each treatment before and after fire, 4) 1993 Prefire – 1995 Postfire: Comparisons within each treatment for the three years of the study with one slash fire (1993) and a pasture fire two years later (1995). Baja sites were low severity and Alta sites were high severity fire treatments.

	Carbon			Nitrogen			Sulphur		
	Total Foliage	Total Wood	TAGB	Total Foliage	Total Wood	TAGB	Total Foliage	Total Wood	TAGB
1993									
Prefire – Prefire	.933	.500	.005	.897	.542	.066	.868	.580	.121
Postfire – Postfire	.011	.000	.378	.011	.000	.364	.011	.000	.355
Baja									
Prefire – Postfire	.000	.000	.012	.000	.000	.004	.000	.000	.003
Alta									
Prefire – Postfire	.000	.000	.000	.000	.000	.000	.000	.000	.000
1995									
Prefire – Prefire	.400	.021	.209	.849	.011	.388	.687	.000	.175
Postfire – Postfire	.305	.001	.157	.140	.001	.176	.422	.023	.181
Baja									
Prefire – Postfire	.000	.000	.032	.000	.000	.026	.000	.000	.007
Alta									
Prefire – Postfire	.000	.000	.007	.000	.000	.003	.000	.003	.006
1993 Prefire – 1995 Postfire									
Baja	.000	.000	.000	.000	.000	.000	.000	.000	.000
Alta	.000	.000	.000	.000	.000	.000	.000	.000	.000

Table 3 (continued)

Significance Tables: P-Values of comparisons for data collected at the Ejido San Mateo site near the Chamela Biological Research Station, Jalisco, Mexico. Table 5: Nutrient statistics for Calcium, Potassium, and Phosphorus. Comparisons are: 1) Prefire-Prefire: Comparison between severities prefire biomass, 2) Postfire-Postfire: Comparison between severities postfire biomass, 3) Prefire-Postfire: Comparisons within each treatment before and after fire, 4) 1993 Prefire – 1995 Postfire: Comparisons within each treatment for the three years of the study with one slash fire (1993) and a pasture fire two years later (1995). Baja sites were low severity and Alta sites were high severity fire treatments.

	Calcium			Potassium			Phosphorus		
	Total Foliage	Total Wood	TAGB	Total Foliage	Total Wood	TAGB	Total Foliage	Total Wood	TAGB
1993									
Prefire – Prefire	.946	.532	.028	.761	.507	.022	.887	.647	.351
Postfire – Postfire	.011	.000	.381	.011	.000	.360	.011	.000	.333
Baja									
Prefire – Postfire	.000	.000	.007	.000	.000	.006	.000	.000	.004
Alta									
Prefire – Postfire	.000	.000	.000	.000	.000	.000	.000	.000	.000
1995									
Prefire – Prefire	.617	.015	.374	.203	.005	.055	.752	.010	.575
Postfire – Postfire	.107	.001	.153	.906	.001	.259	.165	.001	.190
Baja									
Prefire – Postfire	.000	.000	.099	.000	.000	.001	.000	.000	.010
Alta									
Prefire – Postfire	.000	.000	.007	.000	.000	.002	.000	.000	.008
1993 Prefire – 1995 Postfire									
Baja	.000	.000	.000	.000	.000	.000	.000	.000	.000
Alta	.000	.000	.000	.000	.000	.000	.000	.000	.000

Table 4

Biomass Tables: Total aboveground biomass (Mg ha^{-1}) before and after burning and % consumption (combustion factor) from 1993 to 1995 at the Ejido San Mateo site near the Chamela Biological Research Station, Jalisco, Mexico. N = 45 transects per severity of burn for foliage and wood debris components, N = 9 for stumps and N = 3 for trees and TAGB.

(1993)	Low Severity Prefire	Postfire	Combustion Factor (%)	High Severity Prefire	Postfire	Combustion Factor (%)
Fine Fuels						
Litter	7.4 ± .61	0.0 ± .00	100 ± .00	7.4 ± .56	0.0 ± .00	100 ± .00
Att Fol	.47 ± .03	.04 ± .02	88.9 ± 3.8	.41 ± .03	0.0 ± .00	100 ± .13
Dicot	.17 ± .06	0.0 ± .00	100 ± .00	0.2 ± .04	0.0 ± .00	100 ± .00
Wood Debris (diameter, cm)						
0-0.64	2.6 ± .17	.23 ± .09	88.8 ± 3.8	2.4 ± .19	.001 ± .001	99.9 ± .13
0.65-2.54	16.8 ± 1.2	2.0 ± .78	89.1 ± 3.6	15.5 ± 1.2	.46 ± .160	96.8 ± .97
2.55-7.62	24.7 ± 1.9	6.1 ± .84	70.8 ± 4.7	28.0 ± 1.8	2.8 ± .522	87.7 ± 3.7
7.63-20.5						
Sound	29.4 ± 2.8	18.0 ± 3.2	31.7 ± 11.0	31.4 ± 3.5	5.5 ± 1.3	78.5 ± 5.7
Rotten	4.4 ± .88	3.2 ± 1.1	85.1 ± 7.2	5.0 ± 1.2	2.0 ± .93	86.5 ± 9.9
Total	33.8 ± 2.9	21.2 ± 3.1	28.7 ± 10.0	36.4 ± 4.1	7.5 ± 1.5	62.3 ± 14.4
>20.5						
Sound	7.7 ± 2.7	3.1 ± 1.7	56.1 ± 22.9	7.8 ± 2.8	4.4 ± 1.9	71.6 ± 19.4
Rotten	.81 ± .81	0.0 ± .00	100 ± .00	1.2 ± .83	0.0 ± .00	100 ± .00
Total	8.5 ± 2.8	3.1 ± 1.7	60.9 ± 20.8	9.0 ± 2.8	4.4 ± 1.9	77.3 ± 15.7
Totals + Trees + Stumps						
Total Fine Fuels	8.1 ± .61	0.04 ± .06	99.2 ± .29	8.0 ± .56	0.02 ± .02	99.99 ± .005
Total Wood	86.4 ± 4.2	32.7 ± 4.0	62.4 ± 4.1	91.3 ± 5.9	15.2 ± 2.5	80.4 ± 4.0
Total Biomass	94.5 ± 4.3	32.7 ± 4.0	65.4 ± 3.8	99.3 ± 5.9	15.2 ± 2.5	82.8 ± 3.3
Tree	9.9 ± 4.0	.80 ± .80	78.1 ± 21.9	14.8 ± 4.6	1.0 ± 1.0	95.7 ± 4.3
Stump	13.9 ± 5.0	10.1 ± 2.6	27.3 **	20.9 ± 5.7	10.6 ± 3.1	4.43 ± 41.8
TAGB	118.2 ± 2.8	43.6 ± 16.4	62.4 ± 15.1	134.9 ± 1.4	26.8 ± 4.1	80.2 ± 2.8
Ash		3.9 ± .82			4.68 ± .42	

** No SE for 1993 low severity stumps. %Consumption calculated from means only.

Table 4 (continued)

(1994)	Low Severity	High Severity
Fine Fuels		
Litter	3.2 ± .43	3.1 ± .44
Dicot	0.4 ± .24	0.3 ± .10
Corn	1.4 ± .22	1.9 ± .21
Dead Grass	1.1 ± .38	0.5 ± .21
Wood Debris (diameter, cm)		
0-0.64	0.2 ± .04	.07 ± .03
0.65-2.54	1.9 ± .52	.66 ± .15
2.55-7.62	9.1 ± .94	3.1 ± .57
7.63-20.5		
Sound	14.4 ± 2.4	6.5 ± 1.0
Rotten	0.3 ± .12	.23 ± .14
Total	14.7 ± 2.4	6.7 ± 1.1
>20.5		
Sound	0.6 ± .57	
Rotten		0.2 ± .20
Total	0.6 ± .57	0.2 ± .20
Totals + Trees + Stumps		
Total Fine Fuels	6.1 ± .80	5.8 ± .54
Total Wood	26.4 ± 3.2	10.7 ± 1.3
Total Biomass	32.5 ± 3.3	16.5 ± 1.3
Tree	1.0 ± .95	2.1 ± .98
Stump	6.9 ± 1.6	10.6 ± 5.6
TAGB	40.4 ± 11.5	29.2 ± 8.2

Table 4 (continued)

(1995)	Low Severity Prefire	Postfire	Combustion Factor (%)	High Severity Prefire	Postfire	Combustion Factor (%)
Fine Fuels						
Litter	5.0 ± .37	0.0 ± .00	100 ± .00	5.5 ± .45	0.2 ± .17	94.3 ± 5.8
Dicot	0.6 ± .24	0.6 ± .27		1.0 ± .56	0.0 ± .00	100 ± .00
Live Grass	0.4 ± .25	0.0 ± .00	100 ± .00	0.2 ± .17	0.0 ± .00	100 ± .00
Dead Grass	6.8 ± 2.1	0.1 ± .05	86.0 ± 12.3	3.3 ± .59	0.1 ± .10	42.3 ± 41.8
Manure	0.2 ± .23	0.0 ± .00	100 ± .00	1.0 ± .37	0.0 ± .00	100 ± .00
Wood Debris (diameter, cm)						
0-0.64	0.1 ± .03	.03 ± .02	72.2 ± 18	.03 ± .02	0.0 ± .00	100 ± .00
0.65-2.54	1.2 ± .43	.30 ± .16	77.7 ± 8.8	.68 ± .23	0.1 ± .05	70.2 ± 15.1
2.55-7.62						
Sound	6.9 ± .74	3.0 ± .44	50.0 ± 7.0	3.1 ± .54	2.1 ± .49	18.4 ± 16.2
Fall		0.1 ± .11			0.2 ± .12	
Total	6.9 ± .74	3.1 ± .44	50.0 ± 7.0	3.1 ± .54	2.3 ± .49	18.4 ± 16.2
7.63-20.5						
Sound	9.2 ± 1.8	3.9 ± .91	58.4 ± 8.3	8.8 ± 1.5	1.1 ± .42	81.6 ± 6.32
Fall		.98 ± .56			0.3 ± .25	
Rotten	1.1 ± .36	0.0 ± .00	100 ± .00	0.1 ± .10	0.0 ± .00	100 ± .00
Total	10.4 ± 2.0	4.9 ± .99	54.4 ± 8.8	8.9 ± 1.5	1.4 ± .48	72.2 ± 11.2
>20.5						
Sound	.63 ± .63	0.0 ± .00	100 ± .00			
Rotten	.60 ± .39	0.0 ± .00	100 ± .00			
Total	1.2 ± .73	0.0 ± .00	100 ± .00			
Totals + Trees + Stumps						
Total Fine Fuels	13.0 ± 2.2	0.6 ± .27	86.0 ± 7.0	11.0 ± 1.2	0.32 ± .20	87.5 ± 8.0
Total Wood	19.8 ± 2.4	8.3 ± 1.1*	52.3 ± 6.5	12.6 ± 1.8	3.82 ± .72*	67.9 ± 6.0
Total Biomass	32.7 ± 3.1	8.9 ± 1.1*	71.3 ± 4.1	23.6 ± 2.2	4.13 ± .74*	83.6 ± 3.6
Tree	.84 ± .73	.38 ± .34	58.9 ± 5.4	.88 ± .45	.48 ± .48	58.9 ± 5.5
Stump	6.7 ± 2.2	5.5 ± 2.1	17.9 **	4.6 ± 1.8	3.0 ± 2.0	49.2 ± 50.0
TAGB	40.3 ± 6.9	14.8 ± 2.9*	63.1 ± 4.5	29.0 ± 2.8	7.6 ± 3.0*	75.0 ± 7.9
Ash		2.1 ± .15			2.3 ± .17	

*1995 Postfire biomass totals include fall measurements. ** No SE for 1995 low severity stumps. %Consumption calculated from means only.

Table 5

Concentration Tables: Mean nutrient concentrations (%) from 1993 to 1995 at the Ejido San Mateo site near the Chamela Biological Research Station, Jalisco, Mexico. N for each component is in parentheses after component title.

	Carbon (%)	Nitrogen (%)	Sulphur (%)	Calcium (%)	Potassium (%)	Phosphorus (%)
Fine Fuels						
Litter						
1993 (3)	40.8 ± .69	1.9 ± .12	.15 ± .007	2.9 ± .12	.37 ± .04	.08 ± .00
1994 (9)	33.2 ± 1.4	1.2 ± .41	.15 ± .12	1.6 ± .18	.81 ± .09	.09 ± .01
1995 (16)	42.8 ± .26	.94 ± .03	.10 ± .004	.65 ± .06	.78 ± .08	.06 ± .00
Dicot						
1993 (9)	46.0 ± .46	1.4 ± .08	.08 ± .004	1.2 ± .13	.45 ± .02	.09 ± .01
1994 (9)	46.0 ± .46	1.4 ± .08	.08 ± .004	1.2 ± .13	.45 ± .02	.09 ± .01
1995 (9)	46.0 ± .46	1.4 ± .08	.08 ± .004	1.2 ± .13	.45 ± .02	.09 ± .01
Att Fol						
1993 (4)	47.4 ± .25	3.2 ± .12	.33 ± .22	2.0 ± .14	1.7 ± .14	.16 ± .01
Live Grass						
95 (11)	45.2 ± .56	.59 ± .06	.06 ± .005	.18 ± .01	1.3 ± .09	.04 ± .00
Dead Grass						
94 (9)	44.0 ± .04	.41 ± .19	.09 ± .07	.26 ± .01	.91 ± .08	.03 ± .00
95 (14)	44.7 ± .12	.50 ± .02	.09 ± .006	.29 ± .02	1.2 ± .09	.05 ± .00
Manure						
95 (10)	41.5 ± 1.2	1.5 ± .06	.20 ± .02	1.1 ± .04	.39 ± .02	.22 ± .02
Corn						
94 (9)	45.2 ± .18	.68 ± .26	.08 ± .03	.25 ± .18	1.2 ± .93	.05 ± .04
Wood Debris						
1 Hour (0-0.64)						
93 (10)	47.2 ± .09	1.2 ± .22	.11 ± .13	1.5 ± .11	.64 ± .05	.07 ± .00
94 (10)	47.2 ± .09	1.2 ± .22	.11 ± .13	1.5 ± .11	.64 ± .05	.07 ± .00
95 (11)	47.8 ± .17	.76 ± .03	.06 ± .007	1.3 ± .07	.14 ± .00	.03 ± .00

Table 5 (continued)

	Carbon (%)	Nitrogen (%)	Sulphur (%)	Calcium (%)	Potassium (%)	Phosphorus (%)
10 Hour (0.65-2.54)						
93 (10)	46.5 ± .21	.84 ± .09	.07 ± .07	1.0 ± .10	.27 ± .03	.03 ± .00
94 (10)	46.5 ± .21	.84 ± .09	.07 ± .07	1.0 ± .10	.27 ± .03	.03 ± .00
95 (11)	47.8 ± .17	.76 ± .03	.06 ± .007	1.3 ± .07	.14 ± .00	.03 ± .00
100 Hour (2.55-7.62)						
93 (11)	48.0 ± .14	.67 ± .09	.05 ± .07	.93 ± .09	.27 ± .03	.02 ± .00
94 (27)	48.4 ± .24	.36 ± .16	.04 ± .08	.87 ± .05	.22 ± .06	.02 ± .00
95 (10)	47.8 ± .36	.51 ± .02	.11 ± .05	.97 ± .11	.18 ± .03	.02 ± .00
1000 Hour (7.62-20.5)						
93 (14)	48.9 ± .13	.54 ± .08	.04 ± .09	1.1 ± .11	.22 ± .06	.01 ± .00
94 (35)	48.7 ± .21	.37 ± .17	.03 ± .09	.85 ± .04	.15 ± .01	.02 ± .00
95 (10)	48.3 ± .26	.42 ± .02	.03 ± .006	.86 ± .09	.14 ± .02	.02 ± .00
1000 Hour Rotten						
93 (14)	48.9 ± .13	.54 ± .08	.04 ± .09	1.1 ± .11	.22 ± .06	.01 ± .00
94 (35)	48.7 ± .21	.37 ± .17	.03 ± .09	.85 ± .04	.15 ± .01	.02 ± .00
95 (10)	46.5 ± .03	.50 ± .03	.05 ± .004	.83 ± .05	.42 ± .03	.05 ± .00
10,000 Hour (>20.5)						
93 (14)	48.9 ± .13	.54 ± .08	.04 ± .09	1.1 ± .11	.22 ± .06	.01 ± .00
94 (35)	48.7 ± .21	.37 ± .17	.03 ± .09	.85 ± .04	.15 ± .01	.02 ± .00
95 (10)	48.3 ± .26	.42 ± .02	.03 ± .006	.86 ± .09	.14 ± .02	.02 ± .00
10,000 Hour Rotten (>20.5)						
93 (14)	48.9 ± .13	.54 ± .08	.04 ± .09	1.1 ± .11	.22 ± .06	.01 ± .00
94 (35)	48.7 ± .21	.37 ± .17	.03 ± .09	.85 ± .04	.15 ± .01	.02 ± .00
95 (10)	48.3 ± .26	.42 ± .02	.03 ± .006	.86 ± .09	.14 ± .02	.02 ± .00
Ash						
93 (5)	10.3 ± .79	.59 ± .06	.17 ± .54	14.9 ± 2.2	1.9 ± .28	.24 ± .04
95 (16)	16.2 ± .88	.64 ± .03	.16 ± .01	2.7 ± .32	2.6 ± .14	.24 ± .02

Table 6

Carbon Tables: Total aboveground pools (Mg ha^{-1}) of carbon before and after burning from 1993 to 1995 at the Ejido San Mateo site near the Chamela Biological Research Station, Jalisco, Mexico. Calculations were made using: Carbon Biomass = [Component biomass * mean carbon %] * 10. Standard errors calculated with N = 45 transects per severity of burn for foliage and wood debris components, N = 9 for stumps and N = 3 for trees and TAGB.

1993	Low Severity		High Severity	
	Prefire	Postfire	Prefire	Postfire
Fine Fuels				
Litter	3.0 ± .24		3.0 ± .23	
Att Fol	.22 ± .01	.02 ± .008	.19 ± .02	
Dicot	.08 ± .03		.09 ± .02	
Wood Debris (diameter, cm)				
0-0.64	1.2 ± .08	.11 ± .04	1.2 ± .09	.0005 ± .0005
0.65-2.54	7.8 ± .55	.94 ± .36	7.2 ± .56	.22 ± .07
2.55-7.62	11.9 ± .90	2.9 ± .40	13.4 ± .86	1.4 ± .25
7.63-20.5				
Sound	14.4 ± 1.4	8.8 ± 1.6	15.3 ± 1.7	2.7 ± .63
Rotten	2.2 ± .43	1.6 ± .52	2.5 ± .60	.98 ± .46
Total	16.5 ± 1.4	10.4 ± 1.5	17.8 ± 2.0	3.7 ± .73
>20.5				
Sound	3.8 ± 1.3	1.5 ± .85	3.8 ± 1.4	2.1 ± .92
Rotten	.39 ± .39		.58 ± .41	
Total	4.2 ± 1.4	1.5 ± .85	4.4 ± 1.4	2.1 ± .92
Totals + Trees + Stumps				
Total Fine Fuels	3.3 ± .25	.02 ± .008	3.3 ± .23	
Total Wood	41.6 ± 2.0	15.9 ± 1.9	43.9 ± 2.9	7.4 ± 1.2
Total Biomass	44.9 ± 2.1	15.9 ± 1.9	47.2 ± 2.9	7.4 ± 1.2
Tree	4.8 ± 2.0	.39 ± .39	7.2 ± 2.2	.49 ± .49
Stump	6.8 ± 2.4	4.9 ± 1.3	10.2 ± 2.8	5.2 ± 1.5
TAGB	56.5 ± 1.3	21.2 ± 8.0	64.7 ± .62	13.1 ± 2.0
Ash		.40 ± .08		.48 ± .04

Table 6 (continued)

1994	Low Severity	High Severity
Fine Fuels		
Litter	1.1 ± .14	1.0 ± .15
Dicot	.18 ± .11	.13 ± .04
Corn	.61 ± .10	.87 ± .09
Dead Grass	.50 ± .17	.22 ± .09
Wood Debris (diameter,cm)		
0-0.64	.08 ± .02	.03 ± .01
0.65-2.54	.86 ± .24	.31 ± .07
2.55-7.62	4.4 ± .46	1.5 ± .28
7.63-20.5		
Sound	7.0 ± 1.2	3.1 ± .51
Rotten	.13 ± .06	.11 ± .07
Total	7.1 ± 1.2	3.3 ± .53
>20.5		
Sound	.28 ± .28	
Rotten		.10 ± .10
Total	.28 ± .28	.10 ± .10
Totals + Trees + Stumps		
Total Fine Fuels	2.3 ± .32	2.2 ± .20
Total Wood	12.8 ± 1.5	5.2 ± .61
Total Biomass	15.1 ± 1.6	7.4 ± .61
Tree	.50 ± .46	1.0 ± .48
Stump	3.4 ± .77	5.1 ± 2.7
TAGB	19.0 ± 5.5	13.6 ± 4.1

Table 6 (continued)

1995	Low Severity Prefire	Postfire	High Severity Prefire	Postfire
Fine Fuels				
Litter	2.1 ± .16		2.3 ± .19	.07 ± .07
Dicot	.26 ± .11	.26 ± .12	.44 ± .26	
Live Grass	.19 ± .11		.11 ± .08	
Dead Grass	3.0 ± .94	.03 ± .02	1.5 ± .26	.07 ± .05
Manure	.10 ± .10		.42 ± .15	
Wood Debris				
0-0.64	.03 ± .01	.02 ± .01	.02 ± .01	
0.65-2.54	.58 ± .20	.14 ± .07	.33 ± .11	.06 ± .02
2.55-7.62				
Sound	3.3 ± .35	1.4 ± .21	1.5 ± .26	1.0 ± .24
Fall		.05 ± .05		.10 ± .06
Total	3.3 ± .35	1.5 ± .21	1.5 ± .26	1.1 ± .24
7.63-20.5				
Sound	4.5 ± .86	1.9 ± .44	4.2 ± .72	.55 ± .20
Fall		.47 ± .27		.12 ± .12
Rotten	.55 ± .18		.05 ± .05	
Total	5.0 ± .95	2.4 ± .48	4.3 ± .72	.67 ± .23
>20.5				
Sound	.30 ± .30			
Rotten	.27 ± .19			
Total	.57 ± .35			
Totals + Trees + Stumps				
Total Fine Fuels	5.7 ± .99	.29 ± .12	4.8 ± .52	.14 ± .08
Total Wood	9.5 ± 1.2	4.0 ± .51*	6.1 ± .86	1.8 ± .35*
Total Biomass	15.2 ± 1.5	4.3 ± .53*	10.8 ± 1.0	2.0 ± .35*
Tree	.40 ± .35	.18 ± .17	.43 ± .22	.23 ± .23
Stump	3.2 ± 1.1	2.7 ± 1.0	2.2 ± .87	1.4 ± .99
TAGB	18.9 ± 3.4	7.1 ± 1.4*	13.5 ± 1.3	3.6 ± 1.4*
Ash		.34 ± .02		.37 ± .02

*1995 postfire biomass includes fall measurements.

Table 7

Nitrogen Tables: Total aboveground pools (kg ha^{-1}) of nitrogen before and after burning from 1993 to 1995 at the Ejido San Mateo site near the Chamela Biological Research Station, Jalisco, Mexico. Calculations were made using: Nitrogen Biomass = [Component biomass * mean nitrogen %] /100. Standard errors calculated with N = 45 transects per severity of burn for foliage and wood debris components, N = 9 for stumps and N = 3 for trees and TAGB.

1993	Low Severity		High Severity	
	Prefire	Postfire	Prefire	Postfire
Fine Fuels				
Litter	142.9 ± 11.5		142.5 ± 10.8	
Att Fol	15.1 ± .98	1.4 ± .52	13.2 ± 1.0	
Dicot	2.5 ± .87		2.8 ± .57	
Wood Debris				
0-0.64	30.5 ± 2.0	2.8 ± 1.0	29.2 ± 2.3	.01 ± .01
0.65-2.54	141.8 ± 9.94	17.0 ± 6.6	130.9 ± 10.2	3.9 ± 1.3
2.55-7.62	165.2 ± 12.5	40.8 ± 5.6	186.7 ± 12.0	18.8 ± 3.5
7.63-20.5				
Sound	159.2 ± 15.3	97.4 ± 17.2	169.8 ± 18.9	29.6 ± 7.0
Rotten	23.9 ± 4.8	17.6 ± 5.8	27.3 ± 6.7	10.9 ± 5.0
Total	183.1 ± 15.9	114.9 ± 16.7	197.1 ± 22.4	40.5 ± 8.1
>20.5				
Sound	41.8 ± 14.7	16.7 ± 9.5	42.2 ± 15.0	23.8 ± 10.3
Rotten	4.4 ± 4.4		6.4 ± 4.5	
Total	46.1 ± 15.1	16.7 ± 9.5	48.6 ± 15.2	23.8 ± 10.3
Totals + Trees + Stumps				
Total Fine Fuels	160.5 ± 11.8	1.4 ± .52	158.4 ± 10.8	
Total Wood	566.7 ± 25.6	192.2 ± 23.5	592.5 ± 33.5	87.0 ± 13.6
Total Biomass	727.3 ± 28.8	193.6 ± 23.7	751.0 ± 35.2	87.0 ± 13.6
Tree	53.5 ± 21.9	4.3 ± 4.3	79.9 ± 24.8	5.5 ± 5.5
Stump	75. 2 ± 26.5	54.7 ± 14.2	113.0 ± 30.8	57.6 ± 16.8
TAGB	855.9 ± 32.0	252.6 ± 97.6	943.9 ± 14.2	150.1 ± 22.1
Ash		23.3 ± 4.8		27.7 ± 2.5

Table 7 (continued)

1994	Low Severity	High Severity
Fine Fuels		
Litter	37.7 ± 5.0	36.4 ± 5.2
Dicot	5.5 ± 3.4	4.1 ± 1.4
Corn	9.2 ± 1.5	13.1 ± 1.4
Dead Grass	4.7 ± 1.6	2.1 ± .86
Wood Debris		
0-0.64	2.0 ± .47	.83 ± .32
0.65-2.54	15.7 ± 4.4	5.5 ± 1.3
2.55-7.62	33.0 ± 3.4	11.2 ± 2.1
7.63-20.5		
Sound	52.9 ± 8.9	23.7 ± 3.8
Rotten	.98 ± .45	.85 ± .50
Total	53.9 ± 9.0	24.6 ± 4.0
>20.5		
Sound	2.1 ± 2.1	
Rotten		.72 ± .72
Total	2.1 ± 2.1	.72 ± .72
Totals + Trees + Stumps		
Total Fine Fuels	57.1 ± 7.1	55.6 ± 5.4
Total Wood	106.6 ± 13.1	42.8 ± 4.9
Total Biomass	163.7 ± 14.8	98.4 ± 7.1
Tree	3.7 ± 3.5	7.7 ± 3.6
Stump	25.4 ± 5.8	38.8 ± 20.5
TAGB	192. 8 ± 53.6	144.8 ± 24.6

Table 7 (continued)

1995	Low Severity Prefire	Postfire	High Severity Prefire	Postfire
Fine Fuels				
Litter	46.4 ± 3.4		51.3 ± 4.2	1.6 ± 1.6
Dicot	8.1 ± 3.4	8.2 ± 3.9	13.9 ± 8.1	
Live Grass	2.5 ± 1.5		1.5 ± 1.0	
Dead Grass	34.1 ± 10.5	.35 ± .24	16.4 ± 3.0	.74 ± .52
Manure	3.5 ± 3.5		15.2 ± 5.6	
Wood Debris				
0-0.64	.46 ± .23	.27 ± .16	.25 ± .18	
0.65-2.54	9.3 ± 3.3	2.2 ± 1.2	5.2 ± 1.7	.95 ± .39
2.55-7.62				
Sound	35.2 ± 3.8	15.0 ± 2.3	15.5 ± 2.8	10.7 ± 2.5
Fall		.56 ± .56		1.0 ± .62
Total	35.2 ± 3.8	15.6 ± 2.8	15.5 ± 2.8	11.7 ± 2.5
7.63-20.5				
Sound	38.5 ± 7.4	16.2 ± 3.8	36.5 ± 6.2	4.7 ± 1.8
Fall		4.1 ± 2.3		1.1 ± 1.1
Rotten	5.7 ± 1.8		.50 ± .50	
Total	44.1 ± 8.4	20.2 ± 4.1	37.0 ± 6.2	5.8 ± 2.0
>20.5				
Sound	2.6 ± 2.6			
Rotten	2.3 ± 1.6			
Total	4.9 ± 3.0			
Totals + Trees + Stumps				
Total Fine Fuels	95.0 ± 12.4	8.6 ± 3.8	98.2 ± 11.8	2.3 ± 1.7
Total Wood	94.0 ± 11.3	38.4 ± 4.7*	57.9 ± 8.1	18.4 ± 3.4*
Total Biomass	189.0 ± 17.1	46.9 ± 6.1*	156.2 ± 14.8	20.8 ± 3.7*
Tree	3.5 ± 3.0	1.6 ± 1.4	3.7 ± 1.9	2.0 ± 2.0
Stump	27.9 ± 9.1	22.9 ± 8.8	19.1 ± 7.5	12.4 ± 8.5
TAGB	220.3 ± 39.4	71.4 ± 17.6*	178.9 ± 16.8	35.1 ± 13.3*
Ash		13.4 ± .98		14.7 ± 1.1

1995 postfire biomass includes fall measurements

Table 8

Sulphur Tables: Total aboveground pools (kg ha[-1]) of sulphur before and after burning from 1993 to 1995 at the Ejido San Mateo site near the Chamela Biological Research Station, Jalisco, Mexico. Calculations were made using: Sulphur Biomass = [Component biomass * mean sulphur %] /100. Standard errors calculated with N = 45 transects per severity of burn for foliage and wood debris components, N = 9 for stumps and N = 3 for trees and TAGB.

1993	Low Severity		High Severity	
	Prefire	Postfire	Prefire	Postfire
Fine Fuels				
Litter	11.4 ± .92		11.4 ± .86	
Att Fol	1.5 ± .10	.14 ± .05	1.3 ± .11	
Dicot	.15 ± .05		.16 ± .03	
Wood Debris (diameter,cm)				
0-0.64	2.9 ± .19	.26 ± .10	2.7 ± .22	.001 ± .001
0.65-2.54	12.0 ± .84	1.4 ± .56	11.1 ± .87	.33 ± .11
2.55-7.62	12.5 ± .94	3.1 ± .42	14.1 ± .91	1.4 ± .26
7.63-20.5				
Sound	10.4 ± 1.0	6.4 ± .11	11.1 ± 1.2	1.9 ± .46
Rotten	1.6 ± .31	1.2 ± .38	1.8 ± .44	.71 ± .33
Total	12.0 ± 1.0	7.5 ± 1.1	12.9 ± 1.5	2.7 ± .53
>20.5				
Sound	2.7 ± .96	1.1 ± .62	2.8 ± .98	1.6 ± .67
Rotten	.29 ± .29		.42 ± .30	
Total	3.0 ± .99	1.1 ± .62	3.2 ± 1.0	1.6 ± .67
Totals + Trees + Stumps				
Total Fine Fuels	13.1 ± .95	.14 ± .05	12.9 ± .87	
Total Wood	42.3 ± 1.9	13.4 ± 1.7	44.0 ± 2.3	6.0 ± .90
Total Biomass	55.4 ± 2.2	13.5 ± 1.7	56.9 ± 2.5	6.0 ± .90
Tree	3.5 ± 1.4	.28 ± .28	5.2 ± 1.6	.36 ± .36
Stump	4.9 ± 1.7	3.6 ± .93	7.4 ± 2.0	3.8 ± 1.1
TAGB	63.8 ± 2.6	17.4 ± 6.8	69.5 ± 1.1	10.1 ± 1.5
Ash		6.6 ± 1.4		7.8 ± .70

Table 8 (continued)

1994	Low Severity	High Severity
Fine Fuels		
Litter	4.8 ± .64	4.6 ± .66
Dicot	.32 ± .20	.24 ± .08
Corn	1.1 ± .19	1.6 ± .17
Dead Grass	1.0 ± .35	.46 ± .19
Wood Debris (diameter,cm)		
0-0.64	.19 ± .04	.08 ± .03
0.65-2.54	1.3 ± .37	.47 ± .11
2.55-7.62	3.9 ± .40	1.3 ± .24
7.63-20.5		
Sound	4.7 ± .79	2.1 ± .34
Rotten	.09 ± .04	.08 ± .04
Total	4.8 ± .79	2.2 ± .35
>20.5		
Sound	.18 ± .18	
Rotten		.06 ± .06
Total	.18 ± .18	.06 ± .06
Totals + Trees + Stumps		
Total Fine Fuels	7.3 ± .95	6.9 ± .73
Total Wood	10.4 ± 1.2	4.1 ± .47
Total Biomass	17.6 ± 1.6	11.0 ± .84
Tree	.33 ± .31	.68 ± .32
Stump	2.2 ± .51	3.4 ± 1.8
TAGB	20.2 ± 5.1	15.1 ± 1.8

Table 8 (continued)

1995	Low Severity Prefire	Postfire	High Severity Prefire	Postfire
Fine Fuels				
Litter	4.9 ± .36		5.4 ± .45	.17 ± .17
Dicot	.47 ± .20	.48 ± .22	.81 ± .47	
Live Grass	.24 ± .14		.14 ± .10	
Dead Grass	6.3 ± 1.9	.06 ± .04	3.0 ± .54	.14 ± .10
Manure	.46 ± .46		2.0 ± .75	
Wood Debris (diameter,cm)				
0-0.64	.04 ± .02	.02 ± .01	.02 ± .01	
0.65-2.54	.78 ± .27	.19 ± .10	.44 ± .14	.08 ± .03
2.55-7.62				
Sound	7.9 ± .84	3.4 ± .50	3.5 ± .62	2.4 ± .56
Fall		.13 ± .13		.23 ± .14
Total	7.9 ± .84	3.5 ± .50	3.5 ± .62	2.6 ± .56
7.63-20.5				
Sound	2.3 ± .45	.97 ± .23	2.2 ± .37	.28 ± .11
Fall		.25 ± .14		.06 ± .06
Rotten	.61 ± .20		.05 ± .05	
Total	2.9 ± .56	1.2 ± .25	2.3 ± .38	.35 ± .12
>20.5				
Sound	.16 ± .16			
Rotten	.14 ± .10			
Total	.30 ± .18			
Totals + Trees + Stumps				
Total Fine Fuels	12.4 ± 2.1	.54 ± .23	11.4 ± 1.3	.30 ± .19
Total Wood	11.9 ± 1.2	4.9 ± .56*	6.2 ± .83	3.1 ± .58*
Total Biomass	24.3 ± 2.4	5.4 ± .62*	17.6 ± 1.7	3.4 ± .59*
Tree	.21 ± .18	.10 ± .09	.22 ± .11	.12 ± .12
Stump	1.7 ± .55	1.4 ± .53	1.1 ± .45	.74 ± .51
TAGB	26.2 ± 3.6	6.9 ± 1.4*	18.9 ± 2.6	4.2 ± .96*
Ash		3.4 ± .25		3.7 ± .28

*1995 postfire biomass includes fall measurements

Table 9

Calcium Tables: Total aboveground pools (kg ha^{-1}) of calcium before and after burning from 1993 to 1995 at the Ejido San Mateo site near the Chamela Biological Research Station, Jalisco, Mexico. Calculations were made using: Calcium Biomass = [Component biomass * mean calcium %] /100. Standard errors calculated with N = 45 transects per severity of burn for foliage and wood debris components, N = 9 for stumps and N = 3 for trees and TAGB.

1993	Low Severity		High Severity	
	Prefire	Postfire	Prefire	Postfire
Fine Fuels				
Litter	216.2 ± 17.4		215.5 ± 16.3	
Att Fol	9.3 ± .60	.83 ± .32	8.1 ± .64	
Dicot	2.1 ± .73		2.3 ± .48	
Wood Debris				
0-0.64	38.8 ± 2.5	3.5 ± 1.3	37.1 ± 3.0	.02 ± .02
0.65-2.54	174.6 ± 21.2	21.0 ± 8.1	161.3 ± 12.6	4.9 ± 1.6
2.55-7.62	230.0 ± 17.4	56.7 ± 7.8	259.9 ± 16.7	26.1 ± 4.9
7.63-20.5				
Sound	308.8 ± 29.6	188.8 ± 33.4	329.3 ± 36.7	57.5 ± 13.5
Rotten	46.3 ± 9.2	34.1 ± 11.1	52.9 ± 12.9	21.1 ± 9.8
Total	355.1 ± 31.0	222.9 ± 32.3	382.1 ± 43.4	78.6 ± 15.7
>20.5				
Sound	81.0 ± 28.5	32.5 ± 18.3	81.9 ± 29.0	46.2 ± 19.9
Rotten	8.5 ± 8.5		12.4 ± 8.7	
Total	89.5 ± 29.2	32.5 ± 18.3	94.3 ± 29.6	46.2 ± 20.0
Totals + Trees + Stumps				
Total Fine Fuels	227.5 ± 17.6	.83 ± .32	225.9 ± 16.3	
Total Wood	888.0 ± 43.8	336.6 ± 41.6	934.8 ± 60.4	155.8 ± 25.6
Total Biomass	1115.5 ± 46.7	337.4 ± 41.7	1160.7 ± 62.6	155.8 ± 25.6
Tree	103.7 ± 42.4	8.4 ± 8. 4	155.0 ± 48.2	10.6 ± 10.6
Stump	145.8 ± 51.3	107.0 ± 27.9	219.1 ± 59.8	112.7 ± 33.0
TAGB	1365.1 ± 46.5	452.9 ± 171.3	1534.8 ± 18.9	279.1 ± 42.9
Ash		584.2 ± 121.0		695.6 ± 62.4

Table 9 (continued)

1994	Low Severity	High Severity
Fine Fuels		
Litter	49.8 ± 6.7	48.1 ± 6.9
Dicot	4.6 ± 2.9	3.4 ± 1.2
Corn	3.4 ± .56	4.8 ± .52
Dead Grass	2.9 ± .98	1.3 ± .55
Wood Debris (diameter,cm)		
0-0.64	2.6 ± .56	1.0 ± .41
0.65-2.54	19.3 ± 5.4	6.8 ± 1.6
2.55-7.62	79.3 ± 8.2	26.8 ± 5.0
7.63-20.5		
Sound	122.5 ± 20.6	54.9 ± 8.9
Rotten	2.3 ± 1.0	2.0 ± 1.2
Total	124.8 ± 20.8	56.9 ± 9.2
>20.5		
Sound	4.8 ± 4.8	
Rotten		1.7 ± 1.7
Total	4.8 ± 4.8	1.7 ± 1.7
Totals + Trees + Stumps		
Total Fine Fuels	60.8 ± 7.8	57.6 ± 7.0
Total Wood	230.8 ± 27.8	93.2 ± 10.8
Total Biomass	291.6 ± 29.1	150.9 ± 12.4
Tree	8.7 ± 8.1	17.9 ± 8.3
Stump	58.8 ± 13.4	89.8 ± 47.5
TAGB	359.1 ± 103.8	258.6 ± 67.0

Table 9 (continued)

1995	Low Severity Prefire	Postfire	High Severity Prefire	Postfire
Fine Fuels				
Litter	32.3 ± 2.4		35.5 ± 2.9	1.1 ± 1.1
Dicot	6.8 ± 2.9	6.9 ± 3.2	11.6 ± 6.8	
Live Grass	.77 ± .45		.45 ± .30	
Dead Grass	19.7 ± 6.1	.20 ± .14	9.5 ± 1.7	.43 ± .30
Manure	2.5 ± 2.5		10.9 ± 4.0	
Wood Debris (diameter,cm)				
0-0.64	.80 ± .40	.47 ± .28	.44 ± .31	
0.65-2.54	16.3 ± 5.7	3.9 ± 2.1	9.1 ± 3.0	1.7 ± .68
2.55-7.62				
Sound	67.1 ± 7.2	28.7 ± 4.3	29.5 ± 5.3	20.4 ± 4.8
Fall		1.1 ± 1.1		2.0 ± 1.2
Total	67.1 ± 7.2	29.7 ± 4.3	29.5 ± 5.3	22.3 ± 4.8
7.63-20.5				
Sound	79.5 ± 15.3	33.4 ± 7.8	75.4 ± 12.8	9.8 ± 3.6
Fall		8.4 ± 4.8		2.2 ± 2.2
Rotten	9.8 ± 3.2		.86 ± .86	
Total	89.2 ± 16.9	41.9 ± 8.5	76.3 ± 12.8	12.0 ± 4.1
>20.5				
Sound	5.4 ± 5.4			
Rotten	4.8 ± 3.3			
Total	10.2 ± 6.3			
Totals + Trees + Stumps				
Total Fine Fuels	62.1 ± 7.6	7.1 ± 3.2	68.0 ± 8.9	1.5 ± 1.1
Total Wood	183.6 ± 22.2	76.0 ± 9.4*	115.4 ± 16.2	36.0 ± 6.6*
Total Biomass	245.7 ± 24.1	83.1 ± 10.0*	183.4 ± 18.9	37.5 ± 6.7*
Tree	7.2 ± 6.3	3.3 ± 2.9	7.6 ± 3.8	4.1 ± 4.1
Stump	57.7 ± 18.8	47.4 ± 18.1	39.5 ± 15.5	25.5 ± 17.6
TAGB	310.6 ± 77.5	133.7 ± 28.2*	230.4 ± 20.5	67.1 ± 25.2*
Ash		57.3 ± 4.2		63.0 ± 4.7

*1995 postfire biomass includes fall measurements

Table 10

Potassium Tables: Total aboveground pools (kg ha^{-1}) of potassium before and after burning from 1993 to 1995 at the Ejido San Mateo site near the Chamela Biological Research Station, Jalisco, Mexico. Calculations were made using: Potassium Biomass = [Component biomass * mean potassium %] /100. Standard errors calculated with N = 45 transects per severity of burn for foliage and wood debris components, N = 9 for stumps and N = 3 for trees and TAGB.

1993	Low Severity		High Severity	
	Prefire	Postfire	Prefire	Postfire
Fine Fuels				
Litter	27.5 ± 2.2		27.4 ± 2.1	
Att Fol	7.8 ± .51	.70 ± .27	6.8 ± .54	
Dicot	.78 ± .27		.87 ± .18	
Wood Debris (diameter,cm)				
0-0.64	16.3 ± 1.1	1.5 ± .56	15.6 ± 1.2	.007 ± .007
0.65-2.54	45.3 ± 3.2	5.4 ± 2.1	41.9 ± 3.3	1.3 ± .42
2.55-7.62	66.8 ± 5.1	16.5 ± 2.3	75.5 ± 4.9	7.6 ± 1.4
7.63-20.5				
Sound	64.7 ± 6.2	39.6 ± 7.0	69.0 ± 7.7	12.0 ± 2.8
Rotten	9.7 ± 1.9	7.1 ± 2.3	11.1 ± 2.7	4.4 ± 2.1
Total	74.4 ± 6.5	46.7 ± 6.8	80.1 ± 9.1	16.5 ± 3.3
>20.5				
Sound	17.0 ± 6.0	6.8 ± 3.8	17.2 ± 6.1	9.7 ± 4.2
Rotten	1.8 ± 1.8		2.6 ± 1.8	
Total	18.8 ± 6.1	6.8 ± 3.8	19.8 ± 6.2	9.7 ± 4.2
Totals + Trees + Stumps				
Total Fine Fuels	36.0 ± 2.4	.70 ± .27	35.1 ± 2.1	
Total Wood	221.6 ± 10.2	77.0 ± 9.3	232.8 ± 13.4	35.0 ± 5.5
Total Biomass	257.6 ± 10.6	77.6 ± 9.4	267.9 ± 13.6	35.0 ± 5.5
Tree	21.7 ± 8.9	1.8 ± 1.8	32.5 ± 10.1	2.2 ± 2.2
Stump	30.6 ± 10.8	22.2 ± 5.8	45.9 ± 12.5	23.4 ± 6.8
TAGB	309.9 ± 9.5	101.6 ± 38.6	346.2 ± 3.0	60.6 ± 9.0
Ash		75.5 ± 15.6		89.9 ± 8.0

Table 10 (continued)

1994	Low Severity	High Severity
Fine Fuels		
Litter	25.9 ± 3.5	25.0 ± 3.6
Dicot	1.7 ± 1.1	1.3 ± .44
Corn	15.7 ± 2.6	22.4 ± 2.4
Dead Grass	10.3 ± 3.4	4.6 ± 1.9
Wood Debris (diameter,cm)		
0-0.64	1.1 ± .25	.44 ± .17
0.65-2.54	5.0 ± 1.4	1.8 ± .41
2.55-7.62	20.1 ± 2.1	6.8 ± 1.3
7.63-20.5		
Sound	21.6 ± 3.7	9.7 ± 1.6
Rotten	.40 ± .18	.35 ± .20
Total	22.0 ± 3.7	10.0 ± 1.6
>20.5		
Sound	.85 ± .85	
Rotten		.30 ± .30
Total	.85 ± .85	.30 ± .30
Totals + Trees + Stumps		
Total Fine Fuels	53.6 ± 6.9	53.2 ± 4.7
Total Wood	49.0 ± 5.6	19.3 ± 2.2
Total Biomass	102.6 ± 9.1	72.5 ± 5.0
Tree	1.5 ± 1.4	3.2 ± 1.5
Stump	10.4 ± 2.4	15.8 ± 8.4
TAGB	114.5 ± 24.1	91.5 ± 6.3

Table 10 (continued)

1995	Low Severity Prefire	Postfire	High Severity Prefire	Postfire
Fine Fuels				
Litter	38.8 ± 2.9		42.6 ± 3.5	1.3 ± 1.3
Dicot	2.5 ± 1.1	2.6 ± 1.2	4.3 ± 2.5	
Live Grass	5.4 ± 3.1		3.1 ± 2.1	
Dead Grass	84.3 ± 26.0	.86 ± .59	40.4 ± 7.3	1.8 ± 1.3
Manure	.90 ± .90		3.9 ± 1.4	
Wood Debris (diameter,cm)				
0-0.64	.08 ± .04	.05 ± .03	.08 ± .04	
0.65-2.54	1.7 ± .60	.41 ± .22	.95 ± .32	.17 ± .07
2.55-7.62				
Sound	12.5 ± 1.3	5.3 ± .80	5.5 ± .98	3.8 ± .88
Fall		.20 ± .20		.37 ± .22
Total	12.5 ± 1.3	5.5 ± .79	5.5 ± .98	4.1 ± .89
7.63-20.5				
Sound	12.9 ± 2.5	5.4 ± 1.3	12.3 ± 2.1	1.6 ± .59
Fall		1.4 ± .78		.36 ± .36
Rotten	4.8 ± 1.5		.42 ± .42	
Total	17.7 ± 3.5	6.8 ± 1.4	12.7 ± 2.1	2.0 ± .67
>20.5				
Sound	.88 ± .88			
Rotten	.78 ± .544			
Total	1.7 ± 1.0			
Totals + Trees + Stumps				
Total Fine Fuels	131.9 ± 27.1	3.4 ± 1.3	94.4 ± 10.7	3.2 ± 1.8
Total Wood	33.6 ± 4.2	12.8 ± 1.5*	19.2 ± 2.6	6.3 ± 1.2*
Total Biomass	165.5 ± 26.8	16.2 ± 2.1*	113.6 ± 11.4	9.4 ± 2.1*
Tree	1.2 ± 1.0	.53 ± .48	1.2 ± .62	.67 ± .67
Stump	9.4 ± 3.1	7.7 ± 2.9	6.4 ± 2.5	4.2 ± 2.9
TAGB	176.0 ± 15.3	24.5 ± 5.5*	121.3 ± 13.5	14.2 ± 5.5*
Ash		54.5 ± 4.0		60.0 ± 4.4

*1995 postfire biomass totals include fall measurements.

Table 11

Phosphorus Tables: Total aboveground pools (kg ha^{-1}) of phosphorus before and after burning from 1993 to 1995 at the Ejido San Mateo site near the Chamela Biological Research Station, Jalisco, Mexico. Calculations were made using: Phosphorus Biomass = [Component biomass * mean phosphorus %] /100. Standard errors calculated with N = 45 transects per severity of burn for foliage and wood debris components, N = 9 for stumps and N = 3 for trees and TAGB.

1993	Low Severity		High Severity	
	Prefire	Postfire	Prefire	Postfire
Fine Fuels				
Litter	5.9 ± .48		5.9 ± .45	
Att Fol	.75 ± .05	.07 ± .03	.65 ± .05	
Dicot	.16 ± .05		.17 ± .03	
Wood Debris (diameter,cm)				
0-0.64	1.8 ± .12	.16 ± .06	1.7 ± .14	.0007 ± .0007
0.65-2.54	5.0 ± .35	.61 ± .23	4.7 ± .36	.14 ± .05
2.55-7.62	5.0 ± .37	1.2 ± .17	5.6 ± .36	.56 ± .10
7.63-20.5				
Sound	2.9 ± .28	1.8 ± .32	3.1 ± .35	.55 ± .13
Rotten	.44 ± .09	.32 ± .11	.50 ± .12	.20 ± .09
Total	3.4 ± .29	2.1 ± .31	3.6 ± .41	.75 ± .15
>20.5				
Sound	.77 ± .27	.31 ± .18	.78 ± .28	.44 ± .19
Rotten	.08 ± .08		.12 ± .08	
Total	.85 ± .28	.31 ± .18	.90 ± .28	.44 ± .19
Totals + Trees + Stumps				
Total Fine Fuels	6.8 ± .50	.07 ± .03	6.7 ± .45	
Total Wood	16.0 ± .68	4.4 ± .56	16.5 ± .80	1.9 ± .27
Total Biomass	22.8 ± .91	4.5 ± .57	23.2 ± .93	1.9 ± .27
Tree	.99 ± .40	.08 ± .08	1.5 ± .46	.10 ± .10
Stump	1.4 ± .49	1.0 ± .26	2.1 ± .57	1.1 ± .31
TAGB	25.2 ± 1.4	5.6 ± 2.2	26.8 ± .47	3.1 ± .42
Ash		9.4 ± 2.0		11.2 ± 1.0

Table 11 (continued)

1994	Low Severity	High Severity
Fine Fuels		
Litter	2.9 ± .38	2.8 ± .40
Dicot	.35 ± .22	.25 ± .09
Corn	.68 ± .11	.97 ± .10
Dead Grass	.34 ± .11	.15 ± .06
Wood Debris (diameter,cm)		
0-0.64	.12 ± .03	.05 ± .02
0.65-2.54	.56 ± .16	.20 ± .05
2.55-7.62	1.8 ± .19	.62 ± .11
7.63-20.5		
Sound	2.9 ± .49	1.3 ± .21
Rotten	.05 ± .02	.05 ± .03
Total	2.9 ± .49	1.3 ± .22
>20.5		
Sound	.11 ± .11	
Rotten		.04 ± .04
Total	.11 ± .11	.04 ± .04
Totals + Trees + Stumps		
Total Fine Fuels	4.2 ± .51	4.1 ± .41
Total Wood	5.5 ± .67	2.2 ± .26
Total Biomass	9.8 ± .85	6.4 ± .47
Tree	.20 ± .19	.42 ± .20
Stump	1.4 ± .32	2.1 ± 1.1
TAGB	11.4 ± 2.8	8.9 ± 1.2

Table 11 (continued)

1995	Low Severity Prefire	Postfire	High Severity Prefire	Postfire
Fine Fuels				
Litter	3.0 ± .22		3.3 ± .27	.10 ± .10
Dicot	.50 ± .21	.51 ± .24	.87 ± .50	
Live Grass	.17 ± .10		.10 ± .07	
Dead Grass	3.4 ± 1.0	.04 ± .02	1.6 ± .29	.07 ± .05
Manure	.51 ± .51		2.2 ± .82	
Wood Debris (diameter,cm)				
0-0.64	.02 ± .009	.01 ± .006	.01 ± .007	
0.65-2.54	.37 ± .13	.09 ± .05	.20 ± .07	.04 ± .02
2.55-7.62				
Sound	1.4 ± .15	.59 ± .09	.61 ± .11	.42 ± .10
Fall		.02 ± .02		.04 ± .02
Total	1.4 ± .15	.61 ± .09	.61 ± .11	.46 ± .10
7.63-20.5				
Sound	1.9 ± .36	.78 ± .18	1.8 ± .30	.23 ± .08
Fall		.20 ± .11		.05 ± .05
Rotten	.57 ± .18		.05 ± .05	
Total	2.4 ± .47	.97 ± .20	1.8 ± .30	.28 ± .10
>20.5				
Sound	.13 ± .13			
Rotten	.11 ± .08			
Total	.24 ± .15			
Totals + Trees + Stumps				
Total Fine Fuels	7.6 ± 1.2	.55 ± .24	8.1 ± 1.1	.18 ± .11
Total Wood	4.4 ± .57	1.7 ± .21*	2.6 ± .37	.78 ± .15*
Total Biomass	12.0 ± 1.3	2.2 ± .33*	10.7 ± 1.2	.95 ± .18*
Tree	.17 ± .15	.08 ± .07	.18 ± .09	.09 ± .09
Stump	1.3 ± .44	1.1 ± .42	.92 ± .36	.59 ± .41
TAGB	13.5 ± 2.0	3.4 ± .90*	11.8 ± 2.0	1.6 ± .67*
Ash		5.0 ± .37		5.5 ± .41

*1995 postfire biomass includes fall measurements

Table 12 Carbon and nutrient site loss (%) at the Chamela Research Station Jalisco, Mexico (1993-1995) comparing selected tropical forest ecosystems. Actual site loss for carbon is in Mg ha^{-1} and nutrients are in kg ha^{-1}.

Forest Type / Site - Year	Carbon	Nitrogen	Sulphur	Calcium	Potassium	Phosphorus	Study
Tropical Dry Forest / Mexico / El Cielo							Steele, 1998
Low Severity 1993							
% Site Loss	62.5	70.5	72.7	66.8	67.2	77.8	
Actual Loss	35.3	603.3	46.4	912.2	208.3	19.6	
High Severity 1993							
% Site Loss	79.8	84.1	85.5	81.8	82.5	88.4	
Actual Loss	51.6	793.8	59.4	1255.7	285.6	23.7	
Tropical Cattle Pasture / Mexico / El Cielo							Steele, 1998
Low Severity 1995							
% Site Loss	62.4	67.5	73.7	57.0	86.1	74.8	
Actual Loss	11.8	148.9	19.3	176.9	151.5	10.1	
High Severity 1995							
% Site Loss	73.3	80.4	77.8	70.9	88.3	86.4	
Actual Loss	9.9	143.8	14.7	163.3	107.1	10.2	
Tropical Dry Forest / Brazil							Kauffman et al.
Serra Talhada – 1990							1993
Low	73.1	79.3				3.49	
% Site Loss	24.6	428.28				1.22	
Actual Loss							
High							
% Site Loss	96.1	96.11				56.3	
Actual Loss	31.0	525.3				20.5	
Tropical Woodland (Cerrado) / Brazil							Kauffman
Campo cerrado - 1990							1994
% Site Loss	67.0	58.0	67.0			34.0	
Actual Loss	2.6	26.46	3.3			1.1	
Cerrado sensu stricto -1990							
% Site Loss	64.0	32.0	74.0			22.0	
Actual Loss	2.7	25.3	4.2			1.6	

Table 12 (continued)

Forest Type / Site - Year	Carbon	Nitrogen	Sulphur	Calcium	Potassium	Phosphorus	Study
Tropical Evergreen / Brazil							Kauffman 1995
Jacunda - 1992							
% Site Loss	51.5	58.3	43.5	3.3	20.0	31.8	
Actual Loss	76.0	816.6	109.1	30.3	111.0	19.9	
Maraba - 1992							
% Site Loss	51.3	59.6	34.8	8.5	0.8	6.8	
Actual Loss	111.9	1387.2	136.5	108.1	8.3	5.9	
Santa Barbara - 1992							
% Site Loss	40.5	51.6	42.5	8.2	0.7	19.5	
Actual Loss	57.6	1064.2	91.6	30.3	3.1	10.9	
Jamari - 1992							
% Site Loss	56.1	66.1	48.6	10.7	6.8	12.1	
Actual Loss	100.3	1604.5	122.3	98.8	35.5	7.6	
Tropical Evergreen / Brazil							
Balteke - 1995							Guild 1998
% Site Loss	45.6	55.8	49.0				
Actual Loss	79.0	1019	86.9				
Sergpipe - 1995							
% Site Loss	50.9	60.0	49.0				
Actual Loss	99.2	1189.6	94.7				

Table 12 (continued)

Forest Type / Site - Year	Carbon	Nitrogen	Sulphur	Calcium	Potassium	Phosphorus	Study
Tropical Cattle Pastures / Brazil							Kauffman 1995
Francisco - 1991							
% Site Loss	78.6	86.4	45.4	-17.1	26.0	29.9	
Actual Loss	19.4	3.5	0.3	-0.4	1.2	0.1	
Durval - 1991							
% Site Loss	18.7	29.9	23.6	12.4	19.1	26.1	
Actual Loss	11.1	1.7	0.2	0.2	0.4	0.1	
Joao - 1991							
% Site Loss	43.2	56.5	37.5	11.3	8.7	19.7	
Actual Loss	15.5	2.2	0.2	0.1	0.1	0.04	
Tropical Cattle Pasture / Brazil							Guild, 1998
Jamari – 1995							
% Site Loss	56.1	66.1	48.6	10.7	6.8	12.1	
Actual Loss	100.3	1604.5	122.3	98.8	35.5	7.6	
Tropical Grassland / Brazil							Kauffman et al. 1994
Campo limpo - 1990							
% Site Loss	98.0	96.0	89.0			67.0	
Actual Loss	3.3	22.4	3.2			0.9	
Tropical Savanna / Brazil							Kauffman 1994
Campo sujo - 1990							
% Site Loss	96.0	94.0	88.0			45.0	
Actual Loss	3.3	23.8	3.0			1.2	