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Atmospheric Deposition Processes and Their Importance As Sources of Nutrients in a Chaparral Ecosystem of Southern California

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Precipitation and dry fallout were collected over a 2-year period in the Santa Ynez Mountains, Santa Barbara County, California, and analyzed for nutrient content. Mean annual depositions of Ca (2.2 kg/ha), K (0.7 kg/ha), NH_4^+-N (0.5 kg/ha), and NO_3^--N (1.5 kg/ha) were largely derived from dryfall; depositions of Na (7.2 kg/ha), Mg (1.2 kg/ha), and $SO_4^=$-S (3.6 kg/ha) were important in both rainfall and dry fallout. These atmospheric inputs are equal to or larger than the typical annual losses reported in runoff from mature chaparral shrublands, but on the basis of these inputs, more than 70 years may be necessary to replace the nitrogen losses measured in volatilization and runoff after fire. The depositions of NO_3^--N and $SO_4^=$-S at this remote site may be indicative of the natural levels of these ions which, in many other areas of California, are derived from anthropogenic sources.

INTRODUCTION

During fires a large quantity of essential plant nutrients, particularly nitrogen, may be lost from terrestrial ecosystems to the atmosphere [*Raison,* 1979]. These losses have been measured in chaparral shrub ecosystems which are subject to recurrent fires in southern California [*DeBano and Conrad,* 1978; *DeBano et al.,* 1979]. In these ecosystems there are also large nutrient losses in erosion and runoff following fire [*DeBano and Conrad,* 1976]. The marked response of *Adenostoma* chaparral to nitrogen fertilization [*Hellmers et al.,* 1955] has led to the widespread recognition of nutrient limitations to plant growth in chaparral soils. If fires are frequent, large losses may deplete chaparral sites of nitrogen at a more rapid rate than it is replenished by atmospheric deposition and by nitrogen-fixing chaparral species such as *Ceanothus*.

Over the past several years we have studied the rate of deposition of nutrients from the atmosphere in the chaparral near Santa Barbara, California. The goal of these studies was to compare the annual deposition of nutrients to the typical losses in runoff and to the annual nutrient requirements for growth in mature chaparral. Our data also allow a calculation of the time needed to replenish the increased losses which result from fire. In our early studies, we collected rainfall and dry fallout together in open funnels [*Schlesinger and Hasey,* 1980]; more recently, we have separated these deposition processes by collections using an automatic rain collector. Here we report on our recent work, and we review sources of similar data in California.

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METHODS AND MATERIALS

We established a research site on the south slope of the Santa Ynez Mountains (Los Padres National Forest) at 850-m elevation and approximately 10 km north of the Pacific Ocean near Santa Barbara, California. The site was 3 km west of the transect of sites used for precipitation collections in related studies [*Schlesinger and Hasey,* 1980, 1981]. While these sites are close to the ocean, the south slope of this mountain range receives little direct deposition of salt spray and marine aerosols [*Ogden,* 1975, pp. 205–206]. Direct onshore winds are predominant only during the arrival of winter synoptic storms from the Pacific Ocean. Since the coastline near Santa Barbara is oriented in an east-west direction, the onshore wind flow around low-pressure systems generally crosses open ocean, rather than the metropolitan areas to the south. Thus the site is remote from most anthropogenic sources of atmospheric constituents. The site was a clearing in chaparral such that there was a horizontal angle of less than 45° from the top of rain collectors to surrounding vegetation.

Over a 25-month period we measured precipitation in individual rainstorms using a standard U.S. Weather Bureau 8″ (20.3 cm) diameter rain gage. Monthly total airflow was measured with a recording three-cup anemometer mounted 2 m above ground level. A continuous record of air temperature and relative humidity was obtained using a sheltered hygrothermograph (Weathermeasure model H311), but these data are not reported in the present paper.

We used an automatic rain collector (Aerochem Metrics model 101), electronically sensitive to precipitation events, to collect nutrient deposition in rainfall and dry fallout in separate (28-cm diameter) plastic buckets. The buckets of this collector were 2 m above the ground. This rain collector

was originally designed by the U.S. Atomic Energy Commission and tested favorably in the trials reported by *Galloway and Likens* [1976] and *Bogen et al.* [1980]. The plastic buckets were washed with 50% HCl and rinsed 5 times with deionized water. They were transported to the field in plastic bags. Immediately at the end of each storm and at the end of each month, the wetfall bucket was replaced with a clean collector, the volume of precipitation was recorded, and an aliquot of the precipitation was saved for analysis. At the end of each month, the dry fall collector was rinsed by soaking with 250 ml of glass-distilled water for 24 hours. This solution was saved for analysis; thus our analyses include only those ions that are dissolved when dryfall is leached with distilled water (fraction 2 of *Lewis and Grant* [1978]). Only a small number of the dryfall collections contained leaves, insects, or bird excrement; these were removed intact before rinsing. A clean dryfall bucket was placed in the rain collector at the end of each month.

During 15 months of the study, we also collected bulk precipitation using the rain collector designed and tested by *Likens et al.* [1967, 1977] to collect a composite sample of rainfall and dry fallout at the Hubbard Brook ecosystem in New Hampshire. This collector consisted of a 10-cm diameter polypropylene funnel connected to a 1-liter polypropylene bottle with Tygon tubing. At the end of each storm and at the end of each month, this collector was rinsed with a known volume of distilled water, and the rinse water was combined with the precipitation for analysis. An acid-washed collector was replaced in the field at these times.

The various samples were analyzed for Ca, Mg, K, and Na by atomic absorption spectrophotometry as described by *Schlesinger and Hasey* [1980]. Sulfate-S was determined turbidimetrically following a method modified from *Lea and Wells* [1980], using a 1 mg l^{-1} $SO_4^=$-S spike solution. In many cases this spike was a significant addition to concentrations in wetfall collections, typically 0.1–1.0 mg l^{-1} $SO_4^=$-S, but the spike was a smaller addition in relation to concentrations in dryfall rinses, 2.0–9.5 mg l^{-1} $SO_4^=$-S. During the second year of study, the samples were also analyzed for NH_4^+-N and NO_3^--N using ion-specific electrodes as described by *Schlesinger and Hasey* [1980]. Analyses for the nitrogen constituents were performed as soon as possible after collection, usually within 24 hours; thus no preservatives were used in the collectors. Limits to our analytical procedures are shown in Table 1.

For each rainfall event, concentrations of ions (in milligrams per liter) in the wetfall and in the Hubbard Brook collector were multiplied by the volume of precipitation and converted to liters per square meter based on the area of the collector surface, to calculate total deposition (in milligrams per square meter). Concentrations in the water used to rinse the dryfall collector were converted to dry deposition based on the volume of rinse water and the area of the collector. During two months when no rain was measured, ionic constituents were measured in rinses of the wetfall bucket to provide a check of our cleaning and transporting procedures and the operation of the automatic rain collector. On the basis of these data, contaminants added little to our deposition estimates (Table 1).

In this paper we use the term 'bulk precipitation' to refer to collections made using the Hubbard Brook collector. 'Total deposition' refers to the sum of 'wet deposition (wetfall)' and 'dry deposition (dryfall),' as collected in the automatic rain collector. When data are treated as monthly depositions, it should be remembered that these are derived from summing the collections and calculations for the individual rainstorms during the month.

RESULTS AND DISCUSSION

Long-term measurements compiled by the National Oceanic and Atmospheric Administration for Santa Barbara (elevation 3 m) indicate a mean annual rainfall of 45 cm. Sites in the coastal mountains of southern California generally receive greater rainfall than lower elevations along the coast [*Bauer,* 1936; *Miller and Poole,* 1979; *Schlesinger and Hasey,* 1980], but the influence of local topography on rainfall patterns often results in only a weak correlation of increasing rainfall with increasing elevation in the mountains. Santa Barbara County records show a mean annual rainfall of 77 cm for a 33-year period at San Marcos Pass (700-m elevation), along the ridgetop of the Santa Ynez Mountains 2.5 km west of our study site. During the years of study, we recorded 76 and 111 cm of rainfall in the U.S. Weather Bureau gage.

Because of progressive atmospheric cleansing during large storms, the concentrations of ions in precipitation often decrease during the duration of rainfall [*Junge,* 1963; *Georgii and Wötzel,* 1970; *Gatz and Dingle,* 1971; *Kennedy et al.,* 1979]. Thus concentrations are higher in rainfall collections from small storms than from larger storms. To express rainfall concentrations, many workers use weighted average concentrations, calculated by dividing the total deposition in a collection period (in milligrams per square meter) by the total volume of precipitation recorded (in liters per square meter). Table 2 shows the annual weighted average concentrations (in milligrams per liter) in wetfall for the various ions for the 2 years of study. Not surprisingly for this coastal site, Na and Mg are dominant ions, reflecting their abundance in seawater from which aerosols and rainfall nuclei are commonly formed [*Gorham,* 1961]. Concentrations of some ions varied over several orders of magnitude among storms. Weighted averages for some ions are less than or equal to analytical limits (Table 1) as a result of including zero values for concentrations below detection limits. Since low concen-

TABLE 1. Limits to Analytical Procedures

	Ca	Mg	K	Na	NH_4^+-N	NO_3^--N	$SO_4^=$-S
Detection, mg l^{-1}	0.008	0.002	0.01	0.03	0.02	0.10	0.06
Sensitivity, mg l^{-1}	0.08	0.007	0.04	0.02	0.01	0.05	0.04
Background #1	0.04	0.00	0.00	0.16	0.04	0.00	0.25
Deposition* #2, mg m^{-2} $month^{-1}$	0.04	0.16	0.28	0.00	0.04	0.00	0.32

*Deposition in rinses of wetfall collectors during two months with no rainfall.

TABLE 2. Concentrations and Depositions of Nutrient Ions in Wet and Dry Fallout From the Atmosphere in the Santa Ynez Mountains

	Rainfall, cm	Ca	Mg	K	Na	NH_4^+-N	NO_3^--N	$SO_4^=$-S
Weighted average concentrations in wetfall, mg l^{-1}								
1978–1979		0.03	0.06	0.01	0.44	· · ·	· · ·	0.17
1979–1980		0.03	0.06	0.02	0.49	0.02	0.03	0.23
Annual deposition in wetfall, mg m^{-2}								
1978–1979	76	20	40	5	340	· · ·	· · ·	130
1979–1980	111	30	70	20	540	20	30	250
Annual deposition in dryfall, mg m^{-2}								
1978–1979		120	50	50	190	· · ·	· · ·	120
1979–1980		260	70	60	380	40	130	220
Total deposition, mg m^{-2} yr^{-1}								
1978–1979		150	90	50	520	· · ·	· · ·	240
1979–1980		280	140	80	930	50	150	480
Mean annual (this study)		220	120	70	720	50	150	360
Mean annual (extrapolated from *Schlesinger and Hasey* [1980])		140	80	40	610	10	90	· · ·
Overall mean (3 years)		190	100	60	690	30	120	360

All calculations have been rounded.

trations are characteristic of large storms, these values have a disproportionately large effect when concentrations are weighted by storm size. The weighting procedure also precludes the use of standard measures of statistical variation.

We found only nonsignificant negative linear correlations between the ionic concentrations in the wetfall collections and increasing precipitation volume. The correlations between log concentration and precipitation were usually stronger (higher r); for monthly data these correlation coefficients (r) were -0.60* for Ca, -0.01 for Mg, -0.53 for K, $+0.12$ for Na, -0.82* for NH_4^+-N, -0.60 for NO_3^--N, and -0.66* for $SO_4^=$-S (where the asterisk means significant at $P < 0.05$). Thus those ions largely derived from terrestrial and anthropogenic sources (e.g., Ca and K [*Gorham,* 1961]) show a stronger tendency to be cleansed from the atmosphere during rainfall than those mainly derived from the ocean. This conclusion is directly opposite from that of *Kennedy et al.* [1979] in an analysis of rainfall chemistry in northern California. We feel that our results are likely to be more typical for precipitation in which maritime aerosols are involved as condensation nuclei (rainout) while other aerosols are progressively washed from the atmosphere during storms.

In most regions the concentrations of Na and Cl in precipitation can be used as an index of the relative importance of the sea as a source of dissolved constituents in rain and of aerosols for raindrop nuclei. Sodium may be slightly preferred over Cl, for some Cl is apparently also derived from continental or anthropogenic sources [*Likens et al.,* 1977; *Kennedy et al.,* 1979]. Recognizing the possibility that various ions might be fractionated during the production of marine aerosols [e.g., *Glass and Matteson,* 1973], one assumes that all Na is ocean-derived and that the oceanic contribution of other ions will be in a ratio similar to seawater. In the present study the Ca/Na ratio for the weighted average concentrations of these ions in wetfall suggests minimal enrichment of the Ca ion in rainfall; Ca/Na is 0.06 in wetfall versus 0.04 in seawater [*Mason,* 1966, p. 195]. A better indication of the enrichment of Ca from continental sources is shown in Figure 1, which includes the concentrations of Ca and Na in individual wetfall samples. For most samples, the Ca values lie above a line representing the Ca/Na ratio in seawater, especially in small storms with relatively high concentrations of Ca.

Our $SO_4^=$-S/Na ratio for the weighted average concentrations in wetfall is 0.43 compared to a seawater ratio of 0.08. While $SO_4^=$-S is abundant in seawater, there is an important nonmaritime enrichment as well, generally considered to be contributed by organic decomposition and anthropogenic activities [*Friend,* 1973]. Our $SO_4^=$-S data in individual wetfall collections also fall above a line representing the $SO_4^=$-S/Na ratio in seawater, similar to the findings of *Kennedy et al.* [1979]. Ratios for Mg/Na (0.13) and K/Na (0.03) in wetfall show no indication of enrichment of these ions compared to seawater ratios of 0.13 and 0.04, respectively. The Mg values lie close to the Mg/Na ratio in seawater over the full range of concentrations recorded (Figure 1). Comparisons using ratios of nitrogen are not usually made because of the labile nature of these constituents.

In an earlier study [*Schlesinger and Hasey,* 1980], very strong enrichment of Ca and K and slight enrichment of Mg over seawater ratios were observed in bulk precipitation (rainfall plus dry fallout) collections in the Santa Ynez Mountains. While our present data for wetfall show enrichment for Ca, it is now obvious that most of this enrichment in the bulk precipitation values was due to contributions from dryfall in those collections.

Total annual deposition of ions in wetfall and dryfall collections is given for the 2 years of study in Table 2. In accordance with our interpretation of the sources of ions in wetfall collections, the depositions of Ca, K, NH_4^+-N, and NO_3^--N in dry fallout are much larger than the deposition in wetfall, while for Na the opposite is true. For Mg and $SO_4^=$-S, annual deposition in wetfall was similar to deposition in dryfall in both years. The semiarid climate of southern California allows for long periods of soil drying and dispersion of soil dust by wind. Thus there is a strong terrestrial influence on deposition which is manifest in the abundance of dryfall as well as in the enrichment of Ca and K in wet

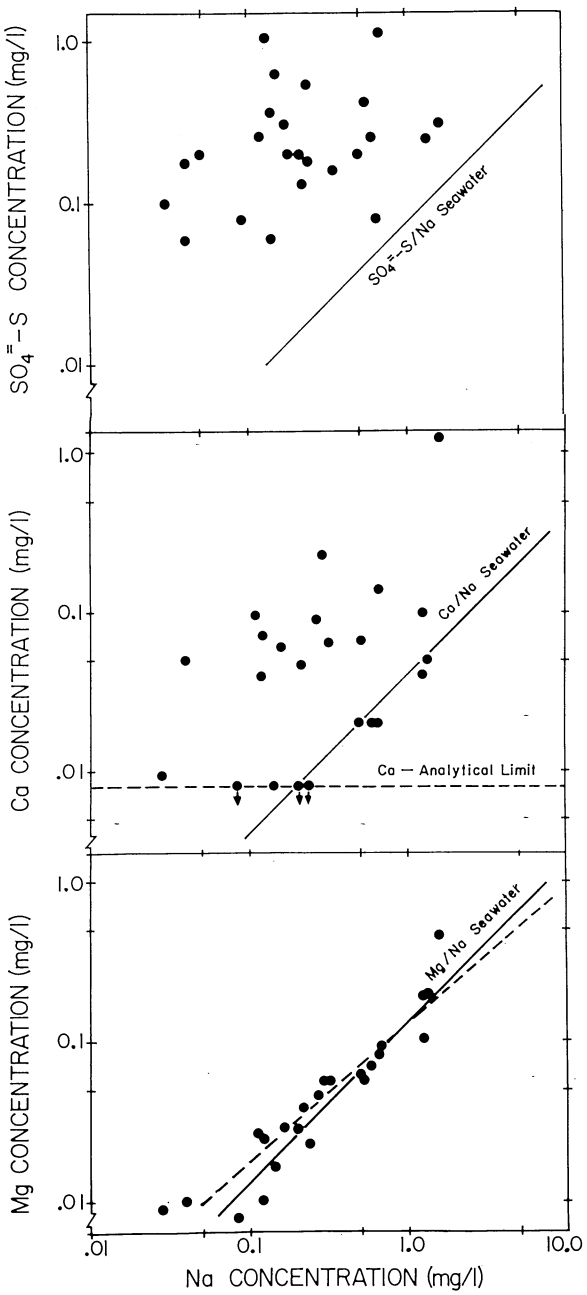

Fig. 1. Concentrations of Ca, Mg, and $SO_4^=$-S in the wetfall precipitation of individual storms in the Santa Ynez Mountains, California, plotted as a logarithmic function of Na concentrations. In all cases the solid line represents the ratio of these ions to Na in seawater. For Mg the dashed line is the least-squares fit linear regression to the data ($F = 143$, $P < 0.0001$ $r^2 = 0.88$). The equivalent regressions for Ca and $SO_4^=$-S are not significant.

deposition. The large amount of NO_3^--N in dryfall confirms earlier reports of its importance as a form of nutrient deposition from the atmosphere in chaparral systems [*Christensen,* 1973; *Schlesinger and Hasey,* 1980; cf. *Hart and Parent,* 1974]. The source of this NO_3^--N may not be local; the ratio of NH_4^+-N to NO_3^--N in the surface soils of the Santa Ynez Mountains is 11.5 [*Christensen and Muller,* 1975], substantially different from the ratio in any of our collectors [cf. *Schlesinger and Hasey,* 1980].

Dry fallout is derived from a number of processes including long-range atmospheric transport and the suspension of soil particles from the local environment. We attempted to separate the importance of the suspension of soil dust from the local area, by expressing monthly dryfall deposition as a function of monthly wind flow and using the Y intercept of this regression to represent dry sedimentation in conditions of no wind [cf. *Munn and Rodhe,* 1971]. Unfortunately, none of these regressions was statistically significant. During the course of our study there were few fires in the Santa Ynez Mountains; during one large fire in October 1979 we noted no unusual depositions of nutrients, such as have been reported in studies in other regions [*Clayton,* 1976].

Monthly depositions in wetfall and dryfall are summed to give total monthly deposition. Total monthly depositions are significantly correlated with monthly precipitation for most ions; the correlation coefficients are higher for Mg ($r = 0.89$*) and Na ($r = 0.93$*) than for Ca ($r = -0.06$), K ($r = 0.77$*), NH_4^+-N ($r = 0.52$), NO_3^--N ($r = 0.09$), and $SO_4^=$-S ($r = 0.80$*) (where the asterisk means $P < 0.05$), though the 95% confidence intervals show overlap among some pairwise comparisons. The magnitude of these coefficients suggests the extent to which monthly depositions vary between the wet and dry seasons in California. Thus Na and Mg, which are not diluted by increasing rainfall volume, tend to be derived from precipitation in winter storms, whereas dryfall is more important for the other ions measured. The low correlation coefficient for Ca is the result of substantial deposition in months with little or no rain, presumably as a result of more airborne dust from local soils.

Total monthly deposition values were summed to give yearly deposition (Table 2). Depositions are higher during 1979–1980, reflecting the greater rainfall received, but also as a result of greater dryfall. Together with the annual deposition values extrapolated from 1977 collections by *Schlesinger and Hasey* [1980], these values give an indication of the annual range in deposition to be expected in the chaparral of the Santa Ynez Mountains. As will be shown later, the variation is relatively insignificant when the importance of atmospheric deposition is assessed in terms of other nutrient fluxes in these ecosystems.

Comparison Between Collectors

The Hubbard Brook collector as developed by *Likens et al.* [1967, 1977] has been used in their ecosystem studies in New Hampshire to collect 'bulk precipitation,' the composite of wet and dry processes as defined by *Whitehead and Feth* [1964]. As a result of the reliability of the Hubbard Brook collector and other advantages, *Galloway and Likens* [1976, 1978] advocate its use and employ it as a standard for the comparison of more elegant collectors. In the present study, the volume of precipitation per storm measured by the U.S. Weather Bureau rain gage was highly correlated with the volume measured by both the wetfall bucket of the automatic rain collector ($r = 0.99$) and the Hubbard Brook collector ($r = 0.99$), but these collectors underestimated the standard rain gage volume by an average of 6% and 8%, respectively, over the range of storms sampled. In a recent comparative study, *Bogen et al.* [1980] also found that this model of automatic rain collector underestimated rainfall by 4%.

For ions other than Na and Mg we found rather poor correlations between the total monthly deposition as measured in the Hubbard Brook collector and the sum of wet and dry depositions in the automatic rain collector (Table 3). An

TABLE 3. Correlation Between Monthly Depositions Received in the Hubbard Brook Collector (Bulk Precipitation) and in the Sum of Wetfall and Dryfall (Total Deposition) in the Automatic Rain Collector

	Ca	Mg	K	Na	NH_4^+-N	NO_3^--N	$SO_4^=$-S
r	0.48	0.98*	−0.10	0.95*	0.48	0.84*	0.88*
Slope	0.32	0.70*	−0.03	0.79*	1.17	0.84*	0.69*
Intercept	13.44	2.10	7.51	2.16	1.49	4.07	2.72
Weighted average concentrations	0.20	0.15	0.14	0.94	0.02	0.12	0.56

Deposition values are milligrams per square meter. Slope and intercept are the factors *m* and *b* in the linear equation 'Total deposition = *m* (bulk precipitation) + *b*.' The converse model offers no different interpretations of data. Also given are the weighted average concentrations (in milligrams per liter) in bulk precipitation.
*$p < 0.05$.

initial interpretation of the data suggests that the Hubbard Brook gage and the automatic rain collector differ mainly as a result of different efficiency of collection for elements with a strong dryfall component. For most ions the automatic rain collector records higher depositions at the lower range of depositions, but the opposite is true at higher levels of deposition (cf. magnitudes of slope and intercept in Table 3). For Na, Mg, and $SO_4^=$-S, however, the Hubbard Brook collector yielded higher estimates of deposition than the automatic rain collector over most of the range of depositions recorded. *Bogen et al.* [1980] found that for various ions the automatic rain collector recorded depositions typically 10% lower than other collectors. We made no presumptions as to which collector is the more accurate, but in view of the increased sophistication and interpretation to be gained from the separation of deposition processes, the automatic rain collector seems preferable despite its higher cost. Notwithstanding, the annual weighted average concentrations calculated for the bulk precipitation collector in this study (Table 3) are similar to those measured using these collectors in an earlier study in the Santa Ynez Mountains [*Schlesinger and Hasey,* 1980].

NUTRIENT BALANCE IN CHAPARRAL ECOSYSTEMS

In mature *Ceanothus megacarpus* chaparral in the Santa Monica Mountains of Los Angeles County, California, *Gray* [1981] measured rather large quantities of available Ca, Mg, and K in the soil, but in the case of nitrogen there were only very low concentrations of NO_3^--N (2.7 mg kg^{-1}), NH_4^+-N (0.4 mg kg^{-1}), and total N (0.012%). There were 86 g m^{-2} of N in the surface litter and upper 1 m of soil. Despite these low available quantities in the soil, atmospheric deposition can contribute only a small portion to the annual plant uptake of nutrients from the soil in mature chaparral. For example, in *Adenostoma* chaparral in San Diego County, gross annual uptake of nitrogen is estimated at 3.4–8.2 g m^{-2} [*Mooney and Rundel,* 1979; *Marion et al.,* 1981]. Data presented by *Gray* [1981] suggest at least 9.0 g m^{-2} yr^{-1} as the gross nitrogen uptake from the soil to the aboveground portion of the stand of *Ceanothus megacarpus*. Annual wood growth retained at least 1.66 g N m^{-2} yr^{-1}, while the remainder returned to the ground in litter fall. This stand had accumulated nearly 39 g m^{-2} of nitrogen in living perennial and standing dead tissues during 22 years of growth after fire. In all cases, these uptake rates and accumulations greatly exceed the estimated total atmospheric deposition of nitrogen of 0.1–0.2 g m^{-2} yr^{-1}.

If our results are representative of various chaparral areas in southern California, the total atmospheric deposition of nutrients equals or exceeds the annual losses which have been reported in runoff from mature, undisturbed chaparral (e.g., Table 4). The thick charcoal-rich varves in the sediments of the Santa Barbara Basin are indicative of the large losses of debris following fires in the chaparral through many millennia [*Byrne et al.,* 1977]. *DeBano and Conrad* [1976, 1978] have measured the losses of nutrients by volatilization in fire and by accelerated runoff after fire for a typical stand of burned chaparral in Santa Barbara County (Table 4). The losses greatly exceed the annual inputs from the atmosphere and indicate that more than 70 years (total loss 161 kg ha^{-1} divided by net input 2.3 kg ha^{-1} yr^{-1}) may be needed to replenish the nitrogen losses from a single fire. Since Ca, Mg, K, and P are largely derived from mineral weathering [*Likens et al.,* 1981], which has not yet been calculated for chaparral ecosystems, similar calculations are not meaningful for these elements.

TABLE 4. Annual Inputs and Losses of Nutrients for Chaparral Ecosystems

Process	Ca	Mg	K	N	P	Source
Input:						
Precipitation	1.9	1.0	0.6	1.5	...	present study
N fixation						
Symbiotic	...	...	...	0.1	...	*Kummerow et al.* [1978]
Asymbiotic				1.0		B. A. Ellis (personal communication, 1980)
Outputs, mature stand:						
Runoff	0.9	0.6	0.6	0.3	0.1	*DeBano and Conrad* [1976]
Outputs, postfire:						
Runoff	67	32	27	15	3.5	*DeBano and Conrad* [1976]
Volatilization	...	...	48	146	...	*DeBano and Conrad* [1978]

Values are kilograms per hectare per year.

There are a number of ways in which these estimates should be improved, including continued regional monitoring and increased study of the importance of nitrogen-fixing processes. Estimates of deposition derived from open collectors are underestimates to the extent that chaparral shrubs intercept aerosols and fog water from the horizontal airstream [*Schlesinger and Hasey,* 1980]. Gaseous forms of S and N may also be absorbed by vegetation. On the other hand, to the extent that the atmospheric deposition of nutrients is derived from soil dust suspended from the local area, estimates of the atmospheric deposition of ions are greater than the actual input of new quantities of these elements for plant growth. Unfortunately, to date no one has devised a way to eliminate this overestimate. Considering chaparral ecosystems on a regional basis, it would be instructive to know the extent to which volatile losses in burned areas result in added deposition in adjacent unburned areas.

Atmospheric pollution by oxides of nitrogen which are later deposited as NO_3^--N in rainfall may have a stimulating effect on chaparral growth in nutrient-poor sites. *Morgan and Liljestrand* [1980] reported rainfall concentrations for a variety of sites in the Los Angeles Basin; on Mount Wilson in the San Gabriel Mountains, concentrations of NH_4^+-N, NO_3^--N, and $SO_4^=$-S in wetfall were 25, 10, and 3 times higher, respectively, than our values for the Santa Ynez Mountains. The effects of this additional nutrient input, balanced against possible deleterious effects such as rainfall acidity, have yet to be evaluated. Our values from a remote site in the Santa Ynez Mountains are useful to compare to data from urban areas with strong anthropogenic nutrient sources.

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